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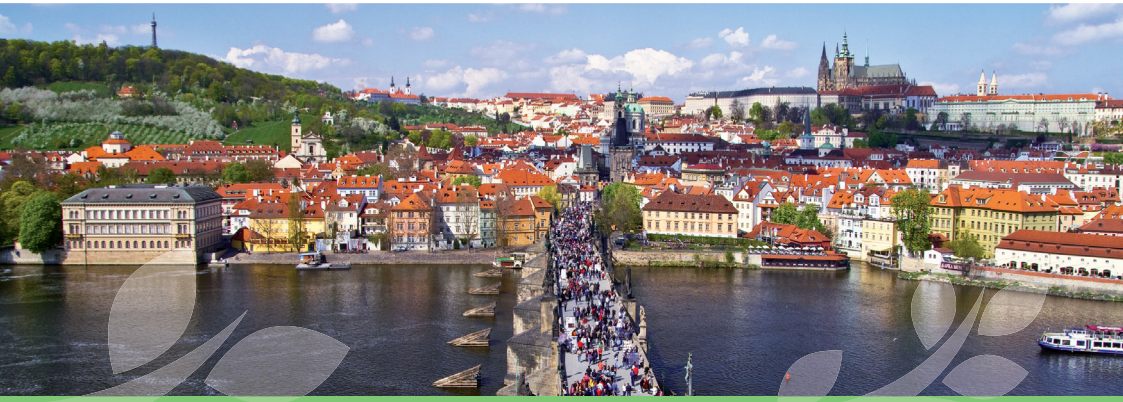

"Weed Science and Management to Feed the Planet"

Proceedings

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CONTENTS

PLENARY SESSIONS

Invited plenary presentation: Weed control at the cross roads – which innovations are on the horizon?

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Weeds are an important element of our biodiversity in cropland. Agriculture, and with it, weed control, certainly impacts wildlife in arable farmland.
However, growing crops as such is a deliberate intervention that impacts biodiversity on farmland and ultimately changes the existing natural environment. Recent meta studies have shown that this is the case for both ecological as well as conventional crop production systems, although the reduction of species in modern conventional crop production systems occurs to a higher degree. According to recent calculations (HFFA Research 2016, Noleppa S.), the species reduction in field crop production systems in Germany amounts to 67% in ecological agriculture and 86% in conventional systems.
Accounting for the significant yield advantages of conventional agriculture and applying modern technologies that increase productivity, however, changes the overall impact index versus ecological production systems, where losses of biodiversity per yield unit are approximately 55% higher (HFFA Research 2016).
Meanwhile the global human population will continue to increase by more than 80 million persons per year, increasing to 9,6 billion by 2050. Therewith the demand for food, feed, fibre and energy will continue to grow. Increasing global wealth invariably leads to consumption of more meat, and this is happening in many areas of the world. This trend is evident when analysing the soybean imports by China as a protein source for animal feed, where approximately 50% of the world pork production and consumption takes place.
In 2015 the country imported 86 million tonnes of soybeans, and based on the average yield this amount corresponds to 32 million hectares of production, or 27% of the global soybean acreage. This development supports the thesis that until 2050 global agricultural production must be increased by 60 to 110%, translating to an annual growth rate of ca. 2.4 %. Yield improvements for the four major crops wheat, corn, rice and soybean are currently providing annual yield increases only between 0.9 – 1.6% (Ray *et al*., 2013). Based on the current global food consumption patterns we are thus not able to match the necessary production growth with the output of our current production systems, so something has to change. If these yield growth rates do not increase further, it is inevitable that additional land has to be transformed to row crop production. Therefore intensification of broad acre crop production driven by technological advances will have a powerful effect on saving land from conversion to cropland. As in the past, yield increases rather than area expansion is the most desirable major source of growth in agricultural output (Byerlee *et al*., 2014).
Investing in the research and development (R&D) of crop related technologies, and consequently, achieving further yield increases will be the most likely route to sufficiently deliver the yield potential of the globally cultivated 1,5 bn ha cropland in order to fulfil future demand. This approach can bear multiple benefits by helping to sustain biodiversity and by avoiding additional losses of carbon sequestration, for example. Vast areas currently not being used for agricultural production, categorized as such by the FAO, as well as many other authors, can be kept uncultivated and protected from deforestation.
However, no matter how we manage to intensify crop production, it must be sustainable (Garnett et al, 2012). In this respect, fertile arable soils must be considered to be of special importance as they are a non-renewable resource as measured by human time spans (Lal, 1994). Protection of soils thus plays a key role in food, climate and human security (Amundson *et al.*, 2015). The overall annual cost of global land degradation has been estimated to equal 300 billion US $ (Nkyonya *et al*., 2016). Sufficient efforts have to be made to slow down or even reverse this trend. Intelligent crop production systems that safeguard our soils must be employed.
Low tillage systems, but especially zero tillage systems, are being increasingly employed in high-yielding broad acre crop production in North America (Fulton, 2010), Australia (Llewellyn, 2012) as well as in South America (Scheid Lopes *et al*., 2012). In recent decades low tillage production systems also have even been increasingly employed throughout the main European cereal cropping areas (Eurostat, 2010). This is providing opportunities to increase carbon sequestration, the efficiency of water utilization as well as avoiding soil erosion. Furthermore, less water losses and lower fuel consumption can be attributed to this change. However, the adoption of low till systems, especially of no tillage crop production, is dependent upon excellent weed control technologies. On a global scale potential yield losses caused by weeds in major broad acre crops are estimated at 34% (Oerke, 2005) and pose the biggest problem regarding yield losses versus other biotic stresses.
Because deep soil tillage (e.g. inversion ploughing) has many environmental disadvantages, this practice leads in many areas to soil degradation. Mechanical control or hand weeding alone provides no viable economic alternative to the application of modern herbicides in controlling weeds. However, as supplemental measures assimilated into integrated management programs, they can provide benefits, particularly in managing increasing weed resistance. Most important is that measures such as crop selection, crop rotation, seeding time, cover cropping, soil tilling, false seed bed preparation for early weed germination, etc., be utilized more often in overall weed management programs to help increase the sustainability of current crop production systems.
The adoption of herbicides in modern high-yielding crop production systems can be regarded as the cornerstone development helping to secure yields and promote global sustainability. Following the introduction of 2,4-D in the 1940s for control of dicot weeds in monocot crops, the rise of the herbicide industry started in the fifties. Increased numbers of new herbicidal active ingredients were launched into the market resulting in broad usage of herbicides to control weeds in all broad acre crops worldwide. From the sixties onwards productivity resulting from the use of herbicides to control weeds grew dramatically. Herbicides also contributed significantly to the green revolution. New product launches peaked in the late nineties and enabled growers to control practically any important grass or dicot weed.
With the introduction of glyphosate (a once in a century discovery) into broad acre cropping systems, conservation tillage began to be widely adopted. Beginning in 1996, glyphosate-tolerant crops (soybean, corn, cotton, etc.) were introduced to the Americas, the same year when the first weed resistance to glyphosate was recorded in Australia (Powles *et al*., 1998). This revolutionary technology was adopted widely within a very short time. American

growers now had the ultimate tool to maximize their crop production economic returns by utilizing the extremely high flexibility of satisfactory application conditions to control weeds. Significant numbers of representatives from both the scientific and the policy-making communities were not convinced that the exclusive use of one herbicide over and over again would cause serious weed resistance issues as had already been experienced with other herbicide classes (e.g. PSII inhibitors, ALS inhibitors, ACCase inhibitors). The huge success of this herbicide tolerance technology finally discouraged the industry to continue the discovery of new active ingredients. The waves of continued agricultural chemical industry consolidations served to reinforce this trend.

Although the market for herbicides generally comprises approximately 45 – 50% of the global crop protection market, many companies have reduced or even completely stepped out of herbicide discovery. At peak levels in the late eighties, globally an estimated 500 – 600 chemists were employed for synthesis of new herbicides by internationally operating companies. This number has decreased to 200 – 300 chemists today (own estimate). Whereas in 1970 45 companies were engaged in herbicide discovery, in 2005 only 8 companies had discovery units (Duke, 2015). It could be expected that this number will further decrease with additional industry consolidation.

This decrease in herbicide R&D has been ongoing despite important changes occurring in the field from 2000 onwards. Nature struck back. The economic challenges of growers and the availability of glyphosate-tolerant crops fostered very monolithic agricultural practices mainly relying on one herbicide for everything and lacking diversity of other weed control tools and of crop rotations. Weed resistance to glyphosate exploded within a few years in North and South America. Moreover, due to lack of suitable diverse herbicide classes within cropping systems, the resistance problem grew dramatically in Europe and Asian broad acre crop production as well.

Thus far herbicide classes operating via 21 modes of action have been introduced into the market (Duke, 2015). More than twenty experimental modes of action (MoAs) have been discovered, some of them in very recent years, yet not one of them has made it to market. Nearly 30 years have passed since a new herbicide with a novel MoA has been launched. Due in part to increasing regulatory hurdles, we are losing herbicides (and MoAs) at a much faster rate than we are replacing them. In the past, resistance problems were solved by the discovery and use of a new chemistry or even MoA. With the rise of metabolic resistance, where structures trump MoA, this is no longer true. This depicts the dramatic situation in the global herbicide market environment.

The reduced engagement in herbicide discovery led to a decrease of herbicide active ingredient patent applications over the years, declining from approx. 200 in 1995 to 60 in 2015. The published herbicidal active ingredient (a.i) pipeline of major international companies shows only 3 to 4 new a.i.s to be introduced into the market by 2020, all from established classes.

At this point it has to be stressed that the average cost of discovering, developing and registering a plant protection active ingredient has risen from *ca*. 145 million US $ in 1995 to 286 million US $ today (M. Phillips, 2016)

The high cost for R & D demonstrates clearly that the thresholds for new entrants into the herbicide R & D market are extremely high. Although the huge demand for new herbicidal a.i.s has become indisputable, no new players have been observed so far. Future developments in China have to be awaited and could change dynamics in herbicide discovery. Serious alternatives to herbicides for weed control are currently not visible. Neither biological herbicides nor mechanical robotic approaches can fulfil the demand for efficient, economic and sufficiently residual weed control in broad acre crop production today. All other alternatives require much higher energy inputs and do not yet achieve sufficient efficacy levels. Certainly there are niche opportunities in specialty crops (*e.g*., vegetables) for specific methods (*e.g*., plastic film mulch used in solarization) or in broad-acre crops for specific weed stages (*i.e*., Harrington seed destructor during wheat harvest). But these methods are not capable of replacing the utility of herbicidal active ingredients.

Consequently there is a global need to increase efforts in herbicide discovery. All available new technologies enabling target discovery, molecule synthesis and process elaboration, candidate selection considering agronomic performance as well as early evaluation on environmental and human safety are needed. We also need to do more to keep each and every herbicide in the market to maintain the diversity of available chemistry. This will give us more options to combat metabolic resistance, a growing threat, which could potentially knock out an entirely new MoA without ever having been applied in the field. We desperately need the help of regulatory officials to understand this and help us with this task without significantly endangering the environment or human health.

In order to successfully promote herbicide discovery and development the Crop Science Division of Bayer has recently launched various initiatives. Exclusive research collaborations are focussed on new target discovery by applying the comprehensive spectrum of systems biology that covers “omics” technologies (Targenomix). Furthermore public research institutions are being approached with an open, web-based platform encouraging the submission of new promising molecular targets (grants4targets initiative) through a financial reward mechanism. Furthermore, grower associations have recognized the need for new herbicides and are co-financing increased research capacities in Frankfurt (Herbicide Innovation Partnership). With the initiation of the Weed Resistance Competence Centre we have increased efforts to understand weed resistance and combat it using integrated solutions, and perhaps even to help us to find ways to reverse resistance to current herbicides.

Weeds are an essential element of our biodiversity, but weeds and weed resistance are perilously endangering global, high-yielding crop production systems. It is worthwhile for many reasons to consider using primarily local initiatives to increase biodiversity. They seem to work best (WSSA, 2015). For the coming 10 to 15 years, we have to manage the portfolio of available functioning herbicides intelligently within the framework of strengthened Integrated Weed Management concepts. Herbicides will remain a foundation for weed control in crop fields. They are extremely valuable resources that are required to safeguard the continuation of high productivity agriculture. With not much that can help on the horizon (by middle of the next decade), we are looking beyond this horizon for new chemical weed control tools to ensure sufficient future food, feed and fibre production.

Reference:

- Amundson R, Berhe A, Hopmans J, Olson C, Sztein AE, Sparks D (2015) Soil and human security in the 21st century. Science, 348 (6235), doi: 10.1126/science.1261071
- Byerlee D, Stevenson J, Villoria N (2014) Does intensification slow crop land expansion or encourage deforestation? Global Food Security 3, 92 – 98
- Fulton M (2010) Foreword. In: Lindwall C, Sonntag B. (Eds.) Landscapes Transformed: The History of Conservation Tillage and Direct Seeding. Knowledge Impact in Society, Saskatoon, Saskatchewan, pp. ix – xiv,
- http://www.kis.usask.ca/ZeroTill/LandscapesTransformed.HistoryofCT.Book.pdf
- (accessed 03.02.13)
- Garnett T, Godfray CH (2012) Sustainable intensification in agriculture: navigating a course through competing food system priorities. Food Climate Research Network and the Oxford Martin Programme on the Future of Food, University of Oxford, UK
- Lal R (1994) Sustainable land use systems and soil resilience, In Greenland DJ & Szabolcs I (Eds.), Soil Resilience and Sustainable Land Use (pp. 41 – 67). CAB-International, Wallingford, Oxon, UK
- Lee Van Wychen (2015) Scientists Advocate a Community-Based Approach to Herbicide Resistance Management. Weed Science Society of America
- Llewellyn RS, D'Emden FH, Kuehne G (2012) Extensive use of no-tillage in grain growing regions of Australia, Field Crops Research 132, 204 – 212
- Nkonya E, Mirzabaev A, von Braun J (2016) Economics of Land Degradation and Improvement – A global assessment for sustainable development. Springer International Publishing AG
- Noleppa S (2016) Pflanzenschutz in Deutschland und Biodiversität. Auswirkungen von Pflanzenschutzstrategien der konventionellen und ökologischen Landbewirtschaftung auf die regional und global Artenvielfalt. HFFA Research GmbH
- Oerke EC (2016) Institute for Plant Disease, Rheinische Friedrich-Wilhelms-Universität Bonn. Crop losses to pests. Journal of Agriculture Science, 144, 31 – 43, Centenary Review
- Phillips M (2016) The Cost of New Agrochemical Product Discovery, Development and Registration. Phillips McDougall Agribusiness Intelligence/Informa
- Powles SB, Lorraine-Colwil DF, Dellow JJ and Preston C. (1998) Evolved Resistance to Glyphosate in Rigid Ryegrass (Lolium rigidum) in Australia. Weed Science, Vol. 46, No. 5 (Sep. – Oct., 1998) pp. 604-607
- Ray DK, Mueller ND, West PC, Foley JA (2013) Yield Trends are insufficient to double global crop production by 2050. Institute of the Environment (IonE), University of Minnesota, Saint Paul, Minnesota, United States of America
- Scheid Lopes A, Guimaraes Guilherme LR, Ramos SJ The Saga of the Agricultural Development of the Brazilian Cerrad, Research Findings
- Shean M (2015) Foreign Agricultural Service. World Agricultural Production. United States Department of Agriculture. Thailand Rice: Production Forecast to Decline on Irrigation Ban
- Shean M (2016) Foreign Agricultural Service. World Agricultural Production United States Department of Agriculture. Philippines Corn: El Nino-Induced Drought Reduces Estimated Production.

Invited plenary presentation: Schulze-Stentrop C. (DE): Application technique – The challenge of future spraying

Christoph Schulze Stentrop *(HARDI International, Product Manager, Denmark)*

Plant protection is under serious scrutiny worldwide, particularly in relation to environmental risks, as well as operator and consumer safety, with the perspective of even more questioning in the future although there are major differences in how plant protection is achieved on a global basis. The presentation deals with differences in plant protection approaches worldwide and emphasizes technical solutions drawing interest in arable crops. What is used today in a few production units could be of wide interest in future plant protection applications.

The overall demand for a higher efficiency in plant protection technique mainly relates to increased capacity, but this should only be done in combination with a higher precision and improved safety. Farming intensity and safety regulations differ worldwide. But in all markets there has been over the past few years a clear trend for sprayers to become bigger and to display increased capacity, although there is still a wide spread between 10 and 50 ha/h work rate. What are the technical limitations imposed by the numerous technical standards and directives that equipment designers and users have to deal with? What changes in application technique are foreseen for the near future? Can we succeed in accomplishing the goal of providing proper plant protection effectively and safely?

The presentation will give a reflection on novel technical solutions being used in modern plant protection equipment around the world, including remarks about their adoption in different areas. Most of these technical solutions are based on electronic sensors helping to better adapt the equipment to the user needs and to do automate the work process. Areas in which improvement is expected and draw-backs of some of the techniques will be discussed as well as how future spraying could be optimized and how new ideas could provide new opportunities.

There are general questions in the discussion about future developments:

- What do future plant protection products demand?
- What does precision mean?
- What will the future spraying be – how does Farming 4.0 look?
- How will more real-time data help to make the best decisions?

Future technical solutions will be based on today's experience including the know-how of the sprayer and application equipment manufacturers and will move towards more precise and "safer" spraying to comply with the demands of plant protection products. Here the volume rate per area can be used as an example. First of all there is a registration volume rate, which varies among countries. Second, there is an optimum volume rate for the best effect of the product at a defined concentration level; and third, the lowest possible volume rate to reach the highest capacity. But we should not forget that there is still a lot of basic and old equipment in the market which is also used for application.

There shall be always in focus that new plant protection machinery is highly complex. "Dangerous" and sensitive liquids in different concentrations are applied by machines with a variety of hydraulic and electronic components in a hard, rough and dusty surrounding. Especially new and better sensors in combination with faster regulation systems and also GPS based information will allow in future the development of more automatic application systems. With a far better documentation, this will help also to understand the differences

in yields and effect of applications. But also here we will see different demands in a global view and especially depending on yield level and precision demands.
Finally it can be stated that plant protection is a big compromise, as it must be done outdoor in different weather conditions, at different crop stages and with different equipment but always aiming to the best result.

Invited plenary presentation: Climate Change, CO_2 and the consequences for weed biology: Threats and opportunities

L.H. Ziska *(USDA-ARS, Crop Systems and Global Change Laboratory)*

Climate Change and CO_2. Increases in the production of greenhouse gases, such as carbon dioxide, CO_2, are likely to continue throughout the 21st century. This increase is likely to have three significant consequences with respect to weed biology. The first is related to differential surface warming with changes in the establishment and spread of both agronomic and invasive weed species. The second is related to the direct effect of rising CO_2 on photosynthesis and growth of these species and the consequences for weed-crop competition. The third is related to how changes in temperature and/or CO_2 will impact the efficacy of weed management.
Temperature and Invasive Weeds. Although the term "global warming" is often used, it is clear that the extent of future temperature increases will vary in time and space. For example, winter temperatures are likely to increase more than summer temperatures. However, winter temperatures are often a significant limitation to the migration and establishment of invasive weeds. Here I will present data on how warming winters, beginning in the 1970s have influenced the northward spread of kudzu (*Pueraria montana*), a noxious invasive weed in North America, and a host for Asian soybean rust (Ziska et al., 2011).
CO_2 and crop/weed interactions. One of the most recognized undesirable characteristics of weedy species is interference in crop production. Human selection of desirable crop species has led to inadvertent selection of other species that simulate or mimic a particular crop (e.g. commercial and wild oat). Therefore, while crops are likely to benefit from the ongoing increase in atmospheric [CO_2], growth of weedy competitors is also likely to be stimulated. Nevertheless, the current paradigm is that rising CO_2 will result in less weedy competition because many of the worst weed species have C_4 metabolism, a photosynthetic pathway that shows a minimal response to rising atmospheric CO_2 concentration. However, the idea that crops are fundamentally C_3 and weeds C_4, and that weed competition will consequently decrease with rising atmospheric CO_2 is overly simplistic. Clearly there are C_4 crops of economic and nutritional importance (e.g., corn [*Zea mays*], grain sorghum [*Sorghum bicolor*], pearl millet [*Pennisetum americanum*], sugarcane [*Saccharum officinarum*]), and many important C_3 weeds (e.g. lambsquarters [*Chenopodium album*], wild oat [*Avena fatua*]). Crop-weed interactions vary significantly by region; consequently depending on temperature, precipitation, and soil, C_3 and C_4 crops may interact with C_3 and C_4 weeds. For all studies that have examined crop/weed interactions for species of the same photosynthetic pathway, crop losses increased with increasing CO_2. In addition, interactions between rising CO_2 levels and other likely abiotic changes, from temperature to drought, do not indicate a de facto advantage of the C_4 photosynthetic pathway over the C_3 photosynthetic pathway as CO_2 increases. I will present information for a number of crop weed competitive outcomes that will illustrate this principle. However, I will also point out that wild relatives of crop species may also have benefit as unique germplasm sources to begin to adapt crops to future CO_2 levels (Ziska et al., 2014).
Climate, CO_2 and Weed Management. Although there is sufficient experimental evidence to indicate that weeds will pose more of a challenge to natural and managed systems in the context of climate change, the extent of any impact will be minimal if weed management,

particularly the widespread and effective use of herbicides, minimizes any future risk. However, there is also a growing body of evidence that [CO_2] and/or climate change may also affect weed management per se (Archambault 2007; Bailey 2003; Manea et al., 2011). While additional data are greatly desired, particularly with respect to biological and cultural weed control, there is sufficient information currently available to begin an initial assessment of both the physical and biological constraints likely to occur before, during and following herbicide application. A review of weed management in the context of climate and CO_2 will focus on a proposed strategy of "monitor, mitigate and manage" (Ziska and McConnell, 2016).

References:

- Archambault, D.J. 2007. Efficacy of herbicides under elevated temperature and CO_2. In: Newton, P.C.D., Carran, A., Edwards, G.R., Niklaus, P.A. (eds), Agroecosystems in a Changing Climate. CRC Press, Boston, MA, pp. 262-279.
- Bailey, S.W. 2003. Climate change and decreasing herbicide persistence. Pest Manag Sci 60, 158-162. doi: 10.1002/ps.785.
- Manea, A., Leishman, M.R., Downey, P.O. 2011. Exotic C4 grasses have increased tolerance to glyphosate under elevated carbon dioxide. Weed Sci. 59, 28-36.
- Ziska, L.H., Blumenthal, D.M., Runion, G.B., Hunt Jr., E.R., Diaz-Soltero, H. 2011. Invasive species and climate change: an agronomic perspective. Climatic Change 105:13-42
- Ziska, L.H., Bunce, J.A., Shimono, H., Gealy, D.R., Baker, J.T., Newton, P.C., Reynolds, M.P., Jagadish, K.S., Zhu, C.W., Howden, M., Wilson, L.T. 2012. Food security and climate change: On the potential to adapt global crop production by active selection to rising atmospheric carbon dioxide. Proc Royal Soc (B) 279:4097-4105.
- Ziska, L.H., Tomecek, M., Gealy, D.R. 2014. Assessment of cultivated and wild, weedy rice lines to concurrent changes in CO_2 concentration and air temperature: determining traits for enhanced seed yield with increasing atmospheric CO_2. Funct Plant Biol 41: 236-243.
- Ziska, L.H., McConnell, L.L. 2016. Climate Change, Carbon Dioxide and Pest Biology: Monitor, Mitigate, Manage. J Ag Food Chem 64: 6-12.

Invited plenary presentation: Global perspectives on plant invasions

Petr Pyšek *(Institute of Botany, Department of Invasion Ecology, The Czech Academy of Sciences, Průhonice, Czech Republic & Department of Ecology, Faculty of Science, Charles University in Prague, Czech Republic)*

Since interest in the widespread phenomenon of plant introductions first began, considerable effort has been given to describe macroecological patterns, identify global invasion hotspots and the direction of exchanges of plant species among world regions on a historical time scale, and quantify the effects invasive species have on resident biota in order to adopt appropriate management measures.

It is therefore surprising that despite such intensive research over several decades, a robust global database of regional alien floras has only recently become available. The publication of the Global Naturalized Alien Floras (GloNAF) database summarizing information on naturalized floras for over 80% of world terrestrial surface (van Kleunen et al. 2015), made it possible to quantify, for the first time, the global biogeographic and phylogenetic patterns of naturalized alien plants. We know that there are currently over 13,000 plant species corresponding to ca 4% of the extant vascular flora that have become naturalized somewhere on the globe. Europe has accumulated the highest number of such species and the Northern Hemisphere is the major donor to other parts of the world. These results demonstrate that naturalization processes by which a plant becomes established in a region to which it was introduced are not random phenomena, but instead exhibit clear phylogenetic and biogeographic patterns that need to be taken into account shall we progress towards a more thorough understanding of the global drivers of plant invasions. This new database resource also allows for the most robust testing thus far of generally accepted mechanisms of plant invasions. This talk will highlight some of these mechanisms and demonstrate that some "conventional wisdom" may be less firmly supported by evidence than previously thought. I will also review the main human-related, climatic and biological drivers of the current large-scale distribution of alien plants' species richness that can only be rigorously described by taking complex interacting factors into account (Pyšek et al. 2015).

The identification of major hotspots of plant invasions potentially allows for a more targeted approach towards plant invaders by managers, another line of research comes that complements the macroecological knowledge of naturalized plants' distributions. Studies on the ecological effects of invasive plants, so-called impacts, came into research focus in the last decade and considerably improved our understanding of mechanisms and magnitudes of the effects invasive plants have on local populations, species, communities and ecosystems (Vila et al. 2011, Pyšek et al. 2012). Although a global synthesis of the impacts of plant invaders still remains to be completed, measures are being taken towards implementing a unified scoring system of ecological impacts of alien organisms, including plants, that would allow for a standardized attitude based on scientific knowledge (Blackburn et al. 2014).

References

- Blackburn T. M., Essl F., Evans T., Hulme P. E., Jeschke J. M., Kühn I. … & Bacher S. (2014) A unified classification of alien species based on the magnitude of their environmental impacts. *PLoS Biology* 12: e1001850
- Pyšek P., Jarošík V., Hulme P. E., Pergl J., Hejda M., Schaffner U. & Vilà M. (2012) A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. *Global Change Biology* 18: 1725–1737
- Pyšek P., Manceur A. M., Alba C., McGregor K. F., Pergl J. … & Kühn I. (2015) Naturalization of central European plants in North America: species traits, habitats, propagule pressure, residence time. *Ecology* 96: 762–774
- van Kleunen M., Dawson W., Essl F., Pergl J., Winter M., Weber E., Kreft H., Weigelt P. … & Pyšek P. (2015) Global exchange and accumulation of non-native plants. *Nature* 525: 100–103
- Vilà M., Espinar J. L., Hejda M., Hulme P. E., Jarošík V., Maron J. L., Pergl J., Schaffner U., Sun Y. & Pyšek P. (2011) Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. *Ecology Letters* 14: 702–708

ORAL SESSIONS

Session 1
HERBICIDE RESISTANCE: Non-Target-Site Resistance 1

Keynote: The Black-grass Resistance Initiative: Interdisciplinary research to unravel multiple herbicide resistance 'from gene-to-field' (737)

Paul Neve *(Rothamsted Research, Harpenden, UK),* ***David Comont*** *(Rothamsted Research, Harpenden, UK),* ***Helen Hicks*** *(University of Sheffield, Sheffield, UK),* ***Catherine Tetard-Jones*** *(Newcastle University, Newcastle, UK),* ***Shaun Coutts*** *(University of Sheffield, Sheffield, UK),* ***Andrea Dixon*** *(Rothamsted Research, Harpenden, UK),* ***Laura Crook*** *(Rothamsted Research, Harpenden, UK),* ***Richard Hull*** *(Rothamsted Research, Harpenden, UK),* ***Dylan Childs*** *(University of Sheffield, Sheffield, UK),* ***Robert Freckleton*** *(University of Sheffield, Sheffield, UK)*

Currently in the United Kingdom, evolved resistance to herbicides, particularly in the grass weed, *Alopecurus myosuroides* (black-grass), is a major agronomic problem, reducing crop yields, impacting profitability and driving farmer decision-making. Non-target site resistance (NTSR) has been implicated as the most widespread resistance mechanism in black-grass, with NTSR and target site resistance (TSR) frequently co-existing in individual plants to confer multiple herbicide resistance (MHR). The rampant evolution of NTSR is particularly worrisome as this mechanism of resistance confers broad cross-resistance to multiple modes of action. The biochemical, genetic, ecological and evolutionary determinants of NTSR are not fully resolved. The Black-grass Resistance Initiative (BGRI), a consortium of Institute and University researchers in the UK commenced an ambitious interdisciplinary project in 2014 to unravel the evolution of NTSR 'from gene-to-field'. The consortium brings together expertise in biochemistry and molecular genetics, population and quantitative genetics, ecology, evolutionary biology, weed science, agronomy and modelling. The BGRI is structured as a series of five inter-dependent work packages to explore the molecular and biochemical basis of NTSR (WP1), the epidemiology of resistance (WP2), quantitative and evolutionary genetics (WP3), eco-evolutionary modelling (WP4) and management of resistance, including economic and environmental impacts (WP5). Here, we will present a project overview as a model for interdisciplinary research in weed science, focussing on early results that are beginning to shed light on the molecular mechanisms of NTSR; field-based research that is establishing spatial and temporal variation in black-grass abundance, herbicide resistance and management interventions; and population-level studies to explore the quantitative and evolutionary genetics of NTSR. We will demonstrate how interdisciplinary approaches that integrate knowledge and understanding of NTSR across scales from cellular to landscape levels can provide novel insight into the evolution and management of herbicide resistance.

Keywords: *Alopecurus myosuroides*, herbicide resistance, non-target site resistance, interdisciplinary, eco-evolutionary

Next generation sequencing validation requested to reveal non-target-site herbicide resistance mechanisms (599)

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Weed-herbicide-resistance is a worldwide problem impacting crop-yields. Herbicide-resistance due to enhanced-herbicide-metabolism (EMR) in weeds is a threat which can confer broad spectrum herbicide resistance. EMR is not genetically well characterized. An RNA-Seq transcriptome analysis was used to identify genes conferring EMR in a population (R) of a major global weed (*Lolium rigidum*), in which herbicide-resistance to diclofop-methyl was experimentally evolved through recurrent selection from a susceptible (S) progenitor population. A reference transcriptome of 19,623 contigs was assembled (454 and Mysequ sequencing). Transcriptomic-level gene-expression was measured using Illumina 100 bp reads. In a forward genetics validation experiment, nine contigs, found overexpressed in R vs S plants, co-segregated with the resistance phenotype in an F_2 population, including CytP450s, GSTs, and GTs. In a physiological validation experiment where 2, 4-D induced diclofop-methyl protection in S individuals due to increased metabolism, several of these genetically-validated contigs were significantly induced. Finally 4 of these were found over-expressed in resistant populations collected in fields. Further studies aiming to characterize the physiological and biochemical function of these gene products will be discussed. In addition a workflow for NGS data validation will be proposed.

Keywords: Non-Target-Site-Resistance, Herbicide metabolism, Diclofop-methyl, ***Lolium rigidum***, Next Generation Sequencing

Gene expression associated with degradation enhancement as the mechanism of resistance to imazethapyr in barnyardgrass (386)

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Barnyardgrass (*Echinochloa crus-galli*) is a major weed of irrigated rice worldwide. In southern Brazil this species has become more problematic due to the occurrence of multiple herbicide resistance. Knowledge about the mechanism of resistance is essential for the adoption of appropriate measures of prevention and control of herbicide resistance. The objective of this study was to evaluate the occurrence and the main genes associated with the herbicide degradation enhancement in barnyardgrass resistant to imazethapyr. The first study consisted of the evaluation of the effect of cytochrome P450 (cytP450) enzyme inhibitors malathion and PBO, both at a dose of 1000 g ha^{-1}, on the efficacy of imazethapyr applied at doses ranging from zero to 848 g ha^{-1}. Inhibitors were sprayed two hours before the herbicide application. The second study comprised the evaluation of the expression of six genes encoding cytP450 enzymes in untreated and treated plants at 24 hours after treatment with imazethapyr at 106 g ha^{-1}. The evaluation of gene expression was performed using standard PCR and qPCR. Three endogenous genes were used based on a previous evaluation of nine genes. The previous application of cytP450 enzyme inhibitors had a significant effect on the injury and dry matter accumulation of barnyardgrass resistant plants. The resistance factor (RF) for dry matter of resistant plants was 15.94. However, in plants in which treated with the cytP450 inhibitors malathion and PBO the RF was reduced to 3.44 and 4.94, respectively. The relative expression of *CYP81A6* gene in resistant plants treated with herbicide imazethapyr was 3.6 times higher compared to the susceptible population without herbicide. The herbicide imazethapyr induced gene expression in both susceptible and resistant population, but this expression was higher in resistant plants. These results indicate the occurrence of enhanced herbicide degradation mediated by cytP450 enzymes in barnyardgrass resistant to imazethapyr.

Keywords: *Echinochloa crus-galli*, P450, CYP, P450 enzyme inhibitors, herbicide metabolism

Metabolism-based ALS inhibitor resistance in *Echinochloa oryzicola* revealed by gene-expression profiling (210)

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Echinochloa oryzicola is one of the most problematic weeds in rice cultivation in Korea, and recent confirmation of herbicide resistance (HR) in *Echinochloa* species has made this grass weed more problematic and difficult to manage. Thus, this study was conducted to investigate the spatial distribution of ALS inhibitor resistant *E. oryzicola* in Korea and to clarify the mechanism of the resistance. 119 accessions were collected nationwide in south Korean rice fields. To evaluate the level of their HR, penoxsulam (PNX) was applied at a range of doses (0, 3.75, 7.5, 15, 30, and 60 g a.i. ha^{-1}). When compared with a susceptible reference *E. oryzicola*, R/S ratios ranged from 0.1 to 31.7 and revealed 5 accessions with high PNX resistance and 5 accessions with medium PNX resistance. We selected 10 accessions including 3 reference PNX resistant *E. oryzicola* accessions with R/S ratio greater than 4.5. *In vitro* ALS assay showed no difference in ALS activity. Whole plant assay with malathion (cytochrome P450 monooxygenase (P450s) inhibitor) applied 24 hour earlier before PNX treatment resulted in increased sensitivity to PNX, suggesting metabolism-based HR. qRT-PCR analyses of 24 genes previously reported responsible for metabolism-based HR found that *EcGST2* and/or *CYP71C42* were up-regulated in 4 accessions, Gimje, Seosan, SNU-E-08.080, and SNU-E-08.236 in 24 hours after penoxsulam treatment, suggesting that the HR in *E. oryzicola* was mainly metabolism-based resistance by up-regulation of *EcGST2* and *CYP71C42*. This is the first report showing that two different gene families related to herbicide degradation were involved in HR in *E. oryzicola*. This work was carried out with the support of „Cooperative Research Program for Agriculture Science & Technology Development (Project title: Development of prediction system for management of rice weeds under climate change, Project No. 01052602)“ Rural Development Administration, Republic of Korea.

Keywords: *Echinochloa oryzicola*, herbicide resistance, ALS inhibitor, P450s, GSTs

Session 2
HERBICIDE RESISTANCE: Biochemical Aspects

Keynote: Resistance to glufosinate is proportional to phosphinothricin acetyltransferase expression and activity in LibertyLink® and WideStrike® cotton (18)

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LibertyLink® cotton cultivars are engineered for glufosinate resistance by overexpressing the *bar* gene that encodes phosphinothricin acetyltransferase (PAT), whereas the insect-resistant WideStrike® cultivars were obtained by using the similar *pat* gene as a selectable marker. The latter cultivars carry some level of resistance to glufosinate which enticed certain farmers to select this herbicide for weed control with WideStrike® cotton. The potency of glufosinate on conventional FM 993, insect-resistant FM 975WS, and glufosinate-resistant IMACD 6001LL cotton cultivars was evaluated and contrasted to the relative levels of PAT expression and activity. Conventional cotton was sensitive to glufosinate. The single copy of the *pat* gene present in the insect-resistant cultivar resulted in very low RNA expression of the gene and undetectable PAT activity in *in vitro* assays. Nonetheless, the presence of this gene provided a good level of resistance to glufosinate on both in terms of visual injury and effect on photosynthetic electron transport. The injury is proportional to the amount of ammonia accumulating. The strong promoter associated with *bar* expression in the glufosinate-resistant cultivar led to high RNA expression levels and PAT activity which protected this cultivar from glufosinate injury. While the insect-resistant cultivar demonstrated a good level of resistance to glufosinate, its safety margin is lower than that of the glufosinate-resistant cultivar. Therefore, farmers should be extremely careful in using glufosinate on cultivars not expressly designed and commercialized as resistant to this herbicide.

Keywords: Glufosinate, phosphinothricin, acetyltransferase, crop physiology, injury

Physiology and response of glyphosate-resistant and conventional soybean grafted plants following glyphosate application (261)

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Grafting is a common horticultural technique used to impart desirable characteristics upon the scion. Because conventional (CN) soybean (*Glycine max*) expressed increased glyphosate tolerance when grafted onto glyphosate-resistant (RR) soybean rootstocks, we examined this phenomenon in depth as a model for development of technology to manage risks associated with herbicide drift. First we examined the effects of soybean growth stage, genotype, and the temperature on the level of tolerance expressed. Glyphosate at 0.84 and 1.68 kg ae/ha was applied on the leaf (234 L ha^{-1}) through TTJ60-11002 nozzles at 276 kPa pressure. Three growth stages, all scion/rootstock combinations of six genotypes (3 CN and 3 RR), and 2 environments were evaluated. Chimeras of CN/CN died and RR/RR were injury free. The mean injury of CN/ RR at the 3, 6 and 10-leaf stages was 72%, 72% and 63% 24 DAT with 0.84 kg ae/ha glyphosate. In CN/RR genotype experiments, scion and rootstock both showed effect on CN/RR tolerance. The CN/RR combinations SC352STS/SCS9392RR and SC352STS/SCS9328RR were the most tolerant, while SC5388STS/SCS9392RR was the most susceptible. Day/night temperatures of 28/22°C or 24/18°C did not affect tolerance of CN/RR plants. No tolerance was observed for the offspring of CN/RR, indicating no transfer of the partial tolerance to the seed. Current studies are focused on investigating two hypotheses: 1) *CP4-EPSPS* mRNA is transferred from rootstock to scion in CN/RR plants; and 2) absorbed glyphosate is transported to the root system of CN/RR to reduce the amount of glyphosate in the scion. *CP4-EPSPS* mRNA was not found in the CN scion of CN/RR chimeras, so we are currently focused on investigating the latter hypothesis.

Keywords: Glyphosate resistance, grafting, soybean, CP4-EPSPS, shikimate

Occurrence of different resistance mechanisms to ALS inhibitors in European *Sorghum halepense* (475)

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Sorghum halepense is an annual grass weed infesting summer crops and in these last years populations resistant to ALS inhibitors have become a threat in European maize fields. Four Hungarian and two Italian *S. halepense* populations resistant to the ALS inhibitor nicosulfuron were investigated to elucidate the level of resistance and mechanisms underlying the resistance. A greenhouse dose-response experiment testing four different ALS-inhibiting herbicides (foramsulfuron, nicosulfuron, imazamox and bispyribac-Na) was performed and a purified seed stock from resistant plants was used to determine the presence of target-site and non-target-site resistance mechanism(s) through: (1) molecular analysis to detect the mutant ALS alleles; (2) in vitro ALS enzyme bioassay; (3) treatment with metabolic inhibitor (i.e. malathion 2 kg ha^{-1}) to investigate the possible presence of enhanced metabolism.
The two Italian populations (07-13 and 12-54a) were highly cross-resistant to all the ALS inhibitors tested and the mutant ALS allele Leu_{574} was identified in all the plants. Different responses were instead observed when the plants of both populations were treated with herbicide plus malathion: plants of population 12-54a showed a significant decrease in plant survival and fresh weight with respect to plants of population 07-13. This suggests that an enhanced metabolism may also be involved in the resistance. The Hungarian populations (08-16, 11-34, 11-40 and 12-49a) proved to be controlled by imazamox, while they were resistant (with different levels) to sulfonylureas and bispyribac-Na. All Hungarian populations, but not all plants of population 12-49a, presented the mutant allele Glu_{376}. ALS enzyme bioassay and treatment with malathion confirmed that in plants of these populations the resistance is very likely due to both target-site and enhanced metabolism of P450 enzymes.
The results clearly suggest that resistance to ALS inhibitors in *S. halepense* can be due to mutant ALS alleles and metabolic resistance.

Keywords: *Sorghum halepense*, ALS inhibitors, target-site resistance, non-target-site resistance

Low doses of glyphosate change the responses of soybean to subsequent glyphosate treatments (93)

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Many herbicides promote plant growth at doses well below the recommended application rate (hormesis). The objectives of this study were to evaluate glyphosate-induced hormesis in soybean (*Glycine max* (L.) Merr.) and determine whether pre-treating soybean seedlings with low doses of glyphosate would affect their response to subsequent glyphosate treatments. Seven doses (1.8 – 720 g ae ha^{-1}) of glyphosate were applied to 3-week-old seedlings, and the effects on the electron transport rate (ETR), metabolite (shikimate, benzoate, salicylate, AMPA, phenylalanine, tyrosine, and tryptophan) levels, and dry weight were determined. The lowest dose stimulated ETR and increased biomass the most. Benzoate levels increased 203% with 3.6 g ae ha^{-1} glyphosate. Salicylate and tyrosine content were unaffected, whereas phenylalanine and tryptophan levels were increased by 60 and 80%, respectively, at 7.2 g ae ha^{-1}. Dose-response curves for these three amino acids were typical for hormesis. In another experiment that was replicated twice, soybean plants were pretreated with low doses of glyphosate (1.8, 3.6 or 7.2 g ae ha^{-1}), and treated with a second application of glyphosate (1.8, 3.6, 7.2, 36, 180, or 720 g ae ha^{-1}) 14 days later. For total seedling dry weight, a 3.6 and 7.2 g ae ha^{-1} glyphosate dose preconditioned the soybean seedlings to have greater growth stimulation by a later glyphosate treatment than plants with no preconditioning glyphosate exposure. Optimal hormetic doses were generally higher with pretreated plants than plants that had not been exposed to glyphosate. Thus, pre-exposure to low doses of glyphosate can change the hormetic response to later low dose exposures.

Keywords: Glyphosate, hormesis, skikimic acid, AMPA, soybean

Session 3
BIOLOGICAL WEED CHARACTERISTICS: Germination and Emergence

Keynote: Modeling weed emergence: artificial neural networks versus non-linear regression procedures (169)

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Artificial Neural Networks (ANNs) are machines with complex functional relations learnable with a limited amount of training data emulating data processing functions of the brain. ANNs have a high potential applicability in ecological systems due to their capacity to describe highly non-linear relationships among variables. In this sense, they represent promising computational tools to accurately model weed emergence and therefore, for prediction purposes to improve weed control. But they have not been widely used with this aim, and so far, they have been proven to be useful only for one weed species (*Avena fatua*). The objectives of the present work were to develop an ANN model for ripgut brome (*Bromus diandrus*) for emergence prediction and to compare their predictive capability against already developed non-linear regression (NLR) models. Thermal-time and hydro-time were used as independent input variables for developing bivariate models. The accumulated proportion of seedling emergence was the output variable. A total of 1610 input/output data pairs corresponding to three years of data collection in two different field trials were used in this study. A total of 16 different scenarios or emergence data sets (differing in sowing dates and soil management) were modeled to compare the goodness of fit (RMSE) by the two approaches. The ANN developed had three layers: one input layer, one hidden layer with 2 neurons, and one output layer.
Both procedures, ANN and NLR, were able to predict satisfactorily *B. diandrus* emergence patterns. However, the ANN improved the fitting accuracy in 11 of the 16 scenarios with RMSE estimates 46% lower compared to NLR models. These results confirm that ANNs are powerful tools for modeling weed emergence, thus they could help improve IWM decision support systems.

Keywords: Thermal time, hidrotime, germination, sigmoidal regression

The use of light in weed emergence models (203)

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In the last 15 years a considerable number of thermal time (TT) or hydrothermal time (HTT) based emergence models have been developed for predicting weed species emergence in order to improve weed control. Most of these models have been developed in climatically restricted areas, and their accuracy might decrease when applied in contrasting climates or latitudes. Light could be a key factor, after temperature and moisture, which could improve these models.
For this reason, an experiment was set in Lleida (Spain), Morris (USA) and Riga (Latvia) from 2011 to 2013, where the emergence of field pennycress (*Thlaspi arvense*) and wild camelina (*Camelina microcarpa*) was weekly followed over the emergence period in each site. The emergence patterns were then subjected to HTT and HTT adjusted by light, whether as daylight hours, solar irradiance or both, to develop emergence models that could reasonably describe the observed data in each site. Results showed that the effect of light is variable depending on the species, but in general light-adjusted models usually improve the accuracy of those based only on HTT.
Although HTT based models could be accurate enough for predicting local emergence patterns, the use of light, and probably other factors not yet considered, is necessary if a common model is to be developed for all climatic and latitudinal sites where a weed species is present.

Keywords: Modelling, Brassicaceae, seedling emergence, hydrothermal time

Seedling emergence of *Solanum villosum* affected by soil depth (324)

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Information on seedling emergence of *Solanum villosum* is important to improve its management. A two-year field experiment was conducted to study the effect of soil burial depth on seedling emergence of this weed. On hundred seeds per pot of the species were buried in January 2010 and 2011outdoors at the depths of 0, 2, 4, 6, 8, and 10 cm in a strip plot design with four replicates. Thereafter, the number of emerged seedlings and soil temperature at all depths were recorded. The pots were kept moist during the experiment. In 2010, the seedling emergence was 34.8%±7.5% (SEM) for seeds placed at the soil surface and emergence decreased with increasing soil depth (19.3%±5.2% at 2 cm and 18.5%±4.9 at 4 cm depth). It reached 33.8%±7.4% at a depth of 6 cm. The maximum emergence (53%±8.3%) was observed at 8 cm depth followed by decrease again at 10 cm depth (6.8%±2%). In 2011, the seedling emergence was 33.8%±6.5% for seeds placed at the soil surface and emergence decreased at depth of 2 cm (10.8%±4.6%) followed by increase at 4 cm (17%±5.9%) and 6 cm (47.3%±9.9%) depths. It reached a maximum (64%±9.9%) at 8 cm followed by 57.5%±6.8% emergence at 10 cm depth. In 2010, seedling emergences took place from mid-February until mid-May with main flush from end of March to early April. In 2011, seedling emergences took place from late-February until late-May with main flush from late March to early April. The mean daily soil temperature was almost the same at all depths, however, the fluctuation in temperature was highest at soil surface and the fluctuation decreased with depth. This information could be used to apply soil disturbance measures to improve control of the species and deplete its seedbank.

Keywords: Seedling, emergence, soil, depth, temperature

The dynamics of grass weed emergence in a long-term crop rotation and tillage experiment (80)

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Grass weeds are major weed problems in North European cropping systems for arable crops. They normally occur in high proportions in winter crops, especially, winter wheat. Problems increase when tillage depth and frequency are reduced, as weed seeds tend to accumulate in the top soil layer and when timing of herbicide applications targets the emergence pattern of these weeds poorly.
Addressing this problem, a field experiment was conducted with the aim to describe, understand and model the cumulative emergence patterns of *Apera spica-venti, Vulpia myuros* and *Poa annua* in winter cereals, subjected to three tillage regimes (P- mouldboard ploughing; $H_{8\text{-}10}$- harrowing to 8-10 cm soil depth; and D- direct drilling) and two crop rotations (R1- winter wheat and R2- winter rye).
No difference was found among the crop rotations for any of the three grasses. The emergence pattern of *P. annua* was not influenced by tillage method. *A. spica-venti* and *V. myuros* showed a similar emergence pattern, that was affected by the different tillage methods. The emergence rate of both species was slower in D than with $H_{8\text{-}10}$ and P. Fifty percent of the grass weed seedlings had emerged in P and $H_{8\text{-}10}$ after 15 and 18 days, respectively.. However, in D, 24 days were required to achieve 50% of the emergence.
This result has important implications for weed control programs in directly drilled winter cereals, as dose and timing of herbicide applications may coincide poorly with the emergence of *V. myuros* and *A. spica-venti.* Late emerging grass seedlings may escape the period of maximum herbicide activity which can lead to reduced control effectiveness.

Keywords: Winter cereals, Direct-drilling, Ploughing, Harrowing

Session 4
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Integrated Weed Management

Keynote: Integrated weed management in cereals and legumes in Australian agriculture (57)

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Crops are widely grown under no-till systems in Australia. There are several benefits associated with no-till systems; however, weeds have become an important biological constraint to crop production. This is mainly because of relying on herbicides only for weed management. In no-till systems, small-seeded weeds with abundant seed production have evolved as dominant weeds in cereal and legume systems. Some of the problematic weeds are *Avena* species, *Chloris virgata*, *Chloris truncata, Conyza bonariensis*, *Echinochloa colona*, *Lolium rigidum*, *Raphanus raphanistrum*, and *Sonchus oleraceus*. The introduction of herbicide-tolerant crops further narrow down herbicide options, leading to the evolution of many herbicide-resistant weeds. Therefore, integrated weed management (IWM) would help to preserve the available herbicide options in Australian agriculture. Some of the IWM components are increasing crop competiveness through adjusting seeding rates and row spacing, and growing competitive crop varieties, the use of strategic tillage and harvest weed seed control, the use of crop rotation including rotation of herbicide-tolerant crops, and precision weed management based on infrared technology.

Keywords: Row spacing, Seed rate, tillage, Australia, Non-chemical

Direct seeding as an alternate establishment method of rice and emerging issues in Indo-gangetic plains of north-western India (637)

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Rice-wheat is the predominant cropping system of north-western Indo-gangetic plains. Manual puddled transplanted rice (PTR) is the conventional method of rice establishment. Direct seeded rice (DSR) has caught the attention of cultivators as an alternate establishment method. A survey was undertaken during 2012-13 with coverage of 114 farmers from nine rice growing districts of Haryana state to know about growers' views about the technique and related issues. A field trial was initiated in 2010 at CCS Haryana Agricultural University, Regional Research Station, Karnal to evaluate the performance of DSR on long-term basis in rice-wheat system.

Survey indicated that the maximum adoption of DSR was by medium farmers (53%) followed by large (24%) and small farmers (23%). Farmers reported a sharp decline (13 m) in the underground water table during last decade mainly due to PTR. Infestation of aerobic grass weeds like *Leptochloa chinensis, Dactyloctenium aegyptium, Eragrostis sp* and sedges like *Cyperus rotundus* was reported to be the major problem under DSR by 98% of respondents, along with problem of iron deficiency (33%) and volunteer rice (10%). Saving of irrigation water, labour, fuel and cost of cultivation were benefits of DSR realized by farmers. Gaps in yields of DSR with PTR narrowed down with passage of time due to better weed management. The long-term field trial indicated that the performance of direct seeded *basmati* rice (2.4-3.9 t/ha) was similar to PTR (2.6-4.1 t/ha) over the years. The rice-wheat system productivity was higher after DSR due to increased productivity of succeeding wheat crop (0.4-0.6 t/ha) than PTR. There was more infestation of weeds (aerobic grasses, broadleaf weeds and sedges) under DSR. The combination of pre- (pendimethalin) and post-emergence (bispyribac-sodium, pyrazosulfuron-methyl) herbicides with need based manual weeding provided effective weed management in DSR in research trials as well as at farmers' fields.

Keywords: Direct seeded rice, Weed management, Weed infestation, Survey, Productivity

Intra-row spraying and inter-row hoeing in spring oilseed rape (341)

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The need for development of alternative weed control measures with reduced amounts of herbicides has increased in Europe due to decreasing number of available herbicides, development of herbicide resistance and a demand on applying integrated pest management (IPM). The aim of this study was to develop a method where intra-row spraying and inter-row hoeing were combined to control annual weeds in spring oil seed rape. The hypothesis was that the method would give the same weed control effects and crop yields as broadcast spraying while reducing total herbicide use more than 50%. Field experiments were performed 2012-2014 in spring oilseed rape in Sweden. The treatments included control, broadcast spraying, inter-row hoeing, and inter-row hoeing+intra-row spraying. The crop was sown with a density of 105 seeds m^{-1} in May at a row distance of 12.5 and 25 cm, respectively. A sprayer boom was constructed and sprayer nozzles (Injet 150025, Spraying system) were mounted on the boom. The nozzles had a flow rate of 0.15 L $minute^{-1}$ (at 200 L ha^{-1}) at 7 bars. The equipment was installed on an inter-row hoe or a seeder. The spraying width was 8 cm and the sprayer nozzles were placed about 30 cm above the crop rows. Metazachlor 375 g L^{-1} and Quinmerac 125 g L^{-1} were applied with 2 L ha^{-1} at sowing or when the weed plants had reached 1-2 leaf stage. Inter-row hoeing was performed about 1-2 weeks after. Results showed that the combination of inter-row hoeing and intra-row spraying gave similar weed control effects and crop yields as broadcast spraying. We conclude that the combination method diminished the overall use of herbicides up to 65-70% in comparison with broadcast spraying, while having similar weed control effects in spring oilseed rape.

Keywords: Annual weeds, Brassica napus, chemical control, integrated weed management, mechanical control

Early Weed Management in corn and the role of bicyclopyrone (738)

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This paper addresses Syngenta's Strategy around Early Weed Management (EWM) in corn and how our herbicide pipeline and portfolio is designed to tame noxious weeds. Data from past decades demonstrate the benefits of EWM as an essential key to maximize corn yields and economic return. Furthermore, new compound information is provided. EWM itself cannot stop weed resistance development. However, by following this concept, the onset and spread of resistant biotypes is severely restrained, as controlling weeds early gives corn a competitive advantage. If weeds cannot develop, they also cannot set any seed. Based on our long experience and various collaborations, Syngenta is advising growers of three key tools for fighting weed resistance in corn, namely (I) controlling weeds early through a pre-emergence herbicide (the most susceptible growth stage of weeds is during the germination period), (II) using a herbicide with residual activity sufficient to control those weeds that have a wide window of germination, and (III) using multiple, overlapping modes of action (MoA) and launching new compounds to extend and refresh the tool box. One of the exciting new tools for fighting resistant and problem weeds in corn is ACURON®, Syngenta's new herbicide. ACURON® is a mixture of four active ingredients which overlap each other to follow our multiple MoA strategy. One of these, bicyclopyrone, is brand-new and is the active ingredient that provides the required step change in weed control. Bicyclopyrone controls more than 70 weed species – and most importantly – eliminates weeds that are very problematic for farmers today, because they increasingly escape current control practices, including *Amaranthus, Ambrosia, Cirsium, Erigeron, Ipomoea, Kochia,* and *Xanthium*. The solution to this issue is bicyclopyrone.

Keywords: Early Weed Management, Resistance Management Strategy, Tough-to-control weeds, Corn / Maize, Bicyclopyrone

Determination the phenology and using geographic information system (GIS) for managing wild mustard (*Sinapis arvensis* L.) in wheat fields (792)

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For wild mustard (*Sinapis arvensis L.)* management in wheat (*Triticum aestivum* L.) fields, four field experiments were conducted in four regions of Iran: Zanjan, Karaj, Varamin and Amol during 2006 and 2007. The GDD for all phenological stages of wild mustard and wheat were calculated and the equations between GDD and growth stages were fitted. The predictive weed management maps were produced for Mazandaran province as a sample. The results showed that despite high variation in phenological stages during the growing season at different sites of experiments, these stages were relatively similar when evaluated based on degree days. Based on the results of this research in four regions, using the constructed models and air temperature, determination of phenological stages of the wild mustard and the suitable time for managing this weed species in wheat is predictable. Pre-planting control of wild mustard in wheat fields with chemical methods (using diflufenican + isoproturon) involving phenological stages and growing degree days (GDD) requirements is possible. The starting and terminating times for application of post emergence herbicides for control of wild mustard in wheat fields were determined to be 400 and 1000 GDD, respectively. Using prediction maps produced by GIS, the suitable time for starting and terminating post emergence chemical control and the suitable time for nitrogen fertilizer application in order to reduce competitive ability of wild mustard against wheat in different regions of Mazandaran province could be determined.

Keywords: Growing Degree Days (GDD), Comparative Phenology, Prediction map

Session 5
WEED ECOLOGY: Weed response and adaptation to changing environments

Keynote: Ziska L. (US): Historical and experimental evidence for a CO_2 induced decline in protein concentration of an important fall pollen source (*Solidago canadensis*) of North American bees (68)

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At present there is substantive evidence that the nutritional content of agriculturally important food crops will decrease in response to rising levels of atmospheric carbon dioxide, C_a. However, whether C_a induced declines in food quality could also be affecting pollinator species is unknown. Flowering late in the season, goldenrod (*Solidago* spp.) pollen is a widely available autumnal food source essential to native bee (e.g., *Bombus* spp.) and honeybee (*Apis mellifera*) health and winter survival. Using floral collections obtained from the Smithsonian Natural History Museum, we quantified C_a induced temporal changes in pollen protein concentration of Canada goldenrod (*Solidago canadensis*), the most widespread *Solidago* taxon, from hundreds of samples collected throughout the United States and southern Canada over the period 1842-2014 (i.e., a C_a from ~280 to 398 ppm). In addition, we conducted a two year *in situ* trial of *S. canadensis* populations grown along a continuous C_a gradient from ~280 to 500 ppm. The historical data indicated a strong significant correlation between recent increases in C_a and reductions in pollen protein concentration (r^2 = 0.85). Experimental data confirmed this decrease in pollen protein concentration, and indicated that it would be ongoing as C_a continues to rise (r^2 = 0.90). Although specific health impacts on pollinators remain to be determined, these data indicate that rising C_a, by reducing pollen protein content, is adversely affecting bee nutrition at the continental level.

Keywords: Goldenrod, Carbon DIoxide, Protein, Pollen, Bees

A positive effect of organic farming on biodiversity in agroecosystems (443)

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Biodiversity is in the focus of attention of many specialists representing different fields of science due to the quick pace of extinction of various species of animals and plants, including weeds. The opinion on the importance of plants that accompany cultivation has recently changed. The role played by plants called by agriculture scientists – conventional weeds – is currently understood and assessed in a special way. This paper presents distribution of cereal field weeds in Southern Poland, as well as their diversity depending on habitat and methods of management and their importance together with protection strategy for segetal species. Research was carried out in crop fields in the south of the country during the implementation of the 'agro-environmental programme' in Poland (2007-2013). Phytosociological were made according to the Braun-Blanquet method and samples of seed material of crop plants were collected. Besides that, a part of the agricultural community (farmers, advisories) of the region has been trained in order to preserve crop field weed species exposed to extinction. Results show that a combination of extensive agriculture and properly crop rotation leads to enrich the agricultural ecosystems without reducing yield. Furthermore it was observed an increase of the public awareness about the importance of the occurrence of rare weed species in agroecosystems.

Keywords: Agro-biodiversity, weeds, organic farming, preservation of weeds, agro-environmental programme

Impact of climate fluctuation on the status of invasive alien weeds in Cauvery delta region of India (570)

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Rainfall and evaporation pattern of a region influences the weeds directly by interrupting the physiological functions involved in the process of seed dormancy and germination and by imparting seed mortality due to excessive drying or soaking. These effects are transferred through soil moisture status. Phytosociological survey of floristic composition of weeds in Cauvery delta region reveals the recent invasion of the wetland rice fields by alien invasive weeds *Leptochloa chinensis* and *Marsilea quadrifolia*. These two weed species dominated over the native weed such as *Echinochloa* sp. (*E. crusgalli* and *E. colona*) and others by virtue of their amphibious adaptation to alternating flooded and residual soil moisture conditions. Both increased and decreased run off, altered wetland water regimes along with the aquatic vegetation and their floristic composition accordingly. In southern India, the water sheds are invaded by floating weeds like *Eichhornia crassipes* under inundation and for *Ipomoea aquatica* under semi or complete dry situation. Soil moisture status with available soil moisture percentage between 40 to 60 is observed to favour the seed germination of invasive weed *Parthenium hysterophorous*, whereas available soil moisture above 80 per cent coinciding with winter months or below 40 per cent coinciding peak summer was detrimental. In a field study conducted at Annamalai University in 2011, it was observed that increasing soil temperature with the summer months of June and July triggered the mass germination of seeds of *Trianthema portulacastrum,* suppressing the native species. The seeds of this weed undergo dormancy during winter and thermo induction to break the dormancy requires soil temperatures above 35°C. Thus the climatic fluctuations contribute considerably for aiding the process of invasion by alien weeds like *L. chinensis, M. quadrifolia, E. crassipes, P. hysterophorus* and *T. portulacastrum*.

Keywords: Climate, Alien weeds, Invasion

Hoffmann A. F. (BR): What are the optimal temperature range and base water potential for germination of three tropical grass weeds? (308)

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Temperature and moisture are important factors influencing the germination rate of non-dormant seeds and here we quantify their effects in three grass species. Laboratory experiments were conducted to determine the optimal temperature range and the base water potential for germination of *Digitaria insularis*, *Digitaria horizontalis* and *Eleusine indica*. We evaluated the germination behavior of these species at nine temperatures (7.5, 12.5, 17.5, 22.5, 27.5, 32.5, 37.5, 42.5, and 47.5°C) and eight water potentials (0, -0.03, -0.06, -0.1, -0.2, -0.4, -0.6 and, -0.9 MPa). The germination of *D. insularis* occurred in a narrow temperature range (27.5 to 37.5°C), indicating a strong temperature dependence. The best germination of *D. insularis* occurred at 32.5°C. *E. indica* had a wide temperature range for germination, varying from 12.5 to 42.5°C. The temperature required for germination of *D. horizontalis* varied from 17.5 to 42.5°C. In general, better germination of *E. indica* and *D. horizontalis* occurred at 22.5°C and 32.5°C. The germination of all species was inhibited when the water potential was below -0.6 MPa at the optimal temperature, while at sub- and supra-optimal temperatures the germination was inhibited at a water potential below -0.4 MPa. Comparison of the germination requirements for *D. insularis*, *D. horizontalis*, and *E. indica* revealed differences in their responses to temperature regimes, whereas they responded similarly to changes in water potential. All three species showed a stronger dependence on temperature than water potential. The germination of *D. insularis* responded the same way to temperature at water potentials from 0 to -0.4 MPa. The seed germination behavior of *E. indica* and *D. horizontalis* changed given certain combinations of temperature and water potential.

Keywords: Germination pattern, seed germination behavior, *Digitaria insularis*, *Digitaria horizontalis*, *Eleusine indica*

Session 6
CROP-WEED INTERACTIONS: Competition and Interactions

Keynote: The *Echinochloa* genomes reveal molecular mechanisms for their environmental adaptation (269)

Longjiang Fan *(Institute of Crop Science & Institute of Bioinformatics, Hangzhou, China)*

Several species of the genus *Echinochloa* are major weeds in different rice cropping systems worldwide. In the absence of human intervention, weeds such as *Echinochloa crus-galli* dominate their ecological niches. The molecular mechanism underlying the success of *Echinochloa* over field crops is unclear. We sequenced the genome of paddy *E. crus-galli* via Illumina and BioPac sequencing platforms. We obtained a genomic assembly of 1.2 Gb representing 85.7% of its predicted genome, with contig and scaffold N50 sizes of 36.5 and 357.5 Kb, respectively. The comparative genome analysis of *E. crus-galli* identified more than 10,000 *Echinochloa*-specific genes and extremely high copy numbers of cytochrome P450 monooxygenase (P450) and glutathione S-transferase (GST) genes, which are two key enzymes for the detoxification of allelopathic compounds or herbicides. We further analysed transcriptomes of co-cultivated *E. crus-galli* and rice and found 200 candidate allelopathy-related genes in *E. crus-galli*. Our findings provide new insights into the adaptation strategy of weeds by evolving more adaptation-related genes than crops to gain a competitive advantage over crops.

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Keywords: *Echinochloa* weeds, genome sequencing, allelopathy, environmental adaptation

Song J.-S. (KR): Modeling the effects of N fertilizer on soybean-weed competition under multiple weed interference (88)

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This study was conducted to investigate the effects of N fertilizer on soybean-weed competition under multiple weed interference in a soybean field, Ussuriysk, Primorski-Krai, Russia (N43°49', E131°36'). Weed species including *Ambrosia artemisiifolia*, *Beckmannia syzigachne*, and *Echinochloa crus-galli* were naturally established and artificially thinned to achieve target weed densities in single and multiple weed interferences in the soybean field where nitrogen fertilizer was applied at different levels (0, 12, 24, 36, 72 kg ha^{-1}) before sowing soybean. Soybean yields recorded at a range of weed densities under single and multiple weed interferences were then fitted to the rectangular hyperbola at each nitrogen level. The estimated weed-free soybean yield (Y_0) increased with increasing N fertilizer from 0 to 36 kg ha^{-1}, but decreased at 72 kg ha^{-1}, indicating that the inverse quadratic model could well describe the relationship between Y_0 and nitrogen level. The weed competitiveness (b) also responded to nitrogen level in the inverse quadratic function. Therefore, by incorporating two inverse quadratic models for parameters Y_0 and b in the rectangular hyperbola, the combined rectangular hyperbolic model could well describe soybean yields as influenced by multiple weed competition and nitrogen level. The model can support our decision-making for herbicide use under different nitrogen use scheme in soybean cultivation in Primorski-Krai, Russia.

Acknowledgments

This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ01052602)" Rural Development Administration, Republic of Korea.

Keywords: Crop-weed interaction, modeling, nitrogen fertilizer, inverse quadratic model, soybean

Mechanisms of P mobilization in the rhizosphere involving weeds and crop plants (318)

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In the present agricultural management, the impact of crop-weed species interactions on P-mobilization is not under consideration, although it might offer crop promoting combinations by increasing the diversity of P mobilization strategies in the rhizosphere. Therefore, the present study aims to select highly P efficient combinations of plant species in arable crop production systems for a decreased need for P-fertilization. For this reason, interactive P mobilization in crop-weed combinations was investigated in a pot trial using a P-deficient soil. Maize was used as a mycorrhizal host crop in combination with five mycorrhizal and non-mycorrhizal weeds. Increased competition for nutrients was represented by very similar strategies for P mobilization between maize and the associated weed species under different combinations. Interactions in joint rhizosphere of mycorrhizal and non-mycorrhizal species were investigated. On one hand, soil phosphatase activity, microbial biomass P, plant available P, and root colonization of arbuscular mycorrhizal fungi were taken into consideration for soil analyses, whereas on the other hand maize yield and the total P content of maize were determined. In conclusion, the presentation will provide a description of plant species-specific mechanisms of P mobilization and a selection of promising combinations of plant species to increase P-use efficiency in crop production.

Keywords: P, rhizosphere, phosphatases, mycorrhiza

Crop responses to weed growth in dry seeded rice systems (804)

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Weeds are major biotic constraint in dry-seeded rice (DSR) causing yield reductions up to 100%. Insights in crop-weed interactions for DSR are important for the development and selection of weed-competitive rice cultivars. The response of two rice cultivars (PR114 and PR115) to weed infestation was studied in a field experiment conducted at Punjab Agricultural University Ludhiana, India in 2012 and 2013. Different weed interference periods were established by keeping the crop weedy and weed free for 0, 14, 28, 42, 56, and 70 days after sowing. Linear regression models for crop plant height and tiller density, in response to weed biomass, show negative correlations. Our models indicated that weed biomass explained 38-50% and 70-75% of variation in plant height, and 77-82% and 90-92% variation in tiller density during the two successive years. This suggests more weed sensitivity of tiller density compared to plant height. Among rice cultivars, the slope in the function describing the relation between plant height and weed biomass was steeper for PR114 than for PR115, while the reverse was found in case of tiller density. This showed that the reduction in plant height in response to an increase in weed biomass was higher for PR114, while the reduction in tiller density was higher for PR115. However, the higher intercept in PR115 during both years (381-383 tillers/m^2) suggests a higher production of tillers by this cultivar under no or low weed pressure, compared to PR114 (with 334-343 tillers/m^2). The higher negative slope for tiller production in PR115 could be due to its shorter crop duration than PR114 by 20 days. Higher plant height and more tillers (under partial weed pressure) describes the weed competitive ability of PR115 over PR114. This study generates pointers for the selection of weed-competitive rice cultivars as a weed management component in DSR.

Keywords: Dry-seeded rice, crop-weed interaction, Weed biomass, cultivar, rice growth

Session 7
HERBICIDES AND APPLICATION TECHNOLOGY: Sprayers

Keynote: Off-target movement of various size spray droplets when applied with an open versus a shielded boom (105)

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Droplet size plays a critical role in herbicide efficacy, deposition, and off-target movement. For this study, four droplet sizes were used Ultra Course (>650 µ), Very Course (401 to 500 µ), Medium (225-325 µ), and Fine (145-225 µ)) with identical sprayers one of which had an open boom and the other a Redball™ hooded boom. A formulation of Roundup PowerMax® at 1.26 kg ae/ha-1 and 1, 3, 6, 8-pyrene tetra sulfonic acid tetra sodium salt (PTSA) at 0.005 kg/3.785 L was used. The field was laid out with one 183 m pass down the field. Small mylar cards were placed in three lines 4, 8, 16, 32, 45, and 64 m downwind of the treated area. Large mylar cards were placed at 75, 90, and 105 m, downwind of the treated area. Three petri dishes were placed within each swath and small mylar cards were placed upwind of the treated area as the untreated check. The petri dishes and mylar cards were collected a minimum of two minutes after sprayer stopped. The mylar cards and petri dishes were analyzed using a fluorimeter. The data were analyzed in SAS 9.4 using the Tukey-Kramer (P<.1) method with the effect being the treatment. At a distance of 4 m the fine droplet produced a RFU value of 3,553 with the open boom as compared to 386 with the hooded boom which represents a 89% reduction in drift. At the same distance, the very course (VC) droplets produced RFU values of 742 and 91 for the open and hooded booms, respectively which equals a 88% reduction in drift. The use of a hooded sprayer decreased the amount of particle drift. As droplet size increases, the difference between hooded spray boom and open spray boom decrease, especially with Very Course (VC) and UC droplet sizes.

Keywords: Shielded sprayer, droplet size, 2,4-D, dicamba

Logarithmic sprayers are indispensable in assessing herbicides with adjuvants, mixtures and herbicide drifts (408)

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The logarithmic sprayer, which in course of travelling time automatically dilutes the herbicide spray concentration exponentially, is an excellent field experimental tool to test efficacy of herbicides, the joint action of herbicides in mixtures, the effect of adjuvants and the drift of herbicides. The sprayer can cover a large dose range and thus take the often high variability of herbicide efficacy into account. By repeating experiments under various environmental conditions one can get a fair idea of the precision of the herbicide-adjuvant efficacy, herbicide mixtures and the herbicide drift assessment and the inherent variability. We have routinely used logarithmic sprayers for all three purposes (Streibig et al 2014).
The research of joint action of mixtures, adjuvants efficacy and herbicide drift assessments in the field on the basis of logarithmic spray experiment is relatively inexpensive. And last but not least the ED levels can be assessed depending on the objectives of the experiment, e.g.-for tolerance of crops ED_{10} and/or control of weeds ED_{90}.
STREIBIG JC, RASMUSSEN J, AND_UJAR D, ANDREASEN C, BERGE TW, CHACHALIS D, DITTMANN T, GERHARDS R, GISELSSON TM, HAMOUZ P, JAEGER-HANSEN C, JENSEN K, JØRGENSEN RN, KELLER M, LAURSEN M, MIDTIBY HS, NIELSEN J, M€ULLER S, NORDMEYER H, PETEINATOS G, PAPADOPOULOS A, SVENSGAARD J,WEISM&CHRISTENSEN S (2014). Sensor-based assessment of herbicide effects. Weed Research 54, 223–233.

Keywords: Herbicide mixtures, Adjuvants, Herbicide drift, ED50, ED90

High resolution chemical application control (669)

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Chemical application in situ has many variables that all need to be accounted for to achieve uniform deposition. The use of large, self-propelled sprayers and rate-controllers aid in limiting variability from a quantitative standpoint but often add significant inconsistency from a qualitative standpoint. The ability to operate in wide speed ranges leads to pressure variations, which in turn, lead to droplet size variations. These variations tend to manifest themselves most on the margins of the fields where misapplications are likely to be observed and also where pest resistance and propagation to other areas may occur. The opposite can also happen in these same locations as a result of boom overlap where excess chemical deposition can actually damage crops and yields. Sprayer operators are limited in their options to combat these issues conventionally. Pulse width modulation, or PWM, systems address all of the above variables automatically and efficiently by maintaining constant pressure independent of speed. New systems that allow for individually controlling each nozzle on a boom are available that provide uniform application in all areas of the field regardless of speed and will shutoff and turn on nozzles with nozzle level resolution which reduces crop damage. These same systems allow for adjusting flow rate on a per nozzle basis to perform turn compensation to correct for under-application on the outside of a boom when turning and over-application on the inside of the boom. They can also be used to account for the presence of dust or higher weed pressure in areas where drift sensitivity is greater. Such systems, available commercially in North America for over 20 years from Capstan Ag Systems, are showing marked reductions in over application all while improving the quality of the chemical deposition and, therefore, maximizing the potential for the chemical to perform as advertised.

Keywords: Pulse Width Modulation, Efficacy, Application Control, Individual Nozzle Control, Turn Compensation

Flight speed, pressure and deflection angle influence on droplet size spectra in aerial applications of glyphosate associated with adjuvants (494)

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Drift is the main concern of an improper glyphosate aerial application. Wind, droplet size, application height and speed are key factors for drift. Droplet size is affected by nozzle, pressure, flight speed, deflection angle, and physical-chemical properties of the spray solution. The objective of this research was to evaluate the effect of flight speed, pressure, deflection angle and the use of adjuvants on droplet size spectra in glyphosate aerial applications. Two studies were conducted in a high-speed wind tunnel. Glyphosate aerial applications were simulated with different wind speeds (160, 190, 220, 250 km h^{-1}) and glyphosate solutions combined with adjuvants (high surfactant oil concentrate, drift reduction agent, nonionic surfactant, polymer, and glyphosate alone). Applications were performed using a CP11-8006 at 276 kPa. In the second study, glyphosate applications were simulated using a CP11-8008 nozzle at different pressures (103, 207, 310, 414 kPa) and deflection angles (8º, 38º, 68º, 98º) at 190 km h^{-1} wind speed. Droplet size spectra were evaluated using a Sympatec Helos laser diffraction instrument measuring 45 cm from the nozzle. The volumetric median diameter (VMD) and the percentage of droplets smaller than 100 µm (D_{V100}) were reported. Glyphosate solutions with adjuvants had a larger VMD than the glyphosate alone solution at 160 km h^{-1} wind speed. At 250 km h^{-1} only the glyphosate solution with polymer had a larger VMD. Conversely, it had the highest D_{V100}. At an 8º deflection angle, the largest droplets were produced at 207 and 414 kPa. For the other angles, higher pressures produced smaller droplets. Across pressures, when the deflection angle was increased, smaller droplets were observed. The D_{V100} and relative span increased and decreased, respectively, as deflection angle increased. The proper configuration of aerial applications is critical to achieve a successful weed control while mitigating unintended effects to the surrounding environment.

Keywords: Drift reduction technologies, high speed wind tunnel, laser difraction, CP nozzle

Session 8
HERBICIDE RESISTANCE: Non-Target-Site Resistance 2

Keynote: Can we improve the management of herbicide-resistant weeds in Australia? (733)

Roberto Busi *(University of Western Australia, Crawley, Australia),* ***Stephen B Powles*** *(University of Western Australia, Crawley, Australia)*

On a global scale, herbicides are an effective tool to remove weeds, yet numerous cases of herbicide-resistant weeds have steadily increased in the last 40 years. At present the response of farmers to the widespread evolution of multi-resistance in *Lolium rigidum* is a much greater reliance on pre-emergence soil-applied residual herbicides including trifluralin, prosulfocarb and pyroxasulfone. Before the commercialization of pyroxasulfone we observed that rapid pyroxasulfone resistance evolution in a *L. rigidum* population could occur by low-dose selection over three generations. We demonstrated that pyroxasulfone low-dose selection resulted in cross-resistance to prosulfocarb and triallate. Recent studies show that prosulfocarb + S-metolachlor and pyroxasulfone resistance can co-evolve by selection with either herbicide. These findings have important applied implications because they can inform farmers on the best use of herbicide tools in the field. As there is an urgent need to reduce the selection pressure for resistance to herbicides that are still effective, I will present results of long-term modelling simulations with the platform PERTH and discuss the effect of herbicide combinations (herbicide rotation vs. mixtures) to achieve optimal control of ryegrass and maximal delay of cross-resistance. I will then briefly review the efficacy and adoption of various weed management practices adopted in Australia aimed at reducing the infestation of *L. rigidum.* This will highlight the importance of crop agronomy tactics to complement the use of effective herbicides for sustainable weed management in Australia and future research needs to explore innovative herbicide solutions for improved control of multi-resistant weeds (i.e. mixtures, synergists, safeners, etc.). There is a continuous need for research that can inform and support farmers' decisions on weed control practices. Research must provide the necessary knowledge and confidence to farmers to achieve effective weed control with chemical and non-chemical tools at the individual field and farm level.

Keywords: Herbicide resistance, *Lolium rigidum*, pre-emergence herbicide, integrated weed management

RNA-seq transcriptome analysis for herbicide tolerance in Palmer amaranth (462)

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The widespread occurrence of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) is threatening the sustainability of crop production in the United States. With glyphosate no longer a viable control option for resistant weeds, glufosinate serves as alternative tool in managing glyphosate-resistant weeds. This study aimed to determine non-target site-based tolerance mechanism in glufosinate-tolerant Palmer amaranth by examining the global gene expression patterns in glufosinate-tolerant and –susceptible plants using RNA Seq. Glufosinate (0.55 kg ai ha^{-1}) was applied to 3- to 4-inch Palmer amaranth seedlings. Susceptible and tolerant plants were selected from parental and F1 Lee-08-C populations, respectively, to avoid confounding effects of genotypic or ecological differences. Leaf tissues from both treated and nontreated seedlings were harvested after 24 h for RNA-Seq analysis. The same plants were also used for ammonia accumulation assay and glutamine synthetase (*GS2*) gene copy number determination. The susceptible plants accumulated two times more ammonia than the tolerant plants. *GS2* copy number between tolerant and susceptible plants did not differ, with *GS2* copies ranging from 1 to 3 in both tolerant and susceptible plants. Global gene expression was measured using Illumina reads from nontreated and treated-susceptible and –tolerant plants. A reference cDNA transcriptome was assembled and assigned putative annotations. Comparison between treated and nontreated susceptible plants revealed 6034 differentially expressed genes. A total of 8154 genes were differentially expressed in the treated relative to the nontreated tolerant plants. Differential gene expression was apparent between treated tolerant and susceptible samples with 357 genes up-regulated and 210 genes down-regulated in tolerant plants. Contigs having the largest fold-change (>10) expression differences were usually annotated with gene ontology terms in the molecular function category. Differentially expressed genes will be further analyzed to identify biochemical pathways that are involved in glufosinate response. In addition, candidate genes will be validated using quantitative real-time PCR.

Keywords: Palmer amaranth, glufosinate tolerance, RNA-Seq, transcriptome analysis, herbicide resistance

Selection of non-target-site resistance (NTSR) to several ALS-inhibiting herbicides in three populations of *Ambrosia artemisiifolia* (65)

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Ambrosia artemisiifolia is an invasive and a noxious weed. In America, it has evolved resistance to different herbicide modes of action. This study uses a recurrent selection approach to assess the capacity of *A. artemisiifolia* to evolve Non-Target-Site Resistance (NTSR) to ALS-inhibiting herbicides. Following establishment of baseline sensitivity to several ALS inhibitors, metsulfuron was used as the first selection agent. The collateral selection of NTSR to tribenuron and imazamox, which are key herbicides for *A. artemisiifolia* control, was assessed in progenies from metsulfuron-selected plants.
Seeds from three field populations (G0, no or low ALS-inhibiting herbicide history) were sampled. Herbicides were applied at the four-leaf stage using a custom-built, single-nozzle (110-04, Albuz, France) sprayer delivering herbicide in 300L/ha water at 400kPa (speed 6.6km/h, temperature 23°C, relative humidity 80%). Plants that survived 4, 8 or 16g metsulfuron/ha were bulk-crossed per herbicide rate. ALS sequencing did not identify resistant ALS alleles in these G0 plants. Seeds were collected on each plant to obtain G1 progenies. Each G1 progeny was sprayed with the selecting G0 rate and a higher rate (16, 24 or 40g metsulfuron/ha). Imazamox and tribenuron were also tested at two rates each on each G1 (12.5 and 50g imazamox/ha, 50g/ha=field rate, and 6 and 30g tribenuron/ha, 30g/ha=field rate). Both herbicides gave full control of G0 plants at the lowest rates assayed.
45% to 60% plants in three G1 progenies survived the highest metsulfuron rates. 2.5% to 5% plants in three other G1 progenies survived the tribenuron field rate and 8% plants in yet another G1 progeny survived the imazamox field rate. Our results show that genetic factors contributing to NTSR to metsulfuron exist in *A. artemisiifolia*. Further selection with metsulfuron entailed evolution of NTSR to imazamox and tribenuron. G2 progenies that underwent an additional selection cycle are currently being assayed.

Keywords: Non-Target-Site Resistance, ALS-inhibiting herbicides, *Ambrosia artemisiifolia*

The herbicide safener cloquintocet-mexyl reduces rye-grass (*Lolium* sp.) sensitivity to an ALS inhibitor and regulates candidate non-target-site-based resistance genes (139)

Christophe Délye *(INRA, Dijon, France),* ***Arnaud Duhoux*** *(INRA, Dijon, France)*

Safeners enable selective control of weeds in botanically related crops by enhancing or triggering herbicide degradation in crop plants *via* mechanisms very similar to mechanisms involved in weed non-target-site-based resistance (NTSR). To assess whether safeners could play a role in NTSR evolution, we investigated the effect of the safener cloquintocet-mexyl on plant phenotype and on the expression level of 18 candidate NTSR genes in *Lolium sp.*. Twelve plants in each of three populations were split into 14 tillers each. Tillers from each plant were used in the following modalities: water (control, 2 tillers), Actirob (adjuvant, 2 tillers), cloquintocet-mexyl, pyroxsulam+Actirob (4 tillers), cloquintocet-mexyl+pyroxsulam+Actirob (4 tillers) applied using a custom-built, single-nozzle (110-04, Albuz, France) sprayer delivering herbicide in 300L/ha water at 400kPa (6.6km/h, 23°C, relative humidity 80%). Actirob (1L/ha), pyroxsulam (18.75g/ha) and cloquintocet-mexyl (18.75g/ha) were at the recommended field rate in every modality. Two tillers per plant and per modality were collected 24hours after application to measure the expression of the candidate NTSR genes. The effect of cloquintocet-mexyl on plant phenotype was rated 4 weeks after application using the remaining 2 tillers in the last two modalities. Overall, addition of cloquintocet-mexyl to pyroxsulam reduced the sensitivity of approx. 25% of the plants tested compared to pyroxsulam alone. A significant up-regulation of 8 candidate NTSR genes was observed 24 hours after application of cloquintocet-mexyl alone. Plants showing a decrease in sensitivity when cloquintocet-mexyl was sprayed with pyroxsulam showed a higher up-regulation than other plants in modalities including cloquintocet-mexyl. An additive effect of pyroxsulam and cloquintocet-mexyl on gene regulation was observed, with a relative effect of cloquintocet-mexyl of up to 48%. We demonstrated that cloquintocet-mexyl can modify herbicide sensitivity and regulate genes potentially involved in NTSR in *Lolium sp.*.

Keywords: Safener, Herbicide, Resistance, Lolium, Genes

Session 9
HERBICIDE RESISTANCE: Herbicide Resistance Modeling

Keynote: Evolution of herbicide resistance: Is there a fitness cost? (390)

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Fitness costs of herbicide resistance in the absence of herbicide selection play key roles in the evolutionary trajectory of herbicide resistance and serve as the theoretical basis for herbicide rotation, one of the most widely practiced herbicide-resistance mitigation strategies. Despite the importance of fitness costs to herbicide-resistance evolution, the acquisition of fitness cost information is surprisingly challenging due to lack of robust short-term study systems. Therefore, a three-year multigenerational greenhouse study was conducted to determine the fitness costs of five herbicide resistances in *Amaranthus tuberculatus* (waterhemp). A synthetic *A. tuberculatus* population was created by bulk crossing parental populations that collectively contained five types of herbicide resistance. The resulting population, which is segregating for the five different herbicide resistances, was subjected to six generations of competitive growth conditions in the absence of herbicide selection. The frequencies of the different resistant traits were determined from both whole-plant herbicide treatments (atrazine, HPPD inhibitors) and molecular markers (glyphosate and PPO and ALS inhibitors) and compared across generations. Our results indicated that most of the resistance traits (atrazine, PPO, ALS and Pro106Ser mutation-based glyphosate resistance) had little or no fitness costs. In contrast, glyphosate resistance conferred by EPSPS gene amplification had a significant fitness cost. The frequency of glyphosate-resistant plants with high EPSPS copy numbers consistently dropped from about 40% to 15% after six generations across all three replicate greenhouse rooms. The results from this novel fitness study indicate that herbicide rotation will not be a particularly effective herbicide-resistance mitigation strategy.

Keywords: Herbicide resistance, Fitness cost, *Amaranthus tuberculatus*

Modeling shattercane population dynamics in a stochastic herbicide-tolerant Sorghum cropping system (102)

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Traditional breeding technology is currently being used to develop grain sorghum germplasm that will be tolerant to acetolactate synthase (ALS)-inhibiting herbicides. This technology (Inzen, DuPont) has the potential to improve sorghum production by allowing for the postemergence control of traditionally hard-to-control grasses in the United States. However, grain sorghum and shattercane can interbreed and introduced traits such as herbicide tolerance could increase the invasiveness of the weedy relative. Moreover, ALS-resistance in shattercane populations has been reported, indicating that over-reliance on ALS-chemistry may also select for resistant biotypes. The objective of this research was to develop a simulation model to assess management options to mitigate risks of ALS-resistance evolution in shattercane populations in US sorghum production areas. Assuming a single major gene confers resistance and gene frequencies change according to the Hardy-Weinberg ratios we constructed a stage-structured (seedbank, plants) matrix model with annual time steps. The model explicitly considered gene flow from Inzen plants to shattercane populations. The management strategies considered in the model were: a) continuous sorghum, b) sorghum *fb* soybeans and c) sorghum *fb* fallow *fb* wheat, where postemergence ALS-herbicides were only used in Inzen years. During sorghum years, two options were tested: continuous Inzen and Inzen *fb* conventional sorghum. The parameter values used in the model were obtained from our research, the literature, and expert opinion. For each management strategy we ran 500 simulations with stochastic levels of herbicide efficacy. Evolution of resistance was predicted to occur rapidly if Inzen sorghum is planted continuously because of high selection pressure (ALS-herbicide application) and gene flow. The time for resistance evolution was predicted to decrease with increased cropping system complexity (more crop diversity than continuous production of Inzen). Crop and herbicide rotation will be key strategies to postpone the evolution of ALS-resistance in shattercane.

Keywords: Crop-to-weed gene flow, Herbicide resistance evolution

Were pre-emergent herbicides protected from resistance by their early seasonal applications and lowered efficacy? (662)

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Populations of weeds have generally evolved resistance to pre-emergent herbicides more slowly than to post-emergent herbicides. Faster evolution of resistance to post-emergent herbicides is often hypothesised to be due to naturally occurring higher frequencies of post-emergent resistant genes. Other factors possibly explaining these different evolutionary rates include the distinctive annual use patterns of the different herbicide groups; that lead to differences in the sequentially emergent weed cohorts affected. A further possible factor is the lowered herbicide efficacy often found in pre-emergent herbicide applications.
This study used individual based simulation modelling to investigate the effect of different herbicide application times, efficacy and allele frequency on evolution of herbicide resistance within a simulated population of *L. rigidum* growing in a wheat crop. Several alternative herbicide scenarios were investigated involving annual applications of a pre-emergent herbicide with residual activity, and/or the application of a post-emergent herbicide applied in-crop, that affected more weed cohorts through the year.
Differences in time-of-application between the two classes of herbicides (applied in separate simulations) was insufficient to generate an additional year of efficient herbicide use. We found that reducing the efficacy of the pre-emergent herbicide delayed evolution of resistance to this herbicide, whilst promoting the rapid build-up of resistance to the post-emergent herbicide. In addition very low weed numbers prior to the evolution of resistance delayed large increases in the numbers of resistant weeds, and extended to five years the gap between when weed populations first exceeded 95% resistant plants and when the population expanded to reach 25 (size equivalent) weeds/ m^2.
Faster evolutionary rates to post-emergent herbicides are primarily due to the lowered efficacy of the pre-emergent herbicide, with large differences in evolutionary rates between pre-and post-emergent herbicides only fully explained in a scenario combining both lower efficiency of, and rarer resistance alleles to, the pre-emergent herbicide.

Keywords: Evolution, allele frequency, simulation modeling

A holistic biological and computer-based modelling approach for rapidly identifying and sustainably managing glyphosate-resistant Amaranths in soybean agro-systems in Argentina (242)

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Populations of *Amaranthus palmeri* and *Amaranthus quitensis* resistant to glyphosate have recently been documented in soybean production systems in Argentina. Given the agronomic importance of these weed species, it is crucial to quickly identify and sustainably control the recalcitrant populations with other effective herbicides. In agreement with classical whole plant pot assays, resistance to glyphosate was speedily confirmed in two *Amaranthus palmeri* and one *Amaranthus quitensis* populations from the Cordoba province, Central Argentina, using the agar-based Syngenta Resistance In-Season Quick (RISQ) test.
Further, both sensitive and glyphosate resistant *Amaranthus* populations were effectively killed with a mixture of metribuzin/S-metolachlor or fomesafen/S-metolachlor applied pre-emergence under glasshouse conditions. Similar levels of control were also observed for both sensitive and glyphosate-resistant AMAPA populations with early post-emergence applications of mixtures of fomesafen/S-metolachlor, glyphosate/fomesafen or diuron/paraquat.
Computer-based model simulations showed that fomesafen/S-metolachlor applied pre-emergence was more effective and managed weed density for a longer period compared to the same mixture employed in early post-emergence (7 years versus 3 years). Fomesafen/S-metolachlor used pre-emergence followed by an early post-emergence application had even better and more consistent control of AMAPA density (9 years). However, repetitive use of the same single-site herbicide fomesafen increased the potential for evolved resistance to protoporphyrinogen IX oxidase inhibiting herbicides. On the other hand, metribuzin/S-metolachlor used in pre-emergence followed by fomesafen/S-metolachlor applied in early post-emergence was the most sustainable herbicide program evaluated in terms of weed density management (>20 years) and resistance risk levels. This study demonstrates the usefulness of a holistic approach for tackling glyphosate resistance in *Amaranthus* species. It also underlines the importance of diversity in herbicide modes of action, combined with optimal application timing, in providing sustainable management of Amaranths in soybean agro-systems in Argentina.

Keywords: Amaranthus spp., Glyphosate resistance, Syngenta RISQ test, pre/post-emergence herbicide programs, population models

Session 10
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Weed Control in Herbicide Resistant Crops

Keynote: Stewardship and diagnostic supporting ALS tolerant sugarbeet to contrast herbicide resistance evolution (551)

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Herbicide tolerant crop varieties are convenient technologies which need proper stewardship. Stewardship should include strategies based on IWM principles to preserve in the long term both technology and farmer yields. The herbicide tolerance trait of the new sugarbeet variety presented was obtained by selecting rare naturally occurring changes in the gene for acetolactate synthase (ALS) during cell division. ALS is an enzyme involved in the biosynthesis of essential amino acids. ALS inhibitors represent compounds featuring high and wide efficacy in controlling broadleaf and grass weeds. The tolerance was not induced but spontaneously occurred in sugar beet cell cultures cultivated in a medium containing the ALS-inhibitor foramsulfuron. In ALS-inhibitor tolerant sugar beets the ALS-inhibiting herbicide cannot bind with ALS enzyme responsible for production of essential amino acids, therefore the production of essential amino acids and proteins is not blocked resulting in normal sugar beet growth. The herbicide tolerant variety is based on conventionally bred sugarbeet varieties that are tolerant to ALS-inhibiting herbicides. Relying on herbicides belonging to the same mode of action in a crop rotation exacerbates the risk for selecting resistant weeds. In order to avoid the selection of herbicide resistant biotypes, pre-launch programs have been established to define different anti-resistance management strategies for the ALS-tolerant sugarbeet. The strategies adopted rely on pro-active resistance management by defining main crop rotations and associated weed control measures. Thus, strategies focus on diversity in the cropping system and monitoring suspected herbicide failures. The stewardship developed to support the herbicide tolerant sugarbeet variety includes diagnostic support by scrutinizing complaints and potentially resistant weeds as well as to provide tailor-made management advice based on investigations of possible herbicide resistance mechanism(s). Applying the above mentioned IWM stewardship measures will allow the sustainable use ALS tolerant sugarbeet and to provide a new weed management option to farmers.

Keywords: Product stewardship, herbicide resistance diagnostic, IWM pre-launch programs, ALS sustainability, proactive resistance management

Chinnusamy C. (IN): Agronomic evaluation of herbicide resistant cotton and maize for better weed management in India (140)

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Herbicide-resistant crops are commercially cultivated in many countries, but in India, they are in initial stages of field evaluation. Hence, field trials have been carried out to evaluate and consolidate the agronomic advantages of herbicide-tolerant transgenic cotton and maize. Herbicide-tolerant stacked traits of maize and cotton were evaluated under BRL I (Bio-safety Research Level I) as confined field trials for their agronomic efficiency at TNAU (Tamil Nadu Agricultural University), Coimbatore, India for three years (2010 to 2013). In both maize and cotton, the potassium salt of glyphosate was sprayed at different doses and WCE (Weed Control Efficiency), phytotoxicity, residual effect on succeeding crops, yield and economics were evaluated. Application of glyphosate at 2700 g a.e./ha led to lower weed density, dry weight and higher WCE in cotton. POE (Post Emergence) glyphosate at 900, 1800 and 3600 g a.e./ha led to lower weed density, dry weight and higher WCE in Hishell and 900 M Gold and in 30V92 and 30B11 maize hybrids. POE glyphosate in maize did not affect the germination percent, vigour or yield of succeeding green gram and sunflower, soybean and pearl millet in cotton trials. Phytotoxicity was not observed in cotton and maize. Higher grain yield was recorded with POE glyphosate at 900 and 1800 g a.e./ha in Hishell and 900 M Gold maize hybrids and higher net returns and BCR (Benefit Cost Ratio) were recorded in glyphosate at 1800 g a.e./ha in transgenic 900 M Gold. POE glyphosate at 900 and 1800 g a.e./ha registered higher grain yield in transgenic 30V92 and 30B11 corn hybrids. In maize and cotton transgenic crops, post emergence weed management with glyphosate proved to be the better management option for higher weed control efficiency.

Keywords: Agronomic, Efficiency, Transgenic, Herbcide, Tolerant crops

The advantages of glyphosate-resistant corn production in China (342)

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Corn is one of the major crops in China with 36 million hectares in 2014. Weed control is the farmer's biggest challenges in corn production. It is estimated that crop yield losses due to weeds are approximately 900 Mt in China. Farmers hope to use broad spectrum herbicides, which kill nearly all kinds of weeds to maintain higher yield of corn, but it was impossible until the development of glyphosate-resistant crops. Glyphosate traditional use has been limited to non-crops and orchards for post-emergence application but now glyphosate-resistant crop system provides corn growers a new way to use it. By fast rate of adoption, GR corn occupied 30% of the global area of corn production in 2014 and was grown in 17 countries. Although no GR corn was commercialized in China, Chinese farmers showed a strong enthusiasm in growing GR corn. In this paper, the necessity of glyphosate-resistant corn production in China was discussed based on China's actual conditions of corn production and herbicide use. Firstly, Glyphosate could replace pre-herbicides such as acetochlor and atrazine, the widely used soil applied herbicide in corn field in China which usually provide poor control in dry soil conditions. Secondly, Glyphosate could replace herbicides such as atrazine, which bring frequent injuries to the following broadleaf crops in northeast China due to residues. Third, GR corn overcomes succession of weed species such as *Commelina communis*, *Cirsium setosum* and *Sonchus brachyotus,*etc. Fourth, GR corn does well with less tillage which needs a burn-down treatment before corn planting in wheat-corn double cropping systems. Lastly, GR corn can help the labour shortage situation in China.

Keywords: Glyphosate-resistant, Corn, China

Possibilities of volunteer Clearfield oilseed rape control (612)

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Clearfield (CL) oilseed rape (OSR) hybrids are tolerant to imidazilonone herbicide. However, there is a certain degree of tolerance to other ALS inhibitors. Control of volunteer CL OSR is more difficult than control of conventional volunteer varieties in succeeding crops. Two small plot trials were carried out in Prague in growing season 2014/15. Main objective of experiments was to evaluate the possibility of volunteer CL OSR in winter wheat and spring barley and compare the reproduction ability of volunteer CL OSR in these cereals. Twelve herbicides with different modes of action were tested in winter wheat. All tested herbicides except ALS inhibitors amidosulfuron + iodosulfuron controlled volunteer CL OSR. Highest efficacy was recorded mainly after autumn application of herbicide isoproturon + pendimethalin, chlorotoluron + pendimethalin + diflufenican and metribuzin, which prevented the reproduction of CL OSR. Efficacy of herbicides diflufenican + flufenacet and diflufenican + isoproturon was higher on volunteer CL OSR compared to volunteer of conventional varieties of OSR and seed production of conventional volunteer OSR after application of these two herbicides was relatively high. Efficacy of spring applied mixed herbicides (ALS inhibitors + synthetic auxin) on volunteer CL OSR was only 90 % but reproduction was not recorded. Seven herbicides were tested in spring barley. No live oilseed rape plants were recorded 6 weeks after application of herbicides amidosulfuron + iodosulfuron + 2,4-D and florasulam + 2,4-D. The efficacy of herbicides florasulam + tritosulfuron, amidosulfuron + iodosulfuron, metsulfuron + tribenuron + fluroxypyr was relative low (46 – 83 %). Competition ability of barley was very strong, therefor low biomass and seed production (less than 30 seeds/m^2) of volunteer CL OSR were recorded on these plots.

Keywords: Clearfield, oilseed rape, volunteer, cereals

Session 11
WEED ECOLOGY: Evolution and Adaptation of Weeds

Keynote: Epigenetic variation may play a major role in rapid post-introduction adaptative evolution of an invasive alien weed (642)

Sheng Qiang Qiang *(Nanjing Agricultural University, Nanjing, China)*

Numerous hypotheses have been proposed to address why an invasive alien weed becomes so aggressive after its introduction and colonization in a new range. However, the driving forces and the innate genetic mechanism of adaptive evolution in invasive plants remain unclear. Epigenetics is considered to be mainly involved in regulation of gene transcription and expression and determination of phenotypic plasticity. DNA methylation, one of four epigenetic paradigms, may be implicated in rapid adaptive evolution of invasive alien plants through the genetic regulation of gene expression related to ecological adaptation. Crofton weed (*Ageratina adenophora*), a highly invasive alien weed, is continuously spreading across subtropical areas in China, north-eastward from the first colonized south-western tropical regions, through cold tolerance evolution. Rapid cold tolerance evolution among 34 populations, represented by 147 accessions of this weed, has clearly driven their continuous expansion northward. The CBF transcription pathway variation, which plays the key role in cold response in plants, is responsible for the observed cold tolerance divergence. Four epialleles of the cold response regulator *ICE1* ranged from 66 to 50 methylated cytosines, representing a 4.4% to 3.3% methylation rate and significantly corresponding to the lowest to highest cold tolerance levels among all geographical populations. The significant negative relation between the transcription levels of the primary CBF pathway members, except for *CBF2*, and the methylation levels among four distinctly geographical populations demonstrated that the *ICE1* demethylation-upregulated transcription level of CBF pathway caused this adaptive evolution consequence. These facts, combined with the cold tolerance variation and methylation found among three native and two other introduced populations, firstly indicate that the *ICE1*-demethylated upregulation of cold tolerance may be the underlying evolutionary mechanism allowing crofton weed to successfully expand northward in China. This notion may be extended to elucidate successful invasion by other alien weeds through post-introduction adaptive evolution.

Keywords: Invasive alien plants, epigenetics, demethylation, adaptive evolution mechanism

Moodley D. (ZA): A global assessment of invasiveness in the *Araceae*: any general invasive traits in a shape-shifting family? (157)

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Şerban Procheş *(University of KwaZulu-Natal, Westville Campus, Durban, South Africa),*
John R.U. Wilson *(Stellenbosch University, Stellenbosch, South Africa)*

Significant progress has been made in understanding biological invasions recently and one of the key findings is that the determinants of naturalization and invasion success vary from group to group. Here we explore this variation for one of the largest plant families in the world, Araceae. This group provides an excellent opportunity for identifying determinants of invasiveness in herbaceous plants, since it is one of the families most popular with horticulturalists, with species occupying various habitats and comprising many different life forms. We first developed a checklist of the 3,494 species of Araceae recognised worldwide using online databases and literature sources. We aimed to determine whether invasiveness across the introduction-naturalization-invasion continuum is associated to particular traits within the family, and whether analyses focused on specific life-forms can reveal any mechanistic correlates. Boosted regression tree models were based on species invasion statuses as the response variables, and traits associated with human use, biological characteristics and distribution as the explanatory variables. The models indicate that biological traits such as plant life form and pollinator type are consistently important. Additionally, large scale drivers such as the number of native regions and numbers of introduced regions are also influential at particular stages in the invasion continuum. We used these traits to build a phenogram showing clades defined by the similarity of characters. We identified nine clades that have a greater tendency to invasiveness (including *Alocasia*, the Lemnoideae and *Epipremnum*). From this we propose a list of species that are not currently invasive where we would recommend a precautionary approach be taken. The successful management of plant invasions will depend on understanding such context-dependent effects across taxonomic groups, and across the different stages of the invasion process.

Keywords: Biological invasions, boosted regression trees, herbaceous family, invasiveness, predictions

Izquierdo J. F. (ES): New model approach for forecasting timing of weed control measures (618)

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Weed emergence models based on hydrothermal degree are used to predict the ideal timing of weed control measures. These models rely on equations such as Gompertz, Weibull or logistic, in which daily soil temperature and moisture are required inputs. These models are good predictors of weed emergence patterns at local and regional scales where fields have similar climatic and soil conditions, but lose accuracy when extrapolated to different scenarios. Another weakness is the subjectivity of the starting point for assessing the accumulation of hydrothermal degrees. Usually the starting date is set to the day of tilling or seeding, however, this assumption has no biological or ecological basis. The sigmoid equations used in these models are good descriptors of weed emergence patterns, therefore, we suggest the use of the differential form of the equation rather than the integrated form for timing purposes. When using the differential form of the equation, validation at local scale and starting date are not required because calculations are based on sigmoid relationships between data recordings. Hydrothermal time accumulation starts when the first weed emergence is recorded in the field. Cumulative emergence and hydrothermal time are added weekly. When the rate of emergence starts to decrease (the data slope begins to flatten), the plateau of the sigmoid curve is approached and, therefore, the maximum percentage of emergence. The best time to spray is when weed emergence reaches 95%, thus, it can be recommended that herbicide be applied when this percentage is reached according to the model. In order to check the accuracy of this approach, a Gompertz equation in its differential form was applied to 35 data sets from different weeds, crops and years in Spain. Results showed that the date predicted by the differential model for 95% weed emergence matched what was observed in the field.

Keywords: Weed control, Gompertz, Model, Timing, Weed emergence pattern

Weed community evolution in conservative and conventional agricultural systems (624)

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The potential shift in weed communities is a common concern in conservation tillage systems. The aim of this study was to determine, in a field study, the weed community evolution over time in conventional and conservative cultural systems. The study was carried out in northern Italy over the period 1997-2012. Two cultural systems were compared: conventional (CONV), based on ploughing, and conservative (CONS), based on minimum tillage. A four-year crop rotation, including wheat, maize, pea, sunflower, rape and soybean was adopted. In both systems weeds were controlled with herbicides. Weed density was assessed for each crop at least twice during the growing season in non treated areas, while weed seed bank (at 0-15 cm depth) was monitored at the end of each crop rotation cycle. For the majority of the crops grown in CONS total weed density was significantly higher than in CONV. In summer crops the most abundant weeds were *Echinochloa crus-galli*, *Chenopodium album* and *Galinsoga quadriradiata,* with the highest density in system CONS. In wheat, weed infestation was mostly represented by *Stellaria media*, *Veronica persica* and *Lamium purpureum*. At the beginning of the study weed seed bank varied from 11838 seed/m^2 in CONV, to 13616 seed/m^2 in CONS. In the following assessments, weed seed bank decreased remarkably in both systems, particularly in CONV. Over the period weed species richness was influenced by the rotation cycle and by the changes in agronomic practices occurred. The highest number of weed species was generally observed in summer crops and in the system CONV. The CONS system was characterized by a higher Simpson index and a lower Shannon value, compared to CONV system. Weed management resulted more simplified in CONV system, due to a more diversified and generally less abundant infestation.

Keywords: Conservation tillage, weed population dynamics, minimum tillage

Session 12
CROP-WEED INTERACTIONS: Competition and Interactions, Integrated Weed Management

Keynote: How can we predict the effects of varying soil water supply on crop-weed competition? (186)

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The outcome of crop-weed competition is driven by the physiological mechanisms that regulate the effect of each species on a given resource, and their response to the quantity of that resource available to the plant. Little published information is available on crop and weed response to soil water supply. This information is critical if we wish to understand the relative importance of weeds in causing crop loss under future climate change scenarios where the frequency and quantity of rainfall may vary greatly in many of the most productive agricultural regions worldwide. Predicting the outcome of interplant competition for soil water requires accurate prediction of soil water supply, plant water demand by each species, and the efficiency with which water is used within each plant. Research on maize and velvetleaf (*Abutilon theophrasti*) transpiration in response to drying soil and water use efficiency under sufficient and water stressed conditions in Nebraska USA will be used as examples of quantifying plant response to available soil water. In a greenhouse study, the critical soil water content below which plants begin to close their stomata occurred at a fraction of transpirable soil water content of 0.36 and 0.41 for maize and velvetleaf, respectively, indicating that maize transpiration will be maintained at optimum levels at a lower soil water content than velvetleaf under short-term drought conditions. In another study, maize transpiration efficiency (TE, cumulative biomass/cumulative transpiration) was greater than that of velvetleaf in both sufficient and water stressed conditions. Moreover, maize TE increased with increasing water stress. While these results suggest that maize is more water-use-efficient than velvetleaf, it is not clear how these results translate to crop performance in the field, or to maize-velvetleaf competition for water. Further research is needed to clarify this linkage between individual plant performance and crop productivity and crop-weed interference.

Keywords: Competition, water use efficiency, transpiration efficiency, modelling, simulation

The effect of weed competition on cotton growth as affected by temperature and carbon dioxide conditions (469)

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The increases in global temperature and atmospheric carbon dioxide (CO_2) concentration affect not only the growth of crops and weeds, but also the competition between them. Therefore, investigations on the effects of these factors on the concurrence between crops and weeds would provide valuable information for the future climate scenarios. The present study was aimed at investigating the effects of temperature and CO_2 on the competition between C_3 cotton and a C_4 weed *Amaranthus retroflexus* L. (AMARE), as well as a C_3 weed *Xanthium strumarium* L. (XANST) in two replicated experiments. Cotton and weed seeds were sown to the pots and grown for 6 weeks under two different temperature (16/30°C and 22/36°C) and CO_2 conditions (ambient 450 ppm or elevated 750 ppm). In each pot, one cotton seedling was grown in competition with one individual weed species. Additionally, cotton plants without competition were maintained to assess biomass reductions due to weeds. Results showed that temperature did not have a significant effect on cotton biomass reduction caused by AMARE competition. However, increased temperature affected cotton-XANST competition significantly in favor of cotton in both experiments. Results pertaining to CO_2 treatments showed that cotton-AMARE competition was affected in favor of cotton in both experiments, so that relative biomass of cotton seedlings (in relation to cotton grown without competition) were greater under elevated CO_2 levels. In the case of cotton-XANST competition, elevated CO_2 did not have a significant effect in the first experiment, while the competition was in favor of XANST in the second experiment. These results showed that climate change would influence the competitive ability of cotton with weeds at different degrees, depending on the weed species and climatic variable.

Acknowledgement: Authors thank the Turkish Council for Scientific Research (TUBITAK) for providing financial support to these studies (Project Code 110 O 184).

Keywords: Carbon dioxide, temperature, cotton, weed, competition

Palmer amaranth (*Amaranthus palmeri*) competition for water in cotton (21)

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Palmer amaranth is a troublesome weed in cotton production. Yield losses of 65% have been reported from season-long Palmer amaranth competition with cotton. To determine whether competition for water is an important factor in crop yield loss, experiments were conduced in 2011, 2012, and 2013 in Citra, FL, and in Tifton, GA. In 2011, infrequent rainfall lead to drought stress. The presence of Palmer amaranth resulted in decreased soil relative water content up to 1 m in depth. Cotton stomatal conductance (*gs*) was reduced up to 1.8 m from a Palmer amaranth plant. In 2012 and 2013 higher than average rainfall resulted in excess moisture throughout the growing season. In this situation, no differences were found in soil relative water content or cotton *gs* as a function of proximity to Palmer amaranth. A positive linear trend was found in cotton photosynthesis and yield; each parameter increased as distance from Palmer amaranth increased. Even in the well-watered conditions, daily water use of Palmer amaranth was considerably higher than that of cotton, at 1.2 and 0.49 g H_20 cm^{-2} d^{-1}, respectively. Although Palmer amaranth removed more water from the soil profile, rainfall was adequate to replenish the profile in 2 of the 3 yr of this study. However, yield loss due to Palmer amaranth was still observed despite the lack of effect on *gs*, suggesting that other factors, such as competition for light or response to neighboring plants during development, may be causing the yield loss.

Keywords: Sap flow, carbon assimilation

Competition of major weeds with wheat across KP Province, Pakistan (281)

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Knowledge on the threshold level for different weeds is important for devising an economically-viable weed-management strategy in wheat. Managing weeds without consideration to the threshold level usually results in decreased net returns. Therefore, a series of experiments were conducted to document the major weeds of different regions of the KP province, Pakistan. A total of 4 different locations were selected and two major weeds of wheat at each location were identified. These studies were conducted for three years (2012, 2013 and 2015). A total of 16 weed documentation studies and 28 field experiments were conducted during the reported period. The objectives were to investigate the competitive abilities of the selected major weeds against wheat at different location and at different densities by using two ecological designs, namely the additive design and the replacement series design. Two weed species were found to be the major yield reducing weeds of wheat at each location. The major weeds were *Rumex dentatus, Phalaris minor, Rumex crispus, Silybum marianum,* and *Neslia apiculata.* This paper presents the competitive abilities of the selected weeds and reduction in yield related variables of wheat for weed management decision making process.

Keywords: Competitive ability, threshold level, yield losses, weed density, wheat and weed

Session 13
HERBICIDES AND APPLICATION TECHNOLOGY: Application Tools and Techniques and Analytical Methods

Keynote: The full protocol for early-season weed mapping with UAV technology (702)

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Jorge Torres-Sanchez *(Institute for Sustainable Agriculture (IAS-CSIC), Cordoba, Spain),*
Ana Isabel de Castro *(Institute for Sustainable Agriculture (IAS-CSIC), Cordoba, Spain),*
Francisca Lopez-Granados *(Institute for Sustainable Agriculture (IAS-CSIC), Cordoba, Spain)*

The application of site-specific weed management (SSWM) practices requires that the weeds be previously located in the crop field, e.g., by generating a weed map. Until now, obtaining these weed maps early in the growing season, which is the moment recommended in many crops for an optimal weed management treatment, has been a great challenge because of the reduced size of the weed and crop plants and their spectral similarity at an early phenological stage. This challenge has been overcome by the combined use of aerial images collected with an Unmanned Aerial Vehicles (UAV) and application of object-based image analysis (OBIA) techniques. This abstract describes the full protocol developed in the last four years by our research group with that objective. The investigation was conducted over several parcels of three herbaceous (wheat, corn and sunflower) and three woody (olive, poplar and grape) crops. The main phases of this protocol involved: 1) configuration and use of the UAV and sensors for image acquisition, 2) determining the finest flight configuration (UAV altitude, image spatial and spectral resolutions, flight length, etc.) for each type of crop, with particular attention to crop evolution (multi-temporal study), 3) optimizing the process of image mosaicing and geo-referencing in order to generate a unique ortho-mosaiced image that completely covers the fields of study, and 4) development of customised and robust OBIA procedures for weed mapping and crop assessment in order to optimize crop-weed management operations adapted to different scenarios. Our results demonstrated that weed emergences could be discriminated with accuracy higher than 90% if image resolutions are correctly selected for each type of crop and scenario, although an agreement with flight length and UAV battery duration is needed in order to optimize the full procedure.

Keywords: site-specific weed management (SSWM), unmanned aerial vehicle, object-based image analysis, herbaceous row crops, woody crops

Tørresen K. (NO): The potential of two tools for integrated weed management to reduce herbicide use against annual weeds in cereals (520)

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Therese W Berge *(Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway)*

With the Directive 2009/128/EC on sustainable use of pesticides, reductions in herbicide use is a European target. The aim of this study was to compare the field-specific herbicide use resulting from simulated integrated weed management (IWM) with farmer's actual use. Two IWM tools applicable for cereals were explored: VIPS – a web-based decision support system, and DAT sensor – a precision farming technology for patch spraying. VIPS (adaptation of Danish "Crop Protection Online") optimizes herbicide – and dose to weed species density- and growth stage (including ALS-herbicide resistant populations), temperature, expected yield, cereal species- and growth stage. Weeds were surveyed (0.25 m^2, n=23-31) prior to post-emergence spraying in spring 2013 (six fields) and 2014 (eight fields). DAT sensor enables automatic patch spraying of annual weeds within cereals. It consists of an RGB camera and custom-made image analysis. DAT sensor acquired more than 900 images (0.06 m^2) per field. Threshold for simulated patch spraying was relative weed cover (weed cover/ total vegetation cover) = 0.042. Treatment frequency index (TFI, actual dose/maximum approved dose summed for all herbicides) was calculated. Without resistance strategy, average TFI for VIPS was higher for winter wheat (0.96) than for spring cereals (0.38). Spring cereal fields with resistance strategies gave an average TFI of 1.45. Corresponding TFI for farmer's applications were 1.40, 0.90 and 1.26, respectively. For one field wherein both tools were explored in 2013 and 2014, TFI values for VIPS were 1.86 and 1.50 due to resistant *Stellaria media*, while TFI for farmer's sprayings were around 1.00. DAT sensor simulated herbicide savings of 69% and 99%, corresponding to TFI values of 0.58 and 0.01, respectively. As measured by TFI, DAT sensor showed a higher potential in herbicide savings than VIPS. VIPS is available without costs to end-users today, while DAT sensor represents a future tool.

Keywords: Annual weeds, cereals, herbicide dose, patch spraying, herbicide resistance

Carbon-seeding technology: Applications for weed management in seed production and beyond (63)

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Activated carbon slurries are used to protect crop plants such as landscape ornamentals and horticultural transplants by inactivating soil-applied herbicides around the rooting zone of the crops. A similar application of this method of plant protection is often referred to as carbon seeding. Carbon seeding involves utilizing a band of activated carbon, generally applied at a rate of 28 kg ha^{-1} in a 2.5 cm band, sprayed over the crop seed row during planting followed by a broadcast application of a soil active herbicide. The activated carbon adsorbs the herbicide, thus protecting the germinating crop seeds underneath the carbon band through seedling emergence. The carbon seeding method allows use of herbicides that would otherwise injure or kill the crop species. This seeding method in combination with the use of herbicides including diuron and pronamide applied at 2.24-2.88 kg ha^{-1} and 0.14-0.28 kg ha^{-1} respectively, is routinely used in Oregon, USA, for establishment of cool-season grass crops grown for seed including perennial ryegrass (*Lolium perenne* L.) and tall fescue (*Festuca arundinacea* Schreb.). The diuron and pronamide control grass weed species including annual bluegrass (*Poa annua* L.) that, if not managed during grass seed stand establishment, can cause significant seed yield loss and reduce seed quality. Carbon seeding techniques for the production of native grass and forb seed also have been developed, but this technique should not be limited to seed production cropping systems. There is significant potential to develop carbon seeding techniques and equipment for weed management in other types of cropping systems and for native plant community restoration efforts.

Keywords: Application technology, grass seed production, annual bluegrass

Banded herbicide application in cotton (183)

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The use of banded herbicide application (BHA) equipped with the cover shield mounted on the field sprayer can simultaneously control the weeds in crop rows using total herbicides and in intra-rows with selective herbicides. The main purpose of this study was to control intra-rows weeds in cotton fields with clethodim or tepraloxydim and troublesome weeds in rows with glyphosate via BHA. For this purpose, the effects of total and selective herbicides used at different rates (glyphosate at 1.44 and 2.88 kg ai ha^{-1} and clethodim at 145.25 and 116.2 g ai ha^{-1}, tepraloxydim at 45 and 36 g ai ha^{-1} in, respectively) on weed species and the response of the cotton to these herbicides were determined in field studies performed at two locations in Menemen (İzmir) and Söke (Aydin), Turkey in 2015. Whether or not the cotton seedlings came in contact with glyphosate was detected by biochemical methods, and the concentration of shikimic acid in the seedlings was measured one to two days after treatment (DAT) by spectrophotometry. In both fields, glyphosate effectively controlled johnsongrass, barnyardgrass, purple nutsedge, and other broad-leaved weeds at 1.44 and 2.88 kg ai ha^{-1} with BHA in row at 28 DAT. Purple nutsedge was not well-controlled by clethodim and tepraloxydim in rows or intra-rows, but barnyardgrass was well controlled by these herbicides. Although johnsongrass was well-controlled by clethodim in both the rows and intra-rows, it was not successfully controlled by tepraloxydim. Shikimic acid levels tended to be higher in cotton seedlings than in the untreated controls, but none of the cotton plants showed any phytotoxicity due to shikimic acid accumulation at 14 and 28 DAT. Cotton lint yields in the plots that used glyphosate were significantly higher than the plots where clethodim and tepraloxydim were applied and also in the untreated control.

Keywords: Banded Herbicide Application, Cotton, Glyphosate, Clethodim, Tepraloxydim

Session 14
JOINT IWSS/INTERNATIONAL BIOHERBICIDE GROUP SESSION: Realizing the Potential of Biological Weed Control

Keynote: Broad leaved weed control by *Phoma macrostoma* in agricultural crops (23)

Russell K. Hynes *(Agriculture and Agri-Food Canada, Saskatoon, Canada),* ***Karen L Bailey*** *(Agriculture and Agri-Food Canada, Saskatoon, Canada),* ***Jo-Anne Derby*** *(Agriculture and Agri-Food Canada, Saskatoon, Canada),* ***Daniel Hupka*** *(Agriculture and Agri-Food Canada, Saskatoon, Canada)*

Phoma macrostoma Montagne received conditional registration in Canada (2011) and the United States (2012) for biological weed control in turf grass. To advance *P. macrostoma* for agricultural use, field trials were conducted to determine the crop tolerance of alfalfa, corn, soybean, pea, potato, wheat, barley and flax to *P. macrostoma*, the efficacy of the bioherbicide on Canada thistle (*Cirsium arvense*), and wild mustard(*Sinapsis arvensis*), and the effect of bioherbicide application timing on weed control. *Phoma macrostoma* was harmful to alfalfa, *Medicago sativa,* (cultivar Longview) in the year of establishment significantly reducing plant number. The plant reductions were dependent on the bioherbicide rate applied. One year-old alfalfa was unaffected. In a multi-year crop rotation study following dry land and irrigation farming practices, wheat (*Triticum* spp), barley (*Hordeum vulgare* L.) and corn (*Zea maize*) germination and growth were unaffected while potato *(Solanum tuberosum* L.) outgrew early symptom development. Soybean (*Glycine max*), pea (*Pisum sativum* L) and flax (*Linum usitatissimum*) were sensitive to *P. macrostoma*. Crops sensitive to *P. macrostoma* will be planted into Phoma-treated soil from the previous year to record soil residue effects. *Phoma macrostoma* effectively reduced Canada thistle, wild mustard, and other broadleaved weed seedlings under field conditions when applied prior to weed emergence. The bioherbicide was most effective on reducing plant number and biomass of wild mustard by 75-100%. The biomass of other broadleaved weed seedlings was reduced by 75%. The control of Canada thistle was more variable with reductions in weed cover ranging from 52-80% and the reductions in biomass from 35-69%.

Keywords: Bioherbicide, Phoma, Canada thistle, Wild mustard

Impact of the biocontrol beetle, *Cassida rubiginosa*, on *Cirsium arvense* in New Zealand (37)

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Cirsium arvense (Californian thistle, Canada thistle, creeping thistle) is one of the worst agricultural weeds in temperate regions of the world. The weed is native to Eurasia, and was inadvertently introduced to New Zealand (NZ) over a century ago, where it is now one of the worst pasture weeds, causing severe productivity losses. As part of the biological control programme against this weed, the leaf-feeding beetle, *Cassida rubiginosa*, was released in NZ in 2007. The beetle is now well-established in most regions and is the most successful biocontrol agent released against *C. arvense* to date. Field surveys at beetle release sites have reported outbreak populations (i.e. 100s of beetles per *C. arvense* shoot) with frequent shoot death, and 63% defoliation measured at one site. To better quantify the impact of this biocontrol agent on its target weed, a controlled field experiment was established in 2014 to determine (1) the effect of defoliation by *C. rubiginosa* on thistle shoot population density from year to year, and (2) the relationship between beetle larval density per shoot and thistle population decline. Isolated patches of the weed were created and varying densities of the beetle larvae (0, 5, 10, or 20 per shoot) were applied to the *C. arvense* patches. Mean percent defoliation was, respectively, 0%, 10%, 19% and 25%. Subsequent changes in thistle shoot densities in response to the beetle density treatments will be measured in spring 2015 (November to December 2015) to assess the impact of the beetle on the weed population density. The percent defoliation required by the beetle to cause thistle population decline will also be discussed in the context of a recently developed matrix population model.

The development of a soil bacterium as a pre-emergent bioherbicide (412)

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Russell K. Hynes *(Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan, Canada),*
Tim Dumonceaux *(Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan, Canada)*

Pseudomonas fluorescens strain BRG100, a soil-borne bacterium, is being assessed and developed as a biological herbicide, with the aim of registering and commercializing it for control of annual grass weeds. This biopesticide significantly affects germination and/or root growth of green foxtail and wild oat, including weed populations that have developed resistance to chemical herbicides. When formulated into a pesta granule and applied to soil, it suppresses weed emergence and aboveground biomass. Prior to large-scale release and registration approval, fundamental knowledge about spatio-temporal interactions and environmental fate in soil are required. In addition, factors such as soil moisture, temperature, and texture affect the establishment, colonization, and survival of the bacterium, thereby influencing the outcome of efficacy trials. Large-scale replicated efficacy trials are required to optimize the placement of the bioherbicide in relation to the crop. An environmental tracking system is needed to study the bacterium's release and dispersal from the formulation and its survival; long-term persistence in the soil is not desirable. The reporter system that utilizes the green fluorescent protein gene (*gfp*) is an excellent model for conducting such studies at the single cell level because it permits rapid, visual detection of the bacterium and provides the level of sensitivity necessary to meet the requirements of the Pest Management Regulatory Agency. These tools will support the development of BRG100 as a reduced-risk weed control product that is environmentally friendly, reduces reliance on and resistance to chemical herbicides and without persistent soil residues in soil.

Keywords: Pseudomonas, fluorescens, bioherbicide, green foxtail

SolviNix LC, the first registered bioherbicide containing a plant virus as the active ingredient (99)

Raghavan Charudattan *(BioProdex, Inc., Gainesville, United States)*

Solanum viarum (SOLVI; tropical soda apple; TSA), a native of South America, is reported to occur in 23 countries. It is an invasive weed in the United States, Australia, and nine other countries in and outside its native range. It is susceptible to several plant viruses that cause nonlethal diseases. An exception is *Tobacco mild green mosaic tobamovirus* strain U2 (TMGMV U2), a widely prevalent virus adapted to species in the Solanaceae, which kills this plant by eliciting a host-specific, hypersensitive, systemic necrosis. This mode of action is the basis for the development and registration of a naturally occurring isolate of TMGMV U2 as the bioherbicide SolviNix LC to control TSA. About a week after SolviNix application, the virus elicits hypersensitive local lesions in the infected leaves. This is followed, about 3 to 4 weeks later, by wilting and systemic necrosis of the plant. Based on extensive host-range, spread, persistence, and other risk-analysis studies, we have determined that SolviNix can be used safely without harm to nontarget plant species, fauna, or the environment. An industrial process has been developed to mass-produce the virus. As a practical, non-chemical TSA-management option, SolviNix provides high levels of TSA control, performs consistently, and is easy to apply. Recommended application methods include spot-spraying with high-pressure sprayers and herbicide wipers. SolviNix LC is unconditionally registered in the United States. It is undergoing experimental use trials for possible registration in Brazil.

Keywords: Bioherbicide, SOLVI, TMGMV, Virus, Noxious Weed

Session 15
HERBICIDE RESISTANCE: Herbicide Resistance Status and Surveys

Keynote: The global status of weed resistance and consequences for agricultural practices (523)

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Resistance of weeds to herbicides is a problem for global agricultural productivity that is growing very rapidly. This presentation will give an overview about the current status of weed resistance, the consequences for agriculture and how farmers are dealing with the issue. For the US, Brazil and Argentina approximately 1/3 of the area, on average, used for corn, soybean and cotton are infested with glyphosate resistant weeds. Besides several species being resistant to ALS, ACCase and PSII, lately weeds in the US have developed resistance against compounds which were introduced to supplement glyphosate, namely auxins and PPOs. Currently in Brazil, Argentina and Paraguay there is strong selection pressure on ACCase, ALS and auxins due to a lack of herbicide diversity in the absence of other control measures. In most cropping systems in Canada the primary weed of concern is wild oat, mainly resistant to ACCase and ALS. In Australia approximately 2/3 of 30 million hectares of field crops are infested with herbicide resistant weeds, especially multi-resistant Lolium. In Europe herbicide resistant weed species show mainly target site resistance (TSR) against ALS, ACCase and PSII herbicides. Additionally, non-TSR is rapidly gaining importance. There has been hardly any change in overall weed management practices over the last 15 years. Adoption of IWM measures is generally limited to farmers who already have severe problems. Only a small percentage of farmers globally try to avoid or manage resistance before it actually occurs on their farm. Other tools that need to be included in order to relieve selection pressure for herbicide resistance are physical, cultural and biological controls. Despite the fact that these measures are well-known to farmers and the fact that they are aware that resistant weeds will spread further, decisions are still driven by seasonal results, weed management simplicity and short-term economic considerations.

Keywords: Herbicide, resistance, IWM

Spatial distribution of herbicide resistant *Echinochloa* spp. in rice fields in California, USA (201)

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The occurrence of herbicide resistance has been an increasing problem in many crops, particularly those cropping heavily depending on herbicide for weed control. Rice farming in California, USA also solely relies on herbicides for weed control, so herbicide resistance (HR) in *Echinochloa* species has already been reported. However, no spatial investigation of HR *Echinochloa* species has been made based on systematic *Echinochloa* seed collection. Therefore, in 2014, we visited rice fields from Sacramento, in the south, to Chico, in the north of California and collected 125 accessions of *Echinochloa* spp. They were then tested with penoxsulam (ALS inhibitor) and cyhalofop-butyl (ACCase inhibitor) to investigate the spatial distribution of herbicide resistance in California rice fields. Whole-plant assays were conducted to primarily screen potentially resistant accessions of *E. oryzicola*, *E. oryzoides* and *E. crus-galli*. Twenty accessions of *E. oryzoides* and *E. crus-galli* survived penoxsulam treatment at a dose of 60 g ai/ha. Sixty three *E. oryzicola, E. oryzoides* and *E. crus-galli* accessions survived cyhalofop-butyl treatment at a dose of 500 g ai/ha. Subsequent dose-response assays revealed that in the case of penoxsulam, the R/S ratios of the 20 accessions selected in the primary screening test ranged from 1.34 to 12.42 when compared to an *E. crus-galli* susceptible biotype, while in the case of cyhalofop-butyl, 60 out of 63 accessions were resistant with R/S ratios ranging from 2.72 to 79.24 when compared to *E. crus galli* and *E. phyllopogon* susceptible biotypes. Further research will be conducted concerning the mechanism that confers resistance. This study was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ01052602)" Rural Development Administration, Republic of Korea.

Keywords: *Echinochloa* species, herbicide resistance, ALS inhibitor, ACCase inhibitor, California rice

Hamouzova K. (CZ): A decade of monitoring herbicide resistance in *Apera spica-venti* in the Czech Republic (502)

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Pavlina Kosnarova *(Czech University of Life Sciences Prague, Prague, Czech Republic),*
Josef Soukup *(Czech University of Life Sciences Prague, Prague, Czech Republic),*
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Herbicide resistance in silky bent grass (*Apera spica-venti)* is an escalating problem due to increased reliance on herbicides as the main method for weed control. Czech University of Life Sciences Prague is conducting herbicide resistance monitoring since 2004. The seed samples were taken only in fields where farmers observed failures after application of herbicides. These samples were then screened on the sensitivity to commonly used herbicide HRAC groups A, B and C1 in dose-response experiments. The aim of the studies was to determine long term developments of resistance in *A. spica-venti* populations. A testing of 500 populations of *A. spica-venti* showed that 68% of samples were resistant to at least one active ingredient. Sixty-six percent of samples tested were resistant to ALS inhibitors, 1% to ACCase inhibitors and 3% to PSII inhibitors, respectively. Two populations contained plant individuals with resistance to three herbicide modes of action. 32% of tested populations were classified as susceptible with the possible causes of poor control incurred by improper application. Most of chlorsulfuron-resistant biotypes were confirmed to be cross-resistant to iodosulfuron and sulfosulfuron. Lower levels of resistance were found to triazolopyrimidines than to sulfonylureas with the inconsistent response of the populations with resistance factors for sulfonylureas ranging from 2 up to >150. The resistance levels and number of resistant populations have increased dramatically in last 3 years. The rapid increase in the incidence of herbicide resistance in silky bent grass, particularly in Group A and Group B herbicides, highlights the importance of adopting an integrated approach in weed management to reach sustainability of the control methods.
This research was funded by project QJ1310128 of the National Agency for Agricultural Research.

Keywords: Cross-resistance, mode of action, multiple resistance, silky bent grass

Herbicide resistant weeds: A case study from wheat growing area of Pakistan (466)

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In 2010-15, field surveys were conducted in wheat fields in different regions of Pakistan. A questionnaire was used to collect data from the farmers. Seeds were assembled from different locations for further studies. *Phalaris minor* (Littleseed canary grass) is a very vital and annual weed of winter cereal crops followed by *Avena fatua*. These are noxious weeds of wheat in Pakistan. Normally, three aryloxyphenoxy propionate herbicides, clodinafop-propargyl, fenoxaprop-P-ethyl and diclofop-methyl are used to control different grassy weeds like *P. minor, Avena sativa* and *Cyperus rotundus* L. High yield of wheat is associated with its continuous use. However, this exercise increases the development of resistant biotypes . The study predicted resistance in all selected areas (Punjab, KPK, Sindh, and Balochistan). Agronomic practices integration can help effective management of *P. minor* and *A. fatua*, especially in the resistant populations.

Keywords: Herbicide resistance, weeds of wheat, Phalaris minor

Resistance of *Conyza bonariensis* to glyphosate: Situation in South Africa (78)

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Prior to the present study, investigation of herbicide resistance was limited to a single region in the country. *C. bonariensis* is often the most dominant and widely distributed weed in both annual and perennial cropping systems. Objectives were to assess the response to glyphosate in 24 *C. bonariensis* populations sampled from both the winter and summer rainfall regions in South Africa, and to compare the accumulation of shikimate in both glyphosate-resistant and glyphosate-susceptible plants. Screening of populations for glyphosate tolerance was done in a greenhouse. At 4-6 leaf stage, plants were treated with glyphosate (Roundup Turbo) at rates of 0, 225, 450, 900, 1800 and 3600 g a.e. glyphosate per hectare (200 L/ha total spray volume). For shikimate analysis, plants were sampled at 0, 2, 4, 6 and 8 D.A.T. and kept at -80^{0}C. Frozen tissue was ground in liquid nitrogen and 100 mg weighed out into Eppendorf tubes. Extraction was done in 0.25 N HCl, followed by vortexing, sonication and centrifuging. The supernatant was taken out and directly used for analysis by HPLC. ED_{50} values calculated from dose-response graphs varied across populations. Glyphosate use history revealed that high glyphosate use frequency, application beyond the label-recommended growth stage, and lack of diversity in herbicide mechanisms of action employed were linked to cases of either high tolerance or resistance. The interaction effect population x dosage x D.A.T. was significant. Shikimate content increased in all the populations from 2 to 6 D.A.T., and continued to increase in susceptible (S) populations but decreased at 8 D.A.T. in resistant (R) populations. This supports reports by other researchers that shikimate accumulates in both S and R biotypes but decreases with time in R biotypes only. Results suggest that a glyphosate-insensitive EPSPS enzyme is not the sole mechanism of resistance of *Conyza bonariensis* to glyphosate. More work is underway to unveil other mechanisms of resistance of this weed to glyphosate, and to find practical solutions for effective control.

Keywords: *Conyza bonariensis*, Glyphosate, Resistance, Shikimate

Herbicide resistance in California orchard and vineyard cropping systems (43)

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Herbicide-resistant weeds, especially glyphosate-resistant biotypes, are currently the most important and rapidly changing weed management issue facing California orchard and vineyard cropping systems. While glyphosate-resistant (GR) winter-annual weeds, including *Lolium* spp., *Conyza canadensis, and Conyza bonariensis* are widespread in and around perennial crops, summer-annual grasses, such as *Echinocloa colona* and others have recently emerged as a new challenges in this crop sector in California. Winter-annual weeds differ with respect to growth and phenology patterns and, as a consequence, different alternative control strategies are needed. Therefore, in addition to continuing research on resistance in widespread problem weeds like *Conzya*, recent efforts have also focused on the distribution, phenology, mechanisms of resistance and invasion potential of summer grasses in perennial crops. The overarching goal of this work is to use a combination of basic and applied research to develop effective, economical and environmentally sustainable weed management practices for orchards and vineyard production systems.

Keywords: Glyphosate-resistance, orchards, vineyards, physiology, phenology

Resistance to propanil in *Cyperus difformis* and *Schoenoplectus mucronatus* from California rice is endowed by a psbA mutation, Valine219 to Isoleucine: implications for management (87)

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Cyperus difformis (CYPDI) and *Schoenoplectus mucronatus* (SCHMU) are major weeds of California rice which evolved resistance to the photosystem II (PSII)-inhibitor propanil. Our objectives were to determine the level of propanil resistance and cross-resistance to other PSII-inhibiting herbicides in newly-obtained CYPDI and SCHMU biotypes, and to elucidate their resistance mechanism such that applied prevention and management practices can be designed to delay the spread of resistant (R) populations across rice fields. Dose-response assays were conducted for a variety of PSII inhibitors, and interactions between propanil and the insecticide carbaryl, a known propanil synergist and aryl acylamidase (AAA) inhibitor, were analyzed to clarify whether propanil metabolism is the resistance mechanism. Rice cv. M-206 was used as a comparison model. Lastly, we sequenced the chloroplast *psbA* gene in R and susceptible (S) biotypes to determine if target-site mutations are present. Propanil-R biotypes displayed a 14-fold level of propanil resistance. Synergism between propanil and carbaryl was greater on rice and S rather than R plants, indicating enhanced AAA-mediated propanil metabolism is not involved in CYPDI and SCHMU resistance to propanil. Unlike previous propanil resistance cases, a $Valine_{219}$ to Isoleucine mutation at propanil's target-site in R-CYPDI and R-SCHMU entails resistance not only to propanil but also to diuron, metribuzin, and bromoxynil. Such modification, however, conferred increased susceptibility to bentazon in Val_{219}Ile mutants, a novel feature. Tank-mixing bentazon and propanil can thus be seen as an interesting option to manage propanil-R and -S phenotypes. Propanil resistance will likely spread by the movement of seeds rather than carried by pollen due to the mutated gene being part of the chloroplast genome. Therefore, efforts to minimize seed movement across fields – such as proper equipment sanitation and leaving resistant fields as last harvest – might delay the spread of propanil-R CYPDI and SCHMU within rice-growing areas.

Keywords: Rice, propanil, *Cyperus difformis*, *Schoenoplectus mucronatus*, herbicide resistance

The influence of growing technology on distribution of *Apera spica venti* in winter wheat fields (721)

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Weeds are a permanent component of agro–ecosystems and remain the most important factor causing yield reduction. Efficient and timely weed control is one of the major tasks of competitive, intensive contemporary agriculture. Herbicides seem to be one of major factors determining changes of weed flora. Sulfonylurea herbicides are widely used for grass and broadleaf weed control in winter cereals in Lithuania, but low efficacy against *Apera spica-venti* sometimes is seen in commercial fields.

The goal of investigation was to evaluate factors influencing amount and distribution of *A. spica-venti* in winter wheat fields where weed control was performed by herbicides at recommended rates. Over the period of 2014 – 2015, 38 wheat fields were chosen according to complaints of farmers about low efficacy of herbicides. Three years history about growing of crops and applied technology was collected from each field. *A. spica venti* plants had three distribution patterns in the survey fields. In 31% of fields individual plants appeared. Patch distribution was recorded in 19% of fields. Half of winter wheat fields had high incidence of *A. spica venti*.

Absence of crop rotation had the highest impact on distribution of this weed, as 96% of winter wheat fields was reseeding year or even longer. Soil tillage was an important factor for appearance of this weed as well, as 62% from all fields had minimal soil tillage. In almost all fields sulfonyl-urea herbicides were used for weed control. Some farmers had been using the same herbicide for weed control for several years. Absence of crop rotation, use of minimal soil tillage, and repeated usage of the same active ingredient for weed control were the main factors governing decrease of herbicide efficacy and likely resistance.

A multifaceted approach to understanding multiple-resistant *Echinochloa colona* (409)

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Echinochloa spp. are a major threat to global agricultural production, particularly in the flooded rice irrigation systems found in the majority of rice producing countries. Historically, herbicides have provided more than acceptable season-long control when available. However, their high efficacy has resulted in continuous use, leading to the evolution of herbicide resistance in many populations in rice production areas worldwide. In Arkansas, USA, 253 accessions of *Echinochloa spp.* have been collected from rice fields since 2010 with the intent of characterizing the species distribution and better profiling of herbicide resistance that impact stakeholders. Of these accessions, 65% were identified as *Echinochloa colona* (junglerice), with resistance to the primary rice herbicides propanil (50%) and quinclorac (40%) being rampant; resistance to imazethapyr and cyhalofop are also detected. Populations with multiple-resistance to as many as 4 herbicides with different modes of action have been identified from these collections. These multiple-resistant populations are considered highly important as the mechanisms endowing multiple resistance could potentially reduce the utility of future herbicides. Studies were conducted to evaluate the resistance mechanisms endowing tolerance to cyhalofop, glufosinate, propanil, and quinclorac in a junglerice accession from Arkansas. When compared with a susceptible standard, this accession is highly resistant to propanil (>32x) and quinclorac (>16x), while only moderately resistant to cyhalofop (~2x); glufosinate resistance levels are yet to be determined. Cross resistance to other grass herbicides- clethodim, fenoxaprop, fluazifop, and quizalofop, was evaluated at recommended field rates; this accession is not cross-resistant to these compounds. These data, along with those in previous research, indicate non-target-site resistance mechanisms possibly acting in concert to endow multiple resistance. Research into the specific mechanisms using both physiological experiments and RNA sequencing technology is ongoing. This research will provide insight into the complex physiological and biochemical processes endowing resistance to multiple herbicide modes of action.

Black grass (*Alopecurus myosuroides* Huds.) resistance to ALS and ACCase inhibitors: A case study approach to study field evolution and management of weed resistance to herbicides over space and time (30)

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Herbicide resistance is an increasing problem for European farmers. However, little is known about the interactions of fields with and without resistance and the underlying driving management factors. Therefore a case study project was initiated in Germany in 2010. The main goal was to study temporal and spatial variability of resistance to ALS and ACCase-inhibitors using *Alopecurus myosuroides* (black grass). The study includes more than 150 fields for which seed samples were collected and analyzed in the laboratory (SNP-analysis to detect target site mutations) and greenhouse (biotests). Field management history of the last 10 years was investigated with intensive farmer interviews to allow a causal analysis of resistance evolution. Resistance levels ranged from low infestation without resistant plants to heavy infestation with confirmed resistance at the greenhouse and laboratory level. The degree to which resistance was pronounced and the pattern of the SNPs (2 *ALS*; 5 *ACCase*) varied from field to field and from one year to the other, suggesting that resistance develops locally on the individual field level. Fields with pronounced resistance were most often farmed with lower diversity of crops and less intensive tillage regimes. Furthermore, less use of delayed seeding was made. Surprisingly, the number of Modes of Action used seemed to have no significant effect on the resistance evolution to ALS inhibitors after 2-3 complete crop rotations. In addition, the effect of herbicide intensity and use of ALS- inhibitors was also less pronounced compared to the non-chemical measures. However, similar management practices were not necessarily leading to the same resistance status. Deeper analyses showed that also particular soil types are correlated with the presence of ALS-resistant black grass populations. An attempt to generate a predictive model and its application to practical agriculture will be discussed in the light of Integrated Weed Management.

Keywords: *Alopecurus myosuroides*, Herbicide Resistance, ALS-Inhibitors, ACCase-Inhibitors, Integrated Weed Management

Session 16
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Weed Management in Rice

Keynote: The weedy rice threat to food security in Asia: global insights into management (521)

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Asia is the world's largest and most important rice-producing region. Pressure on water resources and increased labour costs have led to a major change from transplanted to direct-seeded rice (DSR). DSR offers many advantages, however, weeds, including weedy rice are the main constraint to productive DSR systems. Despite the greater availability of herbicides weeds and weedy rice remain a serious global constraint. This work aims to raise awareness on currently documented weedy rice infestation levels in Asia rice fields and proactively anticipate issues related to the adoption of new and highly effective technologies such as herbicide-resistant rice varieties (Clearfield™). Recent surveys in Vietnam and Philippines indicate the urgent need to increase awareness on weedy rice among Asian growers. After 13 years since Clearfield™ rice commercialization, crop-to-weed gene flow has led to hybridization between weedy rice and the crop and ALS-resistant weedy rice plants have invaded fields where Clearfield rice was grown. The efficacy of a number of management strategies, established to be effective in rice ecosystems in the Americas and Europe, are reviewed and will be presented. Modeling simulations, parametrized on rice crops grown in temperate European conditions, show the importance of weedy rice biological traits and the interaction with several cultural practices such as soil tillage, water management, herbicide treatment efficacy and crop rotation affecting the population dynamics of weedy rice. Importantly, new tactics, based on improved understanding of weedy rice biology and herbicide-weed physiological and biochemical interactions, towards safe and selective chemical weedy rice control in rice crops wil be discussed. Weeds in DSR represent an evolving challenge that will require a global and dedicated effort. Minimizing infestations of weedy rice and the co-evolving issues of herbicide-resistant rice weeds, will significantly contribute to sustain global food production and protect the income of small-hold Asian farmers.

Keywords: Food security, Asia, Weedy rice, Weeds, Herbicide resistance

Introduction of Rinskor™ active, a new arylpicolinate herbicide from Dow AgroSciences (617)

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Rinskor™ active (proposed ISO name in review) is a new arylpicolinate herbicide being developed by Dow AgroSciences with global utility in seeded and transplanted rice and other crops. Data from field trials conducted since 2010 (> 1000 global trials) demonstrates that Rinskor has broad-spectrum activity on certain grass, sedge, and broadleaf weed species in rice. Common use rates are 5 to 50 g ai ha^{-1} depending on use pattern and target species. When used at anticipated label instructions, rice shows excellent tolerance, and no impact on yield has been observed. Key species controlled within defined use patterns include: *Echinochloa crus-galli; E. colona; E. oryzicola; Urochloa plantaginea; U. platyphylla; Cyperus difformis; C. iria; C. rotundus; Schoenoplectus mucronatus; Abutilon theophrasti; Aeschynomene* spp.*; Amaranthus* spp.*; Alisma plantago-aquatica; Ambrosia* spp.*; Chenopodium album; Conyza* spp.*; Heteranthera* spp.*; Ludwigia octovalis; Monochoria vaginalis; Sagittaria trifolia; Sesbania exaltata; Ammannia* spp. *and Xanthium strumarium*. As compared to other auxin chemotypes, Rinskor demonstrates novel characteristics in terms of use rate (some species controlled at less than 5 gai/ha), spectrum (grass, broadleaf and sedge activity), environmental fate (rapid degradation of herbicidal activity in soil and plants), and molecular interaction (unique auxin receptor biding). Rinskor has demonstrated a unique spectrum of activity and the ability to control ALS-, ACCase-, propanil-, and quinclorac target site-resistant grass, sedge and broadleaf species. Rinskor has favorable environmental fate, toxicology, and ecotoxicology properties. Initial registrations are expected in 2017 or 2018.
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™Rinskor is not registered at the time of this presentation. The information presented is intended to provide technical information only and is not an offer for sale.

Keywords: Rinskor™ active, arylpicolinate herbicide, rice, weed control, herbicide resistance

Integrated weed management in dry direct- seeded rice in South Asia (482)

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Considering the diversity and complexity of weed problem, no single method of weed control, whether cultural, manual or chemical would be sufficient to provide season-long sustainable weed control under direct-seeded rice (DSR). An integrated weed management system as a part of integrated crop management systems would be an effective, economical and eco-friendly approach for weed management in DSR. Weed management in DSR requires an integrated approach that utilizes effective cultural (seed rate, competitive cultivars, planting pattern, irrigation and nitrogen management), mechanical (tillage, stale seed bed), ecological and chemical methods in a mutually supported manner. Some of the outstanding examples of integrated weed management in DSR that proved effective in South Asia will be discussed in the presentation. In the western part of India, for example, iincreasing N application rate up to 150 kg ha^{-1} caused significant improvement in grain yield when the weeds were well controlled either by pendimethalin fb bispyribac-sodium or by pendimethalin fb bispyribac –sodium fb 1 hand weeding (HW), respectively; however, under poor weed control condition (pendimethalin fb 1 HW), it resulted in a drastic reduction in yield. Higher seed rates in DSR caused significant reductions in weed dry matter, whereas higher than optimum seed rate (15–30 kg ha^{-1}) caused reduction in yield. Genotype for instance Punjab Mehak 1 produced similar grain yields in paired and uniform planting patterns; whereas, PR 115 had higher grain yield in paired rows (5.6 t ha^{-1}) than in uniform rows (4.9 t ha^{-1}). Genotype IET-21214 with the sole application of bispyribac-sodium produced grain yield similar to the sequential application of pendimethalin and bispyribac-sodium. Plasticity in some genotypes in response to water stress improved their ability to have rapid early growth and smother the weed flora in DSR.

Keywords: Oryza sativa, Aerobic Rice, Sustainable weed management, Rice genotypes, Cultural manipulations

Herbicide resistant weed management program in rice (138)

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Weed control has been a major concern of growers since the beginning of rice production in Turkey. Despite the long history of ALS and ACCase herbicides use in rice, farmers have complained of unacceptable control of *Echinochloa* species by herbicides recently. The objective of this study was to determine herbicide-resistant weed management program in water seeding rice. Experiments were conducted at the Black Sea and Marmara region of Turkey, in 2015. The experiments at each location were arranged in a randomized complete block design with four replications. Fifteen different treatments were applied.Weed control was assessed visually. E. *oryzoides*, and *E. crus-galli* treated with glyphosate at 2.5 l ha^{-1} dose before seeding showed slowly growth inhibition at 14 and 28 DAT in both experimental site. Then, application of cyhalofop-butyl+penoxsulam at 5 l ha^{-1} dose at 12-14 leave stage showed 70% efficacy at 56 DAT. The visual control ratings of *E. oryzoides* and *E. crus-galli* after application of oxadiazon at 2 l ha^{-1} rate as pre-sowing were not enough on *E. oryzoides* in any assessment day. In comparison with previous treatment, to use clomazone instead of oxadiazon at 2 l ha^{-1} showed significantly greater control of *E. oryzoides* and *E. crus-galli* at 28 and 56 DAT. Greater than 85% control of *E. oryzoides* and *E. crus-galli* was achieved at harvest with this combination. The results from these studies conclude the combination of clomazone and oxadiazon at 2 l ha^{-1} application as a pre-sowing fallowing cyhalofop-butyl+penoxsulam at 12-14 leave stage at 5 l ha^{-1} dose was the most effective treatment resulting in excellent long-term control of *E. oryzoides* and *E. crus-galli* and significantly less number of head of weeds from all species before harvest.
The authors thank The Scientific and Technological Research Council of Turkey (TUBITAK) for supporting the Project (TOVAG 2140446).

Keywords: ALS and ACCase resistant weed management, E. *oryzoides*, E. *crus-galli*, clomazone, oxadiazon

Weed management in rice of Asian-Pacific region (549)

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Rice is the major staple for more than half the world's population, with Asian-Pacific Region (APR) representing the largest producing and consuming region. The rice yield in APR ranged from 2.97 t ha^{-1} of Thailand to 7.38 t ha^{-1} of the Republic of Korea, among major rice growing developing countries and was higher in developed countries (viz. Japan: 5.33 t ha^{-1} and Australia: 9.54 t ha^{-1}). An annual yield reduction of 0.2 percent to 2050 in APR was forecasted under continued climate change, while the population was projected to increase several folds and thus necessitating a substantial increase in productivity and production of rice by alleviating the major constraints. Weeds are common biotic constraints that are limiting productivity of rice across the APR. Hence, weed management plays critical role in meeting increasing APR population's rice demand, with minimal green house gas emissions from rice cultivation. Weeds associated with rice in APR varied with the country, method of rice establishment, associated environment and cultural practices used in respective countries. Weeds management is becoming more critical as difficult to control weeds like weedy rice are emerging in response to the switch in method of establishment from traditional transplanting to direct-seeding in developing countries of APR due to the rising labor cost, water shortage and the need for crop intensification. The published research in APR is herbicide based. Manual method of weed control is continued to be used by APR's developing countries' farmers either solely or in combination with herbicides. Based on the synthesis of reviewed literature, economical and effective herbicides based integrated weed management (IWM) options for varying methods of rice establishment are summarised. IWM options that increase the productivity of rice economically with optimal resource use efficiency and minimal global warming potential were identified and future research strategies are suggested.

Keywords: Rice, Asian-Pacific region, Integrated weed management, Herbicides, Global warming potential

Major weeds in rice of Ecuador (48)

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Ecuador is a country on the Pacific coast of South America, with a total land area of 256,370 km^2. In coastal plains rice, among other cash crops, is grown. The crop area is 393100 ha in 2010, of this 78% irrigated. Average yields are 3.8-4.0 ton/ha-1. Weeds are among the major constraints to rice production, and methods for their control are implemented without considering weed species prevalence. For this reason a survey was conducted in 140 ha distributed in main four rice growing areas of the country during the period of September 2014 and May 2015. To this end weed cover and prevailing species were evaluated visually using a scale from 0 to 4, where 1- 1-5% of weed cover and 4- more than 50%. These values were elaborated to determine absolute and relative Frequencies, ΣI-sum of cover values, Im- average cover value, and finally SI- index of infestation severity, obtained as a product of F by Im. Results were grouped in transplanted and direct-seeded rice, and also according to herbicide applications. The most important species in transplanted rice were weedy rice, *Cyperus iria, Eclipta prostrata* and *Echinochloa colona*, while in direct-seeded rice *E. colona,* weedy rice, *Leptochloa fusca* var. *uninervia, Sesbania herbacea*, *Eleusine indica, E. prostrata* and *Echinochloa crus-galli* prevailed. The high weedy rice presence in both rices suggests the presence of weed seeds in crop seeds, and also of water management problems in unleveled fields of transplanted rice. High SI of *E. colona* and *L. fusca* var. *uninervia* in direct-seeded rice were registered in treated fields with cyhalofop or profoxydim which suggest possible presence of herbicide-resistant biotypes, a study to be still conducted in Ecuador. The present results roughly indicate that improved weed management is a need in rice of Ecuador, which may bring substantial yield increases.

Keywords: Ecuador, Rice, Weed, Weedy rice, Echinochloa colona

Long term crop and herbicide rotation to managing weedy rice populations (771)

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Imazethapyr and imazamox are registered for use on imidazolinone-resistant rice (IRR) in the United States, and is used to control red rice (*Oryza sativa* L.). Hybrid rice has shattering characteristics and seed dormancy issues. Repeated reliance on imidazolinone-resistant hybrid rice (IRHR) can cause a serious weed problem. Outcrossing can also occur with red rice causing IR red rice to occur. A 4 year study was established to evaluate crop rotation to manage a weedy rice complex. A location was identified with a history of multiple growing seasons of IRHR with a weedy rice infestation. In 2013, a four year study was established consisting of five different crop rotations and utilizing non-genetically modified ACCase–resistant rice allowing for the use of quizalofop (QRR). The study also employed glufosinate-(GluRS) and glyphosate-resistant (GRS) soybean, and IRHR. The utilization these technologies allowed for crop and herbicide rotation. The study employed 0.2 ha plots. The rotations were: 1) GRS 2013/QRR 2014/GRS 2015/IRHR 2016; 2) Fallow 2013/QRR 2014/GRS 2015)/ IRHR 2016; 3) IRHR 2013/GluRS 2014/QRR 2015/IRHR 2016; 4) GRS 2013/GluRS 2014/GRS 2015/IRHR 2016; 5) GRS 2013/IRHR 2014/GRS 2015/IRHR 2016. Herbicides used during IRHR or QRR were imazethapyr at 105 g ai ha-1, imazamox at 44 g ai ha-1, or quizalofop at 115 g ai ha-1. GRS and GluRS were treated with glyphosate at 1120 g ai ha-1 or glufosinate at 820 g ai ha-1, dimethenamid at 945 g ai ha-1 and pyroxasulfone at 150 g ai ha-1. The fallow rotation was treated with glyphosate and tillage. In 2013, weedy rice plants counts were 0.3 to 17.2 plants m^{-2}, and decreased in 2014 to 0.004 to 2.6 plants m^{-2} with a GluRS or QRR rotation. In 2015, weedy rice decreased to 0 to 2.5 plants m^{-2}. Crop and herbicide rotation can impact weedy rice populations.

Keywords: Red rice, Imidazolinone-reisitant Rice, Weedy rice

Weed management in drip irrigated rice (626)

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A study was carried out in 2015 in northern Italy to assess the efficacy of weed control strategies in rice watered by drip irrigation. Two conventional and one Clearfield varieties were included. Six plots (20m x 18 m each) were randomly selected within each field: three were subjected to the planned weed control strategy, and three were maintained untreated (check). Water was supplied by means of superficial drip irrigation lines 90 cm spaced. All fields were treated in pre-emergence with pendimethalin (687.5 g_{ai}/ha) and clomazone (137.5 g_{ai}/ha). Post-emergence treatments were carried out with cyhalofop-butyl (240 g_{ai}/ha) + profoxydim (80 g_{ai}/ha) followed by MCPA (310 g_{ai}/ha) + byspiribac-sodium (33.6 g_{ai}/ha), in conventional varieties, and with imazamox (33 g_{ai}/ha) + byspiribac-sodium (33.6 g_{ai}/ha) followed by imazamox (37 g_{ai}/ha) + MCPA (266.4 g_{ai}/ha) in Clearfield variety. In each plot weed density and weed cover on the ground were assessed three times during the season. Yield and yield components were assessed at harvest. Weed infestation was mostly represented by *Digitaria sanguinalis*, *Chenopodium album*, *Portulaca olearacea* and *Sorghum halepense*. In check plots weed infestation was particularly high at the first assessment with, on average, 329 plants/m^2, without statistical differences between varieties and with a ground cover above 77%. In treated plots weed infestation was not higher than 17.04 plants/m^2 in conventional varieties, and 17.31 plants/m^2 in Clearfield variety. At the last assessment, weed density in treated plots was on average 43.55 plants/m^2 in conventional varieties, and 64 plants/m^2 in Clearfield variety. In these plots weed infestation was mainly represented by *Digitaria sanguinalis* and, in a less extent, by *Chenopodium album* and *Portulaca oleracea*. In treated plots the highest number of culms (428 culms/m^2) and the highest yield (3.5 t/ha) was observed in the Clearfield variety

Keywords: Drip irrigation, IMI resistant rice, irrigated rice

Benefits of ready mix herbicide on broad spectrum weed control in transplanted rice (*Oryza sativa* L.) (116)

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Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif and Rabi* 2012 to evaluate ready mix herbicides and herbicide combination for control of complex weed flora in transplanted rice. The experiments were laid out in randomized block design with three replications. The treatments comprised of different weed management practices *viz*., Early post emergence bispyribac sodium 25 g ai/ha (T_1) ; Pre emergence pretilachlor 1000 g ai /ha (T_2); Post emergence admixture of chlorimuron ethyl 10 % + metsulfuron methyl 10% 4 g ai/ha (T_3); Pre emergence pyrazosulfuron-ethyl 20 g ai /ha (T_4); Early post emergence bispyribacsodium + ethoxysulfuron (25 + 18.75) g ai/ha (T_5); Early post emergence bispyribac sodium + admixture of chlorimuron ethyl 10 % + metsulfuron methyl 10 % (20 + 4) gram ai/ha (Tank mixture) (T_6); Pre emergence pretilachlor followed by Post emergence ethoxysulfuron (750 / 18.75) g ai/ha (T_7); Pre emergence pretilachlor followed by Post emergence admixture of chlorimuron ethyl 10 % + metsulfuron methyl 10 % (750 / 4) g ai/ha (T_8); Pre emergence pyrazosulfuron-ethyl followed by manual weeding 20 g ha^{-1}(T_9); Pre emergence admixture of pretilachlor (6%) + bensulfuron methyl (0.6%) 6.6% GR 660 g ai/ha (T_{10}); hand weeding twice (T_{11}); and unweeded control (T_{12}).
The hand weeding twice treatment and Pre-emergence application of pretilachlor 750 g ha^{-1} followed by Post emergence admixture of chlorimuron ethyl 10 % + metsulfuron methyl 10 % 4 gram ai/ha treatment, enhanced the growth and yield of transplanted rice (5954 and 5866 kg ha^{-1} DAT respectively). The same treatment reduced the weed growth and nutrient depletion by weeds and increased nutrient uptake by the crop. These factors resulted in highest gross return, net return and B:C ratio followed by Pre emergence pretilachlor 750 g ha^{-1}follwed by Post emergence ethoxysulfuron 18.75 gram a.i., per hectare.

Keywords: Ready mix herbicide, Almix Transplanted Rice

Weed control in sprinkler irrigated dry-seeded rice (352)

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The increasing restrictions on the use of water in agriculture may become a limiting factor for future rice production. The use of sprinkler irrigation, substituting the soil-surface flood irrigation, is a way to reduce water consumption in rice. The farmers in Brazil have increasingly used this water-saving method. However, the sprinkler irrigation system has presented a drawback: the weeds are favored by the system and normally offer an extra degree of difficulty in terms of control, costs and environmental impact. The rice under overhead sprinkler irrigation is highly dependent on herbicides, which generally are sprayed in high doses and higher frequency than in flooded rice. The objective of this research was to identify approaches for chemical control that reduce the overall impact of weeds in sprinkler-irrigated rice. Field experiments were carried out in the Lowlands Experimental Station of Embrapa, in Capão do Leão, RS, southern Brazil, in the 2014 and 2015 cropping seasons. The irrigation system watered 15 mm h^{-1} whenever the soil water tension reached -20 kPa. A Clearfield cultivar was used, seeded in dry soil (350 seeds m^{-2}) in rows spaced at 17 cm apart. Approaches such as the application of glyphosate soon after rice emergence (called the “needle point” technique), integrated (or not) with the use of herbicides of the Clearfield technology package (imazethapyr+ imazapic; imazapyr+imazapic), or with the traditional herbicides used in rice (clomazone, pendimenthalin and penoxsulam) were compared. None of the traditional herbicides were effective to control the high density (> 500 plants m^{-2}) weed community. However, the early application of glyphosate combined with this herbicides was an effective technique for weed control in sprinkler-irrigated rice. This strategy was as efficient as the Clearfield technology, with high levels of control of problem weeds like *Echinochloa crus galli*, *Cyperus difformis* and *Cyperus iria*.

Keywords: Central pivot, herbicides, Oryza sativa, water savings, weed management

Session 17
WEED ECOLOGY: Weed Distribution, Surveys and Mapping / Weed Community Dynamics

Keynote: Where did Monochoria korsakowii in stricken area, affected by 2011 Tohoku earthquake and tsunami, derive from? (127)

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Monochoria korsakowii has been one of the serious weeds in paddy fields in northern and eastern Japan since the occurence of sulfonylurea (SU)-resistant biotype. In recent years, except for SU-resistant biotype, *M. korsakowii* was hardly found in northwest Japan. In addition, it has been listed as an endangered and threatened species in many prefectures in Japan. In paddy fields destroyed by the Tohoku earthquake and tsunami in March 2011, populations of *M. korsakowii* were discovered, which was reported in public journals and local newspapers and became a topic in stricken area. However, where these populations derive from is still unclear. In this study, the salt tolerance and ALS gene sequence of *M. korsakowii* in stricken area were investigated to explore their originations. The results indicated that the germination rate was 0-1.7% in the 0.5M NaCl solution which equaled to the salt concentration of sea water. However, the rate of germination in distilled water was 36.6-91.6%, in spite of a presence of the salinity when dormant seeds waked up. Using neutral red assay, the plasmolysis was confirmed in all lines, including five lines from stricken area which were treated with 0.5M NaCl solution, one control line from Asahata retarding basin in Shizuoka prefecture Shizuoka city. Thereby, salt tolerance was supposed to be absent. Before the devastating earthquake and tsunami, *M. korsakowii* in paddy fields in northeast area exhibited SU-resistance. However, after that disaster, *M. korsakowii* in 7 sites were susceptible and 2 sites presented resistant in stricken area. Most populations were different from those before earthquake disaster, hence it is plausible to propose that under the influence of tsunami, the topsoil was removed and salinity concentration was lower, seed buried in the soil before the wide spread of resistance germinated and shaped populations.

Keywords: Herbicide resistance, *Monochoria korsakowii*, paddy weed, threatened species

Identification and distribution of wild oat (*Avena* spp.) species with molecular and classical methods in wheat areas in Turkey (327)

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Wheat is one of the most important cultural plant in Turkey. Wheat fields cover over one third of total agricultural land of Turkey. *Avena* species are very important as weeds in these areas. Therefore this study was conducted to identificate wild oat species in wheat areas in Turkey between 2013 and 2014. 377 *Avena* spp. populations were collected from all geographical regions of Turkey in wheat fields. All of these populations were identified with molecular and classical methods. As a result of molecular methods, 73 *Avena sterilis* subsp. *sterilis* L., 212 *Avena sterilis* subsp. *ludoviciana* (Durieu) Gillet et Magne., 92 *Avena fatua* L. were identified out of 377 populations in the ratios of %19.36, %56.23 and %24.4, respectively. 70 *Avena sterilis* subsp. *sterilis* with % 18.57, 214 *Avena sterilis* subsp. *ludoviciana* with %56.76, 85 *Avena fatua* with %22.55 and 8 mixed population with %22.55 were detected with morphological methods. Molecular and morphological methods gave similar results at the rate of %96,55. Molecular and classical identifications didn't match on 13 sample. The reason for this incompatibility could be some contaminations in molecular tests, similarity of morphological characters and mixed species in same populations. Therefore, molecular tests will be apply again to these 13 populations which didn't match according to molecular and classical results.

Keywords: *Avena*, identifaction, moloculer, morphological, distribution

The influence of soil management practices on functional traits and biodiversity of weed communities in Swiss vineyards (346)

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Green cover in vine rows provides many ecological services, but can also negatively impact the crop, depending on the weed species. The composition of a vineyard weed community is influenced by many parameters. Ensuring an evolution of the vine row flora into a desired direction is therefore very complex. A key step towards this goal is to know which factors influence the establishment of the weed community and which types of communities are best suited for vineyards.In this study, we analyzed the weed communities of several vineyards in the Lake Geneva region (379 botanical surveys on 117 plots), with the aim to highlight the links between phytosociological profiles, biodiversity, selected functional traits (growth forms, life strategies, root depth and soil management practices (chemical and mechanical weeding, mowing, mulching roll). The level of disturbance allowed to draw a clear distinction between the soil management practices: chemical and mechanical weeding (high disturbance) led to lower biodiversity and tended to favour ruderal to competitive ruderals strategists, mainly therophytes and geophytes. In contrast, mowing and mulching roll (lesser disturbance) led to higher biodiversity and tended to favour the establishment of grassland, whose plants are usually hemicryptophytes. Soil management practices also greatly impacted root depth, with chemical weeding favouring on average 45 % deeper rooting than all other practices evaluated. This could explain some current problems: more herbicide is used, more ruderal weeds with deep roots appear, leading to a vicious circle from which it is difficult to extract. In terms of ecological services, the analyzed parameters are indicators of the competitive potential of weed community for the vine roots. Further studies shall focus on field measurements of root depth and on evolution dynamics of weed communities when soil management is changed.

Keywords: Viticulture, Phytosociology, Root depth, Vitis vinifera

The potential influence of cultivating Bt-transgenic cottons on weed diversity (782)

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Generally, agricultural activities, including homogenized crop species, farmland expanding, environmental impacts of pesticides and fertilizers, have been regarded as important reasons in biodiversity reduction. Do genetically modified (GM) crops affect agricultural biodiversity? The dispersal of plant detritus and secretions, pollen flow and seed movement could lead to the entrance and invasion of transgenes in the natural environment. This will inevitably affect the community composition and dynamics of target and non-target insects, field weeds, soil organisms and aquatic species near crop fields and then the agro-biodiversity. In this report, we surveyed the weed species and abundance in Bt-transgenic and non-transgenic cotton fields in three provinces, Hebei, Henan and Shandong in China. The biodiversity indices of field weeds were calculated and explained with the cultivation of transgenic cotton. The agro-biodiversity effect of GM crops is complex and depends on numerous factors such as the inserted transgene event, plant species characteristics and environmental conditions. The assessment of agro-biodiversity impacts is far from complete and should be studied with case by case method in current and future biosafety assessment of Bt-transgenic crops.

Keywords: Agro-biodiversity, Genetically modified cotton, Weed diversity, biosafety assessment

Potential effects of harvest weed seed control on wild oat populations based on demographic modelling (380)

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Wild oat is a globally problematic weed species that requires new management techniques to manage herbicide resistance; Harvest Weed Seed Control (HWSC) may be an option. Data collected in rotational field studies in Alberta under management regime extremes (no integrated weed management, no herbicide to high integrated weed management, full herbicide) was used to parameterize a periodic matrix model. Elasticity analysis was conducted in addition to an analysis where the model equation was rearranged, population growth rate (λ) was designated and the equation solved for survival of newly shed seed (s_{new}). All populations had λ>1, or growing populations. Elasticity analysis indicated that population growth rate is most highly elastic to the over-winter seed-bank (E_{sw}= 1), followed by seedling survival, fecundity, and survival of newly shed seed (0.63-0.86 across treatments). The latter may be the most accessible life-cycle transition for management. However, decreasing the proportion of newly shed seeds that survives was the most effective and available control strategy only until reduced to 0.1-0.3. Further reductions are less impactful; the seed-bank during the growing season becomes more critical. When averaged across treatments, >80% of newly shed seed must be eliminated to stop the population from growing, resulting in a stable population, but not a decline. Due to pre-harvest seed shattering, causing wild oat populations to decline by using HWSC alone to impact the survival of newly shed seeds will likely not be effective; new management techniques to use in combination with HWSC and IWM strategies are needed.

Keywords: Integrated Weed Management, Herbicide Resistance, Periodic Matrix Model, Elasticity Analysis

The role of soil parameters on weed distribution in apple orchards (790)

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Soil properties effect weed composition and weed density in orchards. Understanding the relationship between the soil properties and weed distribution would allow selecting the best weed control strategies. This study aimed to investigate the correlation between weed density and chemical and physical attributes of soil in apple orchards. The study was carried out in 143 apple orchards representing the surveyed fields in the years of 2012 and 2013 in Kayseri Turkey. Weeds counted and soil samples were collected at the intersection points for physical and chemical analysis. The canonical correspondence analysis (CCA) used for assesses the effects of some soil factors and altitude on grassland species and weeds distribution. Of the identified weed species, 129 belonged to 33 families, 2 of which were monocotyledonous and 31 were dicotyledonous. The species identified in apple orchards belonged to Asteraceae (21 species), Poaceae (15 species) and Brassicaceae (13 species) families. The aggregate stability, Ca, P_2O_5, $CaCO_3$ contents of soils were significantly different among apple orchards. The weed species of *Echinochloa crus-galli* (L.) P. Beauv., *Cuscuta polygonorum* L.,*Acroptilon repens* (L.) D.C. were identified as the indicator of clay soils and the species of *Poa trivialis* L., *Medicago sativa* L., *Plantago lanceolata* L. were identified as the indicator of sandy soils. The species of *Bromus tectorum* L. *Agropyron repens* (L.) Beauv., *Tragopogon latifolius* Boiss. were identified as cosmopolite species able to adapt to every kind of soils.

Keywords: Apple orchards, Weed survey, Ecology, Soil Properties

Semi-natural habitat types provide different disservices in terms of weed infestations in European arable fields (440)

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There is an increasing interest in the conservation of semi-natural habitat (SNH) because they provide ecosystem services for crop production, environmental protection and society. However, their true value can only be estimated if also the level of disservices is known. The EU FP7 project QuESSA (Quantification of ecological services for sustainable agriculture), aims, among others, to assess disservices provided by semi-natural habitat types by quantifying weed densities and community composition in adjacent arable crops throughout Europe. Weed species have also been classified in relation to how problematic they are in arable crops and how desirable they may be for the provisioning of ecosystem services. Therefore in 2014 and 2015 a total of 62 sunflower fields were selected in Italy and Hungary. Weed composition was determined by scoring density and percentage cover of the species in 14 1m^2 plots in each field about 3 weeks after main weed management practices were performed in the crop. The plots were positioned along 2 transects, 10 m apart, at increasing distances into the field. GLM and ANOVA showed that, total weed densities and weed cover were higher next to cropped margins in Hungary while in Italy adjacent SNH type did not affect these variables. The hypothesis that increased distance from the SNH decreases weed density of various weed groups (monocots, dicots, annual, and perennials) was confirmed in Italy but was not so clear in Hungary. In Italy increased weed species richness and abundance were found in fields surrounded by increasing SNH percentage in the 1km radius landscape sector. The preliminary analyses indicate that the response of weed communities to SNH is area specific. This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration.

Keywords: Weed community, species traits, field margin, woodland, ecosystem service

Weed diversity and distribution is influenced by field fragmentation and soil texture in sugarcane fields (485)

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A survey was conducted in sugarcane fields in the dry tropics of Costa Rica to determine how field fragmentation and soil texture affected weed diversity and community structure. Eighty-two and 75 fields were sampled in 1998 and 2000, respectively, including soils with clay, clay-loam, loam, and sandy-loam textures. Weed species presence and cover were quantified in each field in six different sections: row, furrow, irrigation canal, drainage, tractor turn area, and field border. A total of 120 weed species were detected, from which 16% were considered by farm managers, species that required specific weed control actions to prevent interference with sugarcane. Weed richness ranked from higher to lower: border = turn area ≥ drainage ≥ irrigation canal ≥ row ≥ furrow. Soil texture did not influence weed richness but determined weed community structure. The weed community studied had species that showed no preference for microhabitat and species that exhibited clear preferences. *Rottboellia cochinchinensis* was not affected by microhabitat, but its populations in sandy loam soils were lower than in the rest of soil textures. *Cyperus rotundus* populations were larger in the drainage than the other microhabitats, and their cover was higher in coarser than finer soil textures. Our study indicated that fragmentation of sugarcane fields, especially the presence of undisturbed borders, plays an important role in maintaining weed diversity. However, the high weed richness observed in the turn area (highly disturbed) suggested that the availability of resources could under certain circumstances compensate for the limitations imposed by disturbance associated with crop management and allow higher than expected weed richness in areas exposed to cultivation and herbicides.

Keywords: Diversity, ecology, weed, community structure, habitat

Uludag A. (TR): Distribution and mapping of *Sorghum halepense* (605)

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Sorghum halepense (L.) Pers. (Johnsongrass) is a wide spread weed of Mediterranean origin and has become an invasive alien plant in many parts of the world. Its fast propagation comes from its seeds, rhizomes, and its ability of adaption. It was able to invade new habitats by different pathways. Both, breaking apical dominance via tillage and leaving intact rhizomes via conservative agriculture increase the number of individuals through different mechanisms. Its competitive ability shows some similarity in its native range (Turkey, eastern Mediterranean) and its invasive range (USA, Latin America, Australia, Asia). It is a special problem in the Iran-Turan and Euro-Siberian regions similar to Turkey. Recent studies show that its range is continuously expanding. Major invasive plant databases have not covered all findings yet. In consequence, we tried to map the distribution of Johnsongrass in selected countries. Data was gathered from the search through internet from scientific articles, grey literature, data bases and organizational sites to find out distribution information, which was crosschecked where it was available sources. One major obstacle with this perennial is the fact that it is difficult to distinguish between individuals as soil surface penetrating shoots may belong to the same or different plants. Future worldwide problems and research needs will be discussed.

Keywords: Johnsongrass, mapping, distribution, pathway, interference

Genotypic diversity of invasive *Fallopia* spp. in Norway (367)

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Fallopia japonica (Japanese knotweed), *F. sachalinensis* (giant knotweed) and their hybrid, *F.* x *bohemica*, are among the most problematic invasive alien plants in Europe and North America. Clonal reproduction by rhizome growth and regeneration from vegetative fragments are the main means of spread in Europe. However, high levels of genotypic variation within the hybrid indicate that hybridization and sexual reproduction are important for the spread of *F.* x *bohemica*. In Norway, these species are not known to produce seeds, and reproduction is thought to be only clonal. The species flower late in the growing-season, and seed production seems to be limited by climatic conditions. All three species are listed as invasive plants with severe ecological impacts in Norway, but *F. japonica* is recorded to be far more frequent than *F.* x *bohemica* and *F. sachalinensis*. The distribution of *F.* x *bohemica* may however be underestimated due to misidentification as either of the parental species. In this study, we used amplified fragment length polymorphism (AFLP), simple sequence repeats (SSR), and determination of ploidy level by flow cytometry, to aid taxonomic identification and examine the genotypic variation of these species in Norway. We found no genotypic variation within *F. japonica* (n=110). Comparison of *F. japonica* samples from Norway with one *F. japonica* sample from England indicate that they are the same genotype. Previous studies have shown that this clone dominates the *F. japonica* populations in Europe and North America. We found that the majority of the *F.* x *bohemica* samples, except one sample, belonged to a single genotype (n=32). Two genotypes were found among three *F. sachalinensis* samples. The results indicate that the invasive *Fallopia* species do not reproduce sexually in Norway and that control measures can focus on preventing clonal spread.

Keywords: Invasive alien species, *Fallopia japonica*, Japanese knotweed, genotypic diversity, molecular markers

Session 18
CROP-WEED INTERACTIONS: Integrated Weed Management + Parasitic Weeds

Keynote: Why early weed management matters now more than ever (739)

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Weeds are tough competitors with crops. They thrive at the expense of the crop, and worse, they are getting better at surviving even the most accurate, well-applied herbicide treatments. Gone are the days when a new mode of action (MoA) was the answer to a resistant weed problem. But while the search for and investment in new solutions has never stopped, the reality is that there has not been a new commercialized herbicide MoA in many years, and there won't be one for the near future.
Growers and researchers must get serious about developing and implementing integrated weed management solutions. With its new program "Early Weed Management: Your Experience & Our Science", Syngenta encourages and supports the use of sustainable practices that includes crop rotation, herbicide MoA diversity, use of non-chemical tools and a component baptized as Early Weed Management (EWM).
This article defines EWM's principles across different crops and weeds and demonstrates its benefits. By controlling weeds early, when they are still small and most vulnerable, growers do more than just removing a bothersome pest for this year's crop – they actually protect their farm's future by managing difficult weeds effectively, by safeguarding their investment in crop seeds, and by protecting the value of their land.

Keywords: Early Weed Management, Weed Resistance, Crop Rotation, Mode of Action Diversity, Non-Chemical Tools

Optimising the competitive effects of hybrid barley for the control of *Alopecurus myosuroides* (96)

Sarah K Cook *(ADAS UK Ltd, Cambridge, UK),* ***James Marshall-Roberts*** *(Syngenta Ltd, Cambridge, UK)*

Alopecurus myosuroides (black-grass) is the major grass weed in the UK in autumn sown wheat rotations. Resistance of *A. myosuroides* against a wide range of commonly used herbicides is widespread and farmers and agronomists are increasingly turning to non-chemical weed control methods to reduce the dependence on herbicides. Winter barley is an easy to grow, low-risk cereal crop with a guaranteed market. Hybrid winter barley has been available to farmers for several years but recent research has shown it to be highly competitive as it can reduce seed return of *A. myosuroides by 91%.* The objectives of this research were to identify the agronomic factors that contribute to the competitive ability of hybrid barley against *A. myosuroides* and test each of these factors to find both the agronomic and economic optimums.
We studied a range of crop seed rates, varieties, nitrogen rates and timings in a number of replicated trials. In each trial hybrid winter barley was generally compared to conventional winter barley and/or winter wheat and were sown in the autumn at a wide range of sites throughout the UK.
Alopecurus myosuroides populations and seed returns were reduced where hybrid barley was grown. *A. myosuroides* plants in the hybrid barley produced fewer heads (61%), each plant had fewer tillers (43%) and lower seed weights per plant (66%) than those in winter wheat. Applying more nitrogen earlier in the spring was an important factor for improving weed suppression as hybrid barley commences spring growth earlier than conventional varieties.
Hybrid winter barley is a valuable addition to an arable rotation. In addition to control of *A. myosuroides* it yields 0.9t/ha more than conventional winter barley, it matures earlier allowing earlier harvesting and hence additional time for preparing a seedbed for the following crop.

Keywords: Winter barley, *alopecurus myosuroides*, nitrogen, seed rates, varieties

Integration of weed competitive wheat cultivars, seeding rate and pre-emergence herbicides to improve the management of rigid ryegrass (*Lolium rigidum*) (192)

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Presence of widespread herbicide resistance in rigid ryegrass on Australian farms has highlighted the need to reduce reliance on herbicides through integration of non-chemical weed control tactics. Identification of suitable tactics for different situations is therefore required. Recently genes for high early vigour (HEV) have been combined with alternative dwarfing genes to develop wheat genotypes with improved weed suppression. A field experiment was conducted in 2011 to investigate the contribution of HEV genotypes in managing rigid ryegrass. This study investigated combinations of 6 wheat genotypes (3 cultivars and 3 HEV lines), two sowing rates (200 and 400 seeds m^{-2}) and three pre-emergence herbicide treatments (prosulfocarb + *S*-metolachlor (Boxer Gold®), trifluralin (Treflan®), and a no-herbicide control). When averaged across the sowing rates and herbicide treatments, two of the most competitive HEV lines reduced rigid ryegrass seed production by 53 to 59% (10,023 and 11,574 seeds m^{-2}) as compared to weed seed production under variety Wyalkatchem (24,522 seeds m^{-2}) (P<0.001). There were large differences in wheat genotype response to sowing rate. Increases in sowing rate reduced rigid ryegrass seed production from as little as 12% in Wyalkatchem to 69% in the best HEV line (P<0.05). Improved weed suppression of HEV lines was evident in all weed control treatments. FollowingBoxer Gold® treatment, HEV lines reduced weed seed production by 61-74% relative to Wyalkatchem. Such a large reduction in rigid ryegrass seed production in HEV wheat has the potential to reduce future weed populations. HEV lines are currently in early development and often exhibit a yield penalty under weed-free conditions (~ 10%). Further breeding to improve disease tolerance and refine flowering time is likely to reduce this yield gap and provide farmers with a low cost and easy to adopt non-chemical weed control tactic as a component of integrated weed management.

Keywords: Competitive, Wheat, Rigid ryegrass, Seed rate, Pre-emergence herbicides

Characterizing the competitive ability of triticale and wheat cultivars with annual ryegrass, *Lolium rigidum* (583)

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Annual (or rigid) ryegrass (*Lolium rigidum*) is among the most problematic weed species in Australian wheat cropping systems for several reasons. Firstly, many populations have evolved herbicide resistance. Secondly, it is a host for bacteria *Clavibacter spp.* which causes annual ryegrass toxicity (ARGT) resulting in sheep and cattle death in Australia. Thirdly, it competes strongly with grain crops, especially wheat, causing significant yield losses. Triticale, derived from crosses between rye and wheat, combines the environmental stress tolerance of rye and the high yielding traits of wheat. Improving the competitiveness of crops can reduce reliance on herbicides, lowering costs and the risk of developing herbicide resistance. A glasshouse experiment was carried out at the University of New England in Armidale NSW from December 2014 to April 2015 to characterize the early competitive traits of triticale and wheat cultivars against annual ryegrass. Eight triticale lines and two wheat cultivars were grown in pots with ryegrass in a replacement series of crop:weed proportions of 100:0, 75:25, 50:50, 25:75 based on four plants per pot. An additional treatment of 10:90 had 10 plants per pot (i.e. 1 crop and 9 weed). The results showed that there are significant differences between the cultivars in crop biomass loss with increasing ryegrass proportions, which is one measure of competitive ability. The triticale cultivars tested, other than Tobruk, were as competitive if not more competitive than the comparative wheat cultivars used, which indicates that certain triticale cultivars may well be able to be used effectively in weed management strategies that place less reliance on herbicides. This in turn will help combat the problem of herbicide resistance, which is now widespread in modern crop production systems.

Keywords: Triticale, Wheat, Competitive ability, Annual ryegrass, crop competition

Critical time of weed removal of *Digitaria nuda* (Schumach.) in maize (*Zea mays*) in South Africa (89)

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Difficulties to chemically control large crabgrass in maize in South Africa have recently been attributed to the occurrence of naked crabgrass, previously regarded mistakenly as large crabgrass, which, in contrast to the former, can be controlled relatively easily with acetanilide herbicides. Critical periods of weed control (CPWC) for naked crabgrass in maize was determined in field studies during the 2009/10 and 2010/11 growing seasons at two separate localities for an early- and late-planted maize. Weed-free and weed-crop interference treatments of increasing duration were maintained at various crop growth stages in the presence of naked crabgrass. Biomass of naked crabgrass was determined as dry weight m^{-2} quadrat, which yielded 428 g m^{-2} at Potchefstroom (S26°43'41.9", E27°04'47.8") and 594 g m^{-2} at Wesselsbron (S27°42'47.9", E26°26'28.1"). An exponential regression model was fit to determine the CPWC based on an estimated 10% relative grain yield loss in maize. The onset and ending, as well as, the duration of the CPWC differed between seasons and localities. At 10% relative yield loss, the onset of the CPWC ranged between the two (V2) and six (V6) leaf stages, and ended between the twelve (V12) leaf stage and two weeks after tasseling (T + 2). The duration of the CPWC ranged between 22 and 80 days across different planting dates, years and localities. Yield losses ranged from 28 to 82% in the season-long weedy plots. The shifting of planting dates alone did not reduce yield losses since the effect of late infestations of naked crabgrass was significant. Naked crabgrass control from crop emergence is essential, followed by POST herbicide applications during the CPWC to lower the risk of maize yield losses.

Keywords: Critical period duration, grass weeds, weed control, yield loss

Alleviation of root holoparasitic *Orobanche cumana* infection by exogenously applied salicylic acid in host crop *Helianthus annuus* (205)

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The root holoparasitic angiosperm sunflower broomrape (*Orobanche cumana* Wallr.) specifically affects sunflower (*Helianthus annuus* L.) and causes severe damage to this crop all over the world. The present investigation was designed to examine the protective effects of salicylic acid (SA) treatment to an *O. cumana*-susceptible cultivar of sunflower (TK0409). Seeds of sunflowers were pre-treated with 0, 0.5 and 1 mM SA for 6 hr and then inoculated with *Orobanche cumana for 4 weeks.* Infection of *O. cumana* resulted in a significant reduction of plant biomass, endogenous SA level, and the expression of SA-related genes including *pal*, *chs* and *NPR1*. By contrast, *O. cumana* infection enhanced the production of reactive oxygen species (H_2O_2), activities of antioxidant enzymes (POD, CAT, APX) as well as contents of phenolics and lignin. Seed treatment by SA significantly increased the biomass of sunflower by reducing the number and biomass of established *O. cumana plants*. The increase in hydrogen peroxide contents in plants treated with SA appeared to be due to the inhibition of ascorbate peroxidase and catalase by exogenous SA. The enhanced expression of pathogenesis-related genes (*PR3* and *PR12*) indicated that systemic acquired resistance was induced in the SA-treated sunflower in which the level of endogenous SA was also elevated in a dose dependent manner. The increased expression of *hsr* gene, involved in hypersensitive response (HR) expressed in host cell death around the area of infection, indicated that HR was triggered by the SA treatment. Thus, the seed treatment with SA may alleviate the damage of *O. cumana* by *triggering a defense response in sunflower plants leading to a* reduced infection of *O. cumana.*

Keywords: Hypersensitive response, *Orobanche cumana*, salicylic acid, sunflower, systemic acquired resistance

Aspects of glyphosate mechanism in Egyptian broomrape control (238)

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The obligate holoparasite *Phelipanche aegyptiaca* is controlled by the non-selective herbicide glyphosate. Glyphosate inhibits the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), a key enzyme in the biosynthesis of aromatic amino acids (AAA). However, the functionality of this pathway in *P. aegyptiaca* is not straightforward because of the parasite's total dependence on the host plant. We have characterized the mechanism of glyphosate in controlling *P. aegyptiaca* using a glyphosate-resistant tomato (GRT) genotype as the host plant. Shikimate is known to accumulate in response to EPSPS inhibition in a susceptible plant treated with glyphosate. In *P. aegyptiaca*, shikimate accumulation was first detected 24 hours after treatment (HAT) and increased over time. Shikimate levels in the GRT host however did not increase. In addition, free phenylalanine and tyrosine contents decreased 48 HAT in the parasite. Use of GRT as the host demonstrated endogenous EPSPS inhibition in the parasite as well as AAA deficiency. Crossing the GRT host with a tomato line expressing the green fluorescent protein (GFP) under the *AtSUC2* promoter produced a F_1 hybrid that translocated the GFP in the phloem and was resistant to glyphosate. GFP fluorescence in the parasite's tubercles intensified during the early period of parasitism. However, soon after glyphosate application, fluorescence levels gradually decreased and eventually disappeared. These findings demonstrate that glyphosate has a secondary effect on the availability of solutes and their transport to the parasite. In the current study, we provide evidence for the presence of an active EPSPS and AAA biosynthesis pathway in *P. aegyptiaca* and identify the site of primary action of glyphosate in this parasite. We hypothesize that glyphosate prevents self-production of AAA in *P. aegyptiaca* by inhibition of EPSPS as well as nutrient availability from the host. These two factors inhibit normal development of the parasite and eventually lead to its death.

Keywords: Phelipanche aegyptiaca, Broomrape, Glyphosate, EPSP synthase

Assimilating a decision support system ‚PICKIT' for Egyptian broomrape (*Phelipanche aegyptiaca*) control in processing tomato in Israel (243)

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Broomrapes (*Orobanche* and *Phelipanche* spp.) are obligate root parasites causing severe damage to tomato in Israel. Most of their life cycle takes place in the soil subsurface, including seed germination, attachment to the host root, penetration and establishment in the host tissues, and tubercle production. Towards the end of their life cycle they emerge from the soil and produce inflorescences bearing hundreds of thousands of seeds. In the underground stages of their life cycle, when they cannot be seen, the root parasitic weeds are more sensitive to herbicides than in the aboveground developmental stages. Thus, data on their infestation level or phenological stage in the soil sub-surface are essential for effective control. A Decision Support System (DSS) ‚PICKIT' for rational management of the parasite can assist growers. The DSS includes: a) a model for quantification of the temporal variation and prediction of broomrape parasitism by thermal time, (b) a model for estimation of the spatial variation of broomrape infestation using a geographical information system (GIS), (c) herbicide applications via sprayer or via low flow drip chemigation. The DSS was validated between 2013-2015. The DSS was examined at 8 commercial tomato fields (field size ranged between 2-8 ha) under a range of infestation levels. It was found that using the ‚PICKIT' DSS in heavy broomrape infested fields completely controlled the parasite and increased tomato yield by 50 tons per hectare (marketable weight). In 2015, effectiveness of DSS ‚PICKIT' was examined in 18 commercial fields in an area of approximately 300 hectares. The use of 'PICKIT' resulted in excellent broomrape control and increases in tomato yields of 20-50 tons per hectare. The presentation presents the evolution of successful development of DSS from the lab to the field using integrated approach.

Keywords: Degree days model, Decision support system, Egyptian broomrape, Field validation

Molecular markers for identification and quantification of broomrape (*Orobanche* and *Phelipanche* spp.) seeds in a soil sample (247)

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Broomrapes (*Orobanche* and *Phelipanche* spp.) are obligate holoparasites that attack roots of many crops causing severe yield damage worldwide. Broomrape seeds have several characteristics that create problems for both growers and seed certification. Its tiny seed size (200 to 300 mm) makes it very difficult to detect in harvested crop seeds and in soil. Insights in the seed distribution of infested fields and of new fields will help defining strategies for effective control. Such knowledge facilitates the prediction of damage in crops and efficient application of herbicides. For example, using the principles of precision agriculture ("DSS PICKIT") we can predict the developmental stage of the broomrape according to environmental conditions and assist in timing of the herbicide application. Yet knowledge about the broomrape seed-bank is unavailable. In this study our aim was to develop a PCR-based assay specific for broomrape soil-borne seeds and sensitive enough to distinguish between broomrape species in a soil sample. For this purpose, we used PCR primers based upon unique sequences in the internal transcribed spacer (ITS) regions of the nuclear ribosomal DNA of *P aegyptiaca* (the other two common species *O. cumana* and *O. crenata already have specific markers).* Genomic DNA was extracted from soil samples artificially infested with broomrape seeds, or tissue of those three species mentioned above, and subjected to PCR analysis. Using ITS primers, a specific PCR product (375 bp) was amplified and detected only in samples containing *P. aegyptiaca* seeds or tissues. Based on the 375 bp molecular marker, we will develop a new marker to quantify dispersal of *P. aegyptiaca* seeds in a crop field by Real Time PCR. Combination of reliable molecular markers with efficient planning of soil sampling using geo-statistical methods will facilitate the assessment of broomrape seed contamination in a crop field and assist for herbicide application in adequate timing.

Keywords: Broomrape, internal transcribed spacer (ITS), soil sample

Effect of velvetleaf (*Abutilon theophrasti* Medic.) density on corn (428)

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Competition from weeds, particularly velvetleaf (*Abutilon theophrasti* Med.), causes severe yield loss in corn. Field experiments were conducted to investigate the effect of velvetleaf density on growth and yield of corn planted at a standard density of 57,000 plants ha^{-1} (0.70 x 0.25 m) under a conventional tillage system. Effect of competitive interactions on velvetleaf growth was also documented. Experiments were conducted across two years (with different rainfall conditions) following a randomized complete block design with four replications. Treatments included 0, 1, 2, 4 and 8 velvetleaf plants m^{-1} row. Size of each plot was 4.2 m x 5.0 m. Growth variables were measured on corn as well as velvetleaf four times each growing season. Plant height, fresh biomass, leaf area index, and grain yield of corn were analyzed using a four-parameter log-logistic regression model as a function of velvetleaf density. Regression analysis was also performed on velvetleaf growth variables (plant height, fresh biomass, leaf area index, and seed mass per plant) as a function of intra-specific density in corn. Plant height was the least sensitive variable for competition in both species (corn and velvetleaf). However, reduction in other variables due to competition was clearly visible in both species and in both years. Level of corn yield reduction depended on year and velvetleaf density, and ranged from 1.2 to 39.3% in the first year and from 1.2 to 35.9% in the second year for velvetleaf densities from 1 to 8 plants m^{-1} row. On the basis of the 5% yield loss level, the threshold for velvetleaf in corn across the two years ranged from 0.4 to 0.6 plants m^{-1} row.

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Keywords: Competition, competition, corn, velvetleaf, Abutilon theophrasti

Session 19
NON-CHEMICAL WEED CONTROL TOOLS: Preventive Methods

Keynote: Weed suppression by cover crops mixtures using intra- and inter- specific diversity (254)

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Cover crops are commonly used to suppress weeds prior to establishment of a main crop, along with other benefits. Based on natural ecosystem research, which has demonstrated a positive relationship between diversity and productivity, we expected that more diverse cover crop mixtures would produce more biomass and consequently reduce weed biomass. Diversity can be measured at a number of different levels. Here we looked specifically at three levels: functional diversity (legumes: nitrogen-fixing, grasses: non-N fixing), interspecific diversity (multiple species), and intraspecific diversity (multiple cultivars within a species). During the overwinter cropping season (September to June, fall to spring in the Northern hemisphere), in two consecutive years on a research farm in New York, United States, we established an experiment with a randomized complete block, replacement series design. We created a diversity gradient with 49 treatments using 6 annual cover crop species (3 legumes, 3 grasses) and multiple cultivars of each species. Biomass and plant counts for all cover crop species and weeds were collected prior to termination of the cover crops. Preliminary results show that mixtures of multiple cultivars of a single species tend to suppress weeds better (as biomass) than the average of the same cultivars planted alone. The weed suppression in these cultivar mixtures is not correlated with cover crop biomass production (R^2= 0.077, p=0.1375, y=18.25-0.02195x). Additionally, species polycultures suppressed weeds better than species monocultures, and in the species polycultures the weed biomass is not strongly correlated with cover crop biomass production (R^2= 0.050, p=0.0019, y=10.74-0.0087x). The improved weed suppression in cultivar and species mixtures suggests alternative mechanisms for reduced weed success in these diverse cover crop mixtures. For farmers, increasing cultivar richness even in single species cover crop plantings can improve the performance of the cover crops for weed suppression without a substantial increase in management complexity.

Keywords: Cover crops, Biodiversity, Plant competition, Species richness, Integrated weed management

Can weed management in vegetable systems be improved by cover crop species mixtures? Step 2: field implementation (198)

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Cover crops are a fundamental tool for weed control, especially in organic and low input farming. Species with different functional traits can be combined in mixtures to enhance weed suppression. Our aim was to test the relative importance of functional diversity and functional composition (i.e. complementarity) in improving and stabilising the agroecosystem services expected from cover crops.
Following a preliminary screening on cover crop functional traits (Step 1), we identified 8 species belonging to 4 functional groups: large seeded legumes, characterized by higher height (*Pisum sativum* L., *Vicia sativa* L.), small seeded legumes, able to cover quickly the soil (*Trifolium incarnatum* L., *T. squarrosum* L.), highly competitive grasses (*Hordeum vulgare* L., *Avena sativa* L.) and allelopathic brassicas (*Raphanus sativus* L., *Brassica nigra* L.).
We designed 4 two-species mixtures, 4 four-species mixtures and 1 eighth-species mixtures and set a gradient of diversity: (i) pure stands; (ii) co-presence of 2 functional groups; (iii) diversity within 2 co-occurring functional groups, (iv) co-presence of 4 functional groups, (v) diversity within 4 co-occurring functional groups. The trial was conducted in an organic field located in Pisa, Italy. Experimental plots were seeded on 27 October 2014 following a randomized complete block design with three replicates, and devitalized on 6 May 2015.
Weed biomass was significantly lower in mixtures with the higher level of diversity compared to the unweeded control (from -87% up to -97%). Cover crop mixtures proved to be more productive than pure stands, since Land Equivalent Ratio was >1 in all but one mixture. For some species, biomass production was higher in high diversity mixtures compared to pure stands.
Functional diversity in cover crops can play a key role on biomass productivity and weed suppression. Data will be analysed to clarify the role of functional composition on cover crops agroecosystem services provision.

Keywords: Cover crop, mixtures, functional diversity, weed suppression

Use of cover crops as weed management tools in sugarcane fallow (122)

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In the Australian Wet Tropics, new cost effective weed management strategies in sugarcane must be developed to reduce the reliance of herbicides in order to contribute to achieving the target of 60% reduction in pesticide pollutant loads under the ReefPlan governmental program.
This paper presents research trials investigating the weedicide potential of several cover crops and blends that could be used in sugarcane fallows with the intention of limiting the amount of herbicides used in bare fallow and potentially in plant cane.
Two trials designed as split plots with 3 replicates were implemented in fallow blocks at Meringa, Queensland. Treatments compared in each trial were: Ebony cowpea alone, Rongai lablab alone, a blend of Ebony and Rongai lablab (50/50), a blend of Ebony cowpea, Rongai lablab and Jack bean (*Canavalia ensiformis*) (40/40/20) and a blend of Ebony cowpea, Rongai lablab and Shiroe millet (40/40/20). Each treatment was tested at two sowing rates (green manure rate / twice green manure rate) and managed with and without herbicide control.
Cover crop coverage and weed coverage were calculated (using photographic assessment) every second weed and dry biomass and nitrogen available for the following crop were measured after the cover crop was sprayed out.
Results show that the best cover crops to reduce weed coverage were either cowpea alone or mixed 50% with lablab. Adding Jack bean or Millet to the mix did not significantly improve the ground coverage. The high sowing rate tended to increase the speed of legume establishment and coverage and slightly decrease the amount of weeds (no significant differences). Managing weeds (with herbicide) was unnecessary and even slightly decreased the legume biomass. The amount of available N provided by the leading treatments is around 140 kg N/ha and needs to be taken into account for the fertilisation of the following plant cane.

Keywords: Cover crop, Cowpea, Lablab, Sugarcane, Fallow

The weed seedbank after 8 years of winter cover cropping (623)

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Weed establishment and growth can be constrained by cover crops (CC) through different physical and chemical mechanisms, so they can be considered as potential biological filters in weed community. The seedbank determination can provide useful information of the long-term effect of management practices in weed control. Therefore, the aim of this study was to evaluate the long-term effect of winter CC included in a rotation on the size and composition of the viable weed seedbank. A field experiment was established in 2006 in Central Spain, with three treatments, a fallow and two winter CC. Each year, barley (*Hordeum vulgare* L.) and vetch (*Vicia sativa* L.) CC were sown in October and killed by contact herbicide application in early spring. Residues remained on the surface creating a mulch layer during the summer period. In May, a cash crop was planted and harvested before CC sowing. Soil seedbank samples were taken at 0-7 cm depth in winter 2014. Weed abundance and composition were studied after a flotation method. After 8-years of CC rotation, differences in weed composition were found. The seedbank was dominated by *Amaranthus* sp. and *Setaria* sp. (>80%). Cover crops reduced the density of *Datura stramonium* L., *Polygonum* sp, and *Portulaca oleracea* L. However, it was remarkable that both of them enhanced the population of *Setaria* sp., and *Chenopodium album* L. density was higher in barley treatment. Different effects in the soil-plant system by CC species (i.e. nitrogen supply, temperature and soil moisture, light interception) are discussed to explain differences between treatments. No effect observed in the total weed density or richness can be explained by the seedbank buffering effect. The results can help to understand the complexity of plant communities interactions but more research is needed in order to achieve effective weed control strategies.

Keywords: Seedbank, mulch, cover crop, weed control

Multi-tactic weed control in organic no-till soybean production: overcoming cover crop management challenges with a focus on shading (239)

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Maximizing cereal rye (*Secale cereale*) biomass has been recommended for weed management in cover crop-based, organic, no-till planted soybean (*Glycine max*). However, excessive biomass production can cause numerous challenges. Two separate experiments were conducted between 2012 and 2014 in New York, United States, to test the weed suppression effects of (1) maximizing light interception prior to cover crop termination with mixtures of barley (*Hordeum vulgare*) and cereal rye, and (2) enhanced shading from earlier canopy closure with high soybean seeding rates. For the first experiment, barley and cereal rye were seeded in a replacement series to assess the weed suppressive ability of each cover crop in monoculture (barley:cereal rye, 0:100 and 100:00) and in mixture (25:75, 50:50, and 75:25). As the proportion of cereal rye increased, total cover crop biomass increased and light transmittance through the canopy decreased. Average weed biomass, which was dominated (≥ 60%) by *Ambrosia artemisiifolia*, ranged from 300 to 1,200 kg ha^{-1} ($P < 0.05$) in 2013 and 2014 across all treatments. Weed biomass tended to decrease as the proportion of cereal rye increased; however, we observed disproportionately lower weed biomass than expected in some mixtures given the relatively low cover crop biomass produced. For the second experiment, soybean was planted at five rates: 198,000; 420,000; 618,000; 778,000; and 914,000 seed ha^{-1}. Average weed biomass decreased from more than 1,300 to less than 300 kg ha^{-1} ($P < 0.05$) as planting rate increased. Despite being approximately double the recommended planting rate for conventional soybean, the 778,000 seed ha^{-1} rate was the highest yielding and most profitable when seed costs and market value were considered. Our results indicate that by shifting the focus from biomass to shading, there is potential to avoid the challenges associated with thick cover crop mulch while still providing adequate weed suppression.

Keywords: Cover crops, organic rotational no-till, roller-crimper, reduced tillage, mulch

Allelopathic effect of hairy vetch (*Vicia villosa*) cover crop on weeds: field evidences in a Mediterranean organic vegetable agro-ecosystem (363)

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Hairy vetch, is widely utilized as winter cover crop in Mediterranean areas. Besides its soil fertility building capacity, the weed control potential of vetch is acknowledged. After vetch termination, allelopathic compounds of residues (i.e. cyanamide) can play a role in weed growth inhibition. Termination strategy could influence the allelopathic compounds distribution in the rizosphere and thus their bioavailability. In this research, the effect of vetch termination on weed control, focusing on the assessment of allelopathic mechanisms, was evaluated during tomato (*Lycopersicon esculentum*) cycle in an organically managed agro-ecosystem in Central Italy. The following strategies were compared: i) no vetch control (FA); green manured vetch (GM) and iii) flattened vetch by roller crimper (RC). Weeds were monitored during tomato cycle. In order to assess the allelopathic potential of vetch, cyanamide was assayed in its residues at termination (HPLC). Furthermore, bioassay tests were performed by assessing the phytotoxicity of vetch extracts on seeds of selected target weeds. Soil mineral nitrogen (SMN) was also analyzed to evaluate the nutritional contribution to weed growth. Results showed significantly different weed community development in the three treatments. Redroot pigweed resulted as one of the main representative species of the studied system. Its density and covering decreased significantly, in a different extent, either in GM and RC respect to FA, despite the increase of SMN in vetch treatments respect to FA. High levels of cyanamide (81.0 mg kg^{-1} d.m.) were quantified in vetch at termination. The bioassay tests showed an high inhibition of vetch extracts on germination and root elongation of redroot pigweed seeds, compared to control. Results confirmed the influence of the termination strategy on the potentialities of hairy vetch in control weeds and the relevance of the allelopathic mechanisms in modulating vetch/weeds interactions.
This research was carried out in frame of the *Ortosup* research project

Keywords: Allelochemicals, weed management, cyanamide, organic farming, roller crimper

Comparison of different cultivations of *Raphanus sativus* var. *oleiformis* Pers. as cover crop on weed suppression (128)

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Weed suppressing ability of oil radish (*Raphanus sativus* var. *oleiformis* Pers.) as cover crop is attributed to early plant development and high competitiveness for natural resources. Time and cultivation method are mandatory for high weed control efficacy within the field.
In 2015, field and greenhouse experiments were conducted to evaluate the weed suppressing ability of oil radish. The cover crop was sown in 4 treatments plus untreated control over a period of 3 weeks before and after winter wheat harvest. Fertilization effects on oil radish in regard to biomass and weed suppression were measured.
Sowing of oil radish at wheat harvest and after stubble cultivation resulted in highest biomass yields 7 and 12 weeks after sowing (WAS). Fertilization revealed no significant differences of oil radish biomass compared to unfertilized treatments. Weed density (weeds m^{-2}) was found to be correlated with cover crop biomass (g) over all treatments. In the greenhouse experiment, highest oil radish biomass and weed suppression (7 WAS) was observed in treatment 3 weeks before wheat harvest.
Due to exceptional dryness in 2015, early sowing of coated oil radish seeds in winter wheat resulted in low germination and biomass yield within the field. However, the high potential of coated cover crop seeds for weed control is demonstrated in greenhouse trials. The selection of the oil radish cultivation method deserves special consideration to biotic and abiotic factors in the field.
This study emphasizes the high weed suppression by oil radish as cover crop in autumn under different cultivation methods. New systems, as sowing oil radish in the previous main crop, may contribute to effective weed control.

Keywords: Cover crop, oil radish, weed suppression, biological weed control, weed density

Cultural weed management of Indian weedy rice through deep tillage and flooding (224)

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In India rice is grown across diverse agro-ecological zones. At present, increased labor costs and water scarcity compel the farmers towards shifting to direct seeding of rice (DSR). Again, DSR faces heavy infestation of weedy rice resulting havoc yield losses. Non availability of any selective herbicide against weedy rice makes the cultural weed management approaches the best option for controlling it. With this views studies were carried out during 2013 in containment chamber of ICAR-Directorate of Weed Research, Jabalpur, India in randomized complete block design with eight weedy rice accessions (WRAs) of diverse Indian agro-ecological zones showing sharp indication of shifting to DSR i.e. Jabalpur-MadhyaPradesh (JMP); Gwalior-MadhyaPradesh (GMP), Ranchi-Jharkhand (JK), Utai-Chhattisgarh (CG), Patna-Bihar (BR), Varanasi-UttarPradesh (VUP), Ghazipur-UttarPradesh (GUP) and Thrissur-Kerala (KL) replicated thrice to determine the response of WRAs to varied seed burial and flooding depths (0, 2, 4, 6, 8 and 10 cm) in their seedling emergence. The different seed burial and flooding depths exhibited wide variation on WRAs emergence. Seedling emergence gradually decreased with increase in burial depth and the lowest value was found under 10 cm. Practically, at this depth the emergence was reduced by 54.0, 31.7, 79.2, 15.0, 15.8, 32.5, 73.3 and 80.8% for JMP, GMP, JK, CG, BR, VUP, GUP and KL respectively. Depth of flooding showed more impact than that of seeding depth on WRAs seedling emergence. The WRAs possess potentiality to emerge even from 10 cm water depth. Accessions from JK, KL, BR and GMP have more ability to germinate under anaerobic situations. A flooding depth of even 2 cm reduced the emergence by 84.0, 46.7, 28.3, 61.7, 43.3, 48.3, 73.3 and 35.0% in JMP, GMP, JK, CG, BR, VUP, GUP and KL respectively. Weedy rice emergence can be suppressed by deep tillage burying their seeds below the maximum depth of emergence and by flooding fields to create anaerobic condition.

Keywords: Indian Weedy Rice, Deep tillage, Flooding, Cultural weed management, DSR

Using analytic hierarchy processing and grower feedback to promote adoption of integrated management strategies for dodder (*Cuscuta* spp.) in cranberry (179)

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Analytical Hierarchy processing (AHP) uses pairwise comparisons in conjunction with a ratio scale to indicate the strength of preference or importance of various criteria. Preference is weighted as an increasing integer range for one criterion and as the inverse of that range for the other criterion. Since control options, environmental concerns, and economic pressures can be in conflict and make weed management decisions difficult, AHP can be a great tool to resolve seemingly divergent management objectives. AHP can prioritize strategic alternatives and identify key indicators by incorporating the decision maker's preferences and experiences along with other quantitative data. We identified dodder (*Cuscuta* spp.) management in cranberry for our AHP model development. Dodder is a particularly good candidate as no one single tactic provides adequate control and integration of techniques is mandatory.
Our objective was to design farm-specific dodder management programs. We developed prototype surveys based on three separate key factors for dodder management: preemergence options, labor-intensive strategies, and herbicide use. For example, herbicide use, seed removal, scouting, and sanitizing equipment were criteria selected as preemergence options. Individualized instruction (for 13 growers) was needed to increase the likelihood of proper responses since the ratio scale format was very different from our typical surveys. Growers seemed very receptive to the idea of using AHP to aid in their management decisions. Once data are analyzed, we will verify that participants' actual preferences were correctly communicated in the surveyed format. Our next step is to incorporate their feedback from and develop surveys that can be used to gain preference information from a larger group of growers. We believe this effort will allow us to identify the most important and useful strategies for the industry by doing a composited evaluation as well as provide a method for individualized strategy development for dodder control.

Keywords: Analytic Hierarchy Processing (AHP), Dodder, Multi-criteria decision making, Integrated pest management (IPM), Cranberry

Monitoring weeds in organic spring cereals in Northern Europe (320)

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This study is a component of the recently started CORE Organic PRODIVA project, a collaboration between international weed research institutions, which aims to improved utilization of crop diversification for weed management in northern European organic arable cropping systems. The overall goal is to maintain a diversified and manageable weed flora that can support beneficial organisms. The objective of this specific research is: to identify practical weed challenges, to investigate the role of crop diversification measures for weed control in the field and to cluster weed species into groups in accordance to their susceptibility for the applied crop diversification techniques. In order to reach this objective a diversity of methods are utilised. Data collection is taking place on 71 organic arable farms in five countries (Denmark, Sweden, Finland, Latvia and Germany) over the course of two years (2015-2016). An on farm weed survey is carried out in spring sown cereals and combined with the collection of the field history with a focus on the implementation of crop diversification measures. All data are collected at the University of Rostock, processed and analysed for interactions with the crop diversification measures. Results will be communicated towards the stakeholders and serve scientific purposes.

Keywords: Crop diversity, Weed diversity, Field surveys, Organic spring cereals, Farmer's participation

Session 20
HERBICIDES AND APPLICATION TECHNOLOGY: Soil and Environmental Impacts

Keynote: A national survey of the effect of previous atrazine use on enhanced atrazine degradation in US soils (74)

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In 2014, Cooperators from 16 U.S. states supplied matched sets of field samples: one soil with no previous atrazine use, and one with 5 or more years of continuous atrazine use under field conditions. Dissipation curves obtained were fit to simple first order kinetics and a half life in days (DT50) was calculated. "Enhancement" was defined as a ratio of the DT50 of the non-history/history soil being > 2.0. 53 of a possible 61 comparisons indicated enhanced degradation of atrazine based on this criteria. The average DT50 in all non-history soils was 14.5 days, and in history soils was 2.3 days, yielding an average enhancement factor of 6.3X, meaning the atrazine in soils with a history of atrazine use degraded 6.3 times more rapidly. Given that fields with either 0 or 5+ years of atrazine use were examined, the goal was to determine if enhanced atrazine degradation is a widespread, region-wide phenomenon as opposed to determining how many years of exposure are needed for enhanced atrazine degradation to occur. Another factor not considered is atrazine use rate, which varies depending on the region of the U.S. from which soil samples were collected. Enhanced atrazine degradation was observed in most states, with enhancement indicating reduced residual weed control where atrazine was used in multiple consecutive years. These findings indicate that residual control of atrazine in some soils may be reduced, and perhaps atrazine may be used more effectively in postemergence applications. Also, environmental models may be over-estimating the persistence of atrazine. Atrazine damage to rotational crops may also be over-stated on some current use labels.

Keywords: Zea mays, atrazine, enhanced degradation, soil, microbial

Accelerated dissipation of sulfosulfuron activity in soil (79)

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Sulfonylurea herbicides are highly important in global agriculture. Understanding factors affecting degradation is essential for long-term weed management. A reduction of sulfosulfuron soil activity has been observed in processing-tomato fields. We hypothesized that accelerated microbial degradation, caused by repeated sulfonylurea application, is the reason for sulfosulfuron reduced activity. Our objectives were: (i) develop a bioassay to determine the mechanism of sulfosulfuron accelerated dissipation, and (ii) study the role of microbial degradation in this process. Sorghum (*Sorghum halepense*) was used as a test plant for sulfosulfuron activity. Quartz-sand or soil were mixed with sulfosulfuron solution, distributed to 3 petri-dishes, seeded with 10 seeds and incubated at 25 ˚C for 5 days, followed by root length measurement. In the dose response bioassay, sorghum root length varied significantly depending on sulfosulfuron application rate with ED_{10}, ED_{50} and ED_{90} values of 5.7, 34.7 and $>9.4*10^5$ nM, respectively, confirming that sorghum is an effective test plant. The role of biodegradation in sulfosulfuron (40 ng ai g^{-1} soil) persistence was evaluated using a bioassay in sterilized vs. non-sterilized soil taken from areas with suspected accelerated sulfosulfuron degradation. A 4-fold increase in sulfosulfuron phytotoxicity to sorghum in the form of 56% root growth inhibition was observed in sterilized soil. Reduced phytotoxicity of sulfosulfuron on sorghum in soil samples compared to equivalent application rates in the relatively inert quartz-sand was also observed. These results demonstrate the contribution of biological activity to the reduction in sulfosulfuron soil activity and provide an indication that microbial activity may lead to accelerated dissipation of sulfosulfuron. Possible mechanisms involved in observed accelerated dissipation of sulfosulfuron and other sulfonylurea herbicides in soil is currently being investigated using analytical methods. The effect of field herbicide application history on residual activity of sulfosulfuron using sorghum bioassay is also being examined. Results would allow development of strategies to prevent or overcome sulfonylurea accelerated degradation.

Keywords: Sulfonylurea herbicides, biodegradation, persistance, residual herbicide activity

Multi-crop bioassay of simulated dicamba residue in soil (459)

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Dicamba (3,6-dichloro-2-methoxybenzoic acid) is a common growth regulator herbicide used to control broadleaf weeds. The introduction of dicamba-resistant soybean (Glycine max L.) and the subsequent anticipated increase in dicamba use rates creates an elevated risk to susceptible crops in rotational crops. Producers grow a variety of crops that are susceptible to this chemical, so adequate precautions should be taken. This study addresses potential of soil residual dicamba to cause injury to four susceptible, high value crops: dry bean (Phaseolus vulgaris L.), soybean, sugar beet (Beta vulgaris L.), and sunflower (Helianthus annuus L.).
Experiments were conducted near Erie and Hillsboro, North Dakota. Rates of dicamba from 0 – 2809 g ae ha^{-1} were applied to bare ground in mid-May to simulate dicamba residues remaining from the previous year. Each crop was planted into the treated area. The effect of dicamba on the growth and development of the crops was measured in three ways. Stand counts were taken at emergence and before harvest. Visible injury was recorded as a percentage (100% = total death) at 7, 14, 21, and 28 days after emergence. Seed and beet weights were taken at harvest. While injury was seen in dry bean and soybean depending on location, no yield differences could be detected by herbicide treatment in any crop. This work supports that dry bean, soybean, sugar beet, and sunflower yield will not be impacted by amounts of dicamba less than 2809 g ae ha^{-1} present at the time of planting, which is more than double the suggested rate to use in dicamba resistant soybean. More work needs to be done to ensure the safety of crops across the region and in different environments.

Keywords: Soil-residual dicamba, susceptible crops, bioassay, dicamba injury, crop response

Persistence and dissipation of penoxsulam and butachlor in transplanted paddy (110)

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Weeds are a major impediment to rice and out of the losses due to various biotic stresses, weeds account for nearly one third. Thus the use of herbicides has become an imperative in rice. Penoxsulam is a relatively new triazolopyrimidine sulfonamide herbicide for controlling broadleaf weeds and certain grasses while butachlor is a chloroacetanilide herbicide used to control grass and sedge weeds. Ready mix formulations because of their multiple mode-of-action are gaining importance to control the wide array of weeds. As the ready mix formulation of penoxsulam (1%) and butachlor (40%) is new, a study on its persistence was carried out in a paddy in India. A field experiment on this new formulation to understand the residual fate and dissipation was conducted. The mixture was applied at 820 g and 1640 g a.i. ha^{-1}. Paddy leaf, soil, field water samples were collected at 2 hr, 1, 3, 7, 15, 30, and 45 d after application (DAA) and rice grain, straw and soil samples were collected at harvest. Penoxsulam was analyzed using HPLC while butachlor was analyzed using GC-ECD. The dissipation of both the compounds followed first order kinetics. No residues of penoxsulam or butachlor were detected in the paddy plant or in water seven DAA of the herbicide while both the compounds persisted up to 30 DAA in soil. The half-life values of penoxsulam and butachlor ranged from 1.89-2.95 d and 2.08-3.04 d in paddy plant, 5.19-6.84 d and 6.27-7.00 d in soil, 2.28 d and 1.36-1.44 d in water, respectively. No residues were found in rice grain, straw, husk and soil at harvest. Thus application of the new ready mix formulation will not pose any toxic residues in the harvested paddy.

Keywords: Penoxsulam, Butachlor, paddy, dissipation, half life

Dissipation of imidazolinone herbicides applied in green gram from soil by GC/MS tandem mass spectrometry (682)

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A herbicide should persist during current crop season for effective weed control but carryover effect to next cropping season is not desirable. Finding duration of herbicide persistence at applied rate is helpful for determining the toxicity of herbicides on subsequent sensitive crops. Therefore, planning the correct sequence of herbicide usage together with crop selection and soil residue analysis has become a necessary part of rotation management in agriculture. An experiment was conducted during 2014-15 at the Agronomy Research Farm of CCS, HAU Hisar. Imazethapyr and its ready mixture with imazamox were applied PPI, PRE and POE at 70 and 140 g ha^{-1} and soil samples along with control were collected on 0 (1 hr after application of treatment), 7, 15, 30, 60, and 90 d after treatment (DAT). The samples were processed after the validation of analytical method (column method) and analyzed by GC/MS Tandem-mass spectrometry. LOD and LOQ were 1 ppb and 0.003 ppm. Recovery of the herbicides at different fortification levels (0.01 and 0.25 µg) were collected and recorded > 80% recovery in both imazethapyr and its ready-mixture with imazamox. Results revealed that imazethapyr half-life was 10.6 d with 81.5% dissipation of residues at 60 DAT using the recommended dose (70 g ha^{-1}). Residues 90 DAT were below detectable limit of 0.003 ppm. Double recommended dose of imazethapyr (140 g ha^{-1}), half-life period was 12.52 d with 81.7% residues dissipation at 60 DAT. Residues level were below detectable limit at 90 DAT. In imazethapyr + imazamox treatment, half-life was 8.81 d with 80.7% dissipation of residues at 60 DAT using 70 g ha^{-1}. At double the recommended dose of imazethapyr + imazamox (140 g ha^{-1}), the half-life period was 10.60 d with 85.1% residues dissipation at 60 DAT. These results have greater significance planting sequential herbicide sensitive crops.

Keywords: Herbicie persistence, Half life, Crop damage, Herbicide mixture, i\Imidazolinone herbicides

Evaluating the time required for dissipation of halosulfuron from low density polyethylene mulch using bioassay and analytical methods (20)

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Injury and yield reduction of vegetable crops has been reported following halosulfuron application to low density polyethylene mulch (LDPE) prior to transplanting. Field studies were conducted to determine the effect of halosulfuron application to LDPE on watermelon and squash at various timings prior to transplanting, dissipation from LDPE under field dry conditions, and temperature effects over time on degradation in laboratory experiments. Data indicated halosulfuron applied at 78 and 156 g ai ha^{-1} 27 or 23 days prior to transplanting (DPT), and 78 g ha^{-1} applied at 17 or 14 DPT did not significantly reduce squash yield and number. However, halosulfuron applied at 90 g ha^{-1} nine and 1 DPT in 2013, and one DPT in 2014, reduced squash yield and number. At 90 g ha^{-1}, halosulfuron applied one DPT resulted in reduced watermelon yield and fruit number; however, there were no significant effects on watermelon bioassay. Halosulfuron applied at 26 or 52 g ha^{-1} had similar dissipation rates on LDPE mulch under dry conditions in the field with half-lives of 2.8 and 2.6 d, respectively. Twenty-one days after treatment (DAT), 90% of halosulfuron had dissipated from the LDPE, with none detectable 35 DAT. Halosulfuron degradation evaluated on a thermal-gradient table established the effects of time and temperature. Temperatures of 10 to 42 C were evaluated for 15 days. Minor halosulfuron degradation was observed for the first 48 hours of incubation at temperatures below 40 C. Significant degradation occurred at 4 days after trial initiation (DTI) when temperature exceeded 25 C. At 7 DTI, halosulfuron degradation was 17, 32, 43, and 71%, at 30, 35, 38 and 42 C, respectively. By 10 DTI, 27, 45, 58 and 84% of halosulfuron was degraded for these temperatures, respectively. In contrast, 6 and 9% of halosulfuron was degraded at 20 and 25 C at 10 DTI, with little to no degradation at temperatures below 20C.

Keywords: Halosulfuron, herbicide persistance, herbicide dissipation, exponential decay equation, herbicide half-life

Characteristics and degradation mechanism of fomesafen (193)

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Fomesafen {5-[2-chloro-4-(trifluoromethyl)phenoxy]-N-(methylsulfonyl)-2-nitrobenzamide} is a selective herbicide which may be applied postemergence for control or suppression of broadleaf weeds, grasses and sedges in soybean. Fomesafen is generally most effective and consistent when used postemergence working through contact action. Fomesafen is one of the most persistent herbicides of those typically applied postemergence in soybean and has one of the longest periods of soil residual activity. Because of this soil persistence as well as the sensitivity of corn to fomesafen residues, the label of most fomesafen products like Flexstar and Prefix requires a 10-month rotational interval between fomesafen application and corn planting. However, soil persistence may be influenced by environmental conditions and subsequent microbial activity. Microbial degradation may have been reduced due to the extended winter experienced in 2015. The role of aspergillus flavus in fomesafen degradation was evaluated by building a fomesafen degrading aspergillus flavus cDNA library which was screened to determine the degradation of the gene into E. coli and E. coli strains. Under optimal conditions, bacteria degrade within 72h of fomesafen application with a degradation rate of nearly 100%. The use of HPLC-MS (High Performance Liquid Chromatography – Mass Spectrometry) was used to analyze fomesafen degradation into microbial products. A more thorough understanding of microbial fomesafen degradation mechanisms will be discussed.

Keywords: Fomesafen, post-emergence, degradation, HPLC-MS

Degradation kinetics of acetochlor 90% EC in paddy and maize under West Bengal climatic condition (334)

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Acetochlor, a chloroacetanilide group of herbicides, first introduced by Monsanto Company in 1985. Acetochlor is effective as pre-emergence herbicide against broadleaf weeds *viz*. *Monochornia vaginalis*, *Portulaca oleracea*, *Phyllanthus niruri*, etc. in crop field by inhibiting lipid synthesis. A residue study was conducted in rice and maize crop field for one season in Jaguli Experimental field, B.C.K.V, Mohanpur, Nadia West Bengal during 2014. Acetochlor 90 EC was supplied by Sinochem India Ltd.,New Delhi and applied in the rice and maize crop field at 150 mL ha^{-1} and 300 mL ha^{-1} as recommended and double the recommended doses respectively at early stage of crop in addition to maintaining untreated control plots. Soil and plant samples were collected at 0 (2 hr after application), 3, 7, 15 and 30 d after application. Samples were extracted following QuEChERS method and finally analysed by GLC-ECD. The LOQ of acetochlor was determined to a resolution of 0.05 ppm. The average recovery of acetochlor in rice and maize plant and field soil samples were above 90%. The half-life value of acetochlor was determined as 15.05-16.72 d in paddy soil and 9.12-11.25 d in rice plants and 17.06-18.62 d in maize soil and 7.92-10.03 d in maize plants. The dissipation behaviour of acetochlor followed first order kinetics irrespective of crop or dose. Acetochlor residues were not detected in grain, husk and straw of rice and grain and green cobs of maize crop and field soil at harvest irrespective of dose. This research established that applications of acetochlor in these crop field will not pose any residual toxicity problems.

Keywords: Acetochlor, pre-emergence, GLC-ECD, QuEChERS, Half life

Transfer of plant protection products in different pedological and climatic environment (613)

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Since the 90's ARVALIS-Institut du végétal has implemented several experiments on water quality in France. The aim is to link cultural practices with a monitoring of the water quality at the field scale in order to reduce risk of diffuse pollution by pesticides. More than 95 000 analyses of water samples have been collected for 134 active ingredients and 7 metabolites on 5 experimental sites. Five experimental devices have been monitored with lysimeters or drainage and runoff collectors in order to follow the water quality: La Jaillière (hydromorphic silty clay soils), Magneraud (calcareous clay soils), Geispitzen (capping loamy soils), Lyon Saint-Exupéry (gravel soils) and Thibie (chalky soils). Monitoring data have been used to set parameters for mechanistic models of pesticide transfer (MACRO, RZWQM) in order to evaluate their predictive quality and to define their domains of validity. The results show that certain active ingredients have different behavior according to the pedological and climatic environment. For herbicides like isoproturon or diflufenican the position of the application in accordance with the winter flow period can significantly reduce the risk of transfer. The evaluation of MACRO and RZWQM shows good results with mobile active ingredients like isoproturon but require a precise configuration. The integration of data relative to hydraulic conductivity and certain characteristics of active ingredients measured in the field (Koc-DT50) increase the quality of the simulations of both models. These experiments enable a better understanding of pesticide transfer at the field scale and allow to advise farmers in order to reduce the risk of diffuse pollution by herbicides.

Keywords: Water quality, diffuse pollution, herbicide, risk management, modelling

Overcoming the reduced efficacy of glufosinate ammonium under low ambient temperatures (118)

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The efficacy of glufosinate ammonium (GA), a glutamine synthase inhibitor, is drastically reduced when applied at temperatures below 10 C. Long-term field experiments lead farmers to avoid its applications when such temperatures occur. The wide spread occurrence of glyphosate-resistant weed biotypes (e.g., *Conyza* spp.) along with reduced efficacy observed in other annual species such as members of the Fabaceae, *Malva* spp.*, Mercurialis annua, Lamium amplexicaule*, *Urtica urens,* etc., led us to look for alternative post applied herbicides to improve weed management in perennial crops (e.g., citrus orchards, vineyards and other plantations). During the winter of 2013/2014 and 2014/2015 we conducted several field experiments testing several treatments comprising GA tank-mixtures with low rates of PPO-inhibiting herbicides or paraquat. While GA at 800 g ai ha^{-1} (recommended rate) and GA combined with glyphosate (1200 g ae ha^{-1}) were not sufficiently effective against the target weed species infesting orchards and plantations, GA (800 g ai ha^{-1}) tank-mixed with flumioxazin (125 g ai ha^{-1}), provided almost 100% weed control. The addition of paraquat (500 g ai ha^{-1}) was found compatible and gave very good control of *Oxalis pes-capre,* a hard to kill weed thriving under low light intensity environments. We concluded that the reduced efficacy of GA observed under Mediterranean winter conditions (10 to 15 C) could be alleviated when combined with low rates of PPO-inhibiting herbicides such as flumioxazin or with a PS I-inhibitors like paraquat.

Keywords: Glufosinate ammonium, PPO inhibitors, Reduced efficacy

Session 21
JOINT IWSS/INTERNATIONAL BIOHERBICIDE GROUP SESSION: New Ideas and Directions in Biological Weed Control

Keynote: *Plectosphaerella cucumerina* – a potential biohebricide for *Cirsium arvense* (39)

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Plectosphaerella cucumerina, a fungal pathogen of several plant species globally, has recently been confirmed as a naturally-occurring disease-causing agent in *Cirsium arvense* in pastures in New Zealand. To explore its potential as a bioherbicide, five green-house/growth-cabinet experiments were conducted between 2006 and 2013, two in New Zealand and three in Canada (the latter comparing Canadian and New Zealand isolates). A sixth experiment, in a pasture in New Zealand, provided "proof-of-concept" using the New Zealand isolate. The fungus defoliated *C. arvense* plants under both the greenhouse and field conditions when applied at 10^{13} conidia ha^{-1} in water volumes ranging from 250-1500 L ha^{-1}. In the greenhouse, disease levels were highest with multiple applications of conidia, temperatures around 20°C and 48 h leaf wetness following application. Under field conditions, the addition of Pulse wetting agent greatly enhanced disease levels. Overall, the isolates of *P. cucumerina* obtained from *C. arvense* both in New Zealand and Canada caused similar levels of disease under a range of environmental conditions indicating a global opportunity for its development as a bioherbicide. We thank Meat and Wool New Zealand (now Beef+Lamb NZ) and the Foundation for Research Science and Technology for funding Experiment 1 (under Projects 05AR/16 and C10X0811 respectively). We also thank the Ministry for Business, Innovation and Employment, New Zealand, for funding Experiments 5 and 6 through AgResearch core funding. Experiments 2, 3 and 4 were funded under Agriculture & Agri-Food Canada A-base research.

Keywords: Mycoherbicide, Canada thistle, Biological weed control

Arthropod – fungal interaction in biocontrol of *Eichhornia crassipes* (76)

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There are reports on individual impact of arthropods and phytopathogenic fungi on biocontrol of the aquatic macrophyte, waterhyacinth, *Eichhornia crassipes*. But due to their overlapping niches, interspecific interactions among these biocontrol agents is high and there is a paucity of information on possible positive or negative impact they may have on each other, hence affecting the biocontrol. Three fungi, *Fusarium oxysporum* (FO), *F. roseum* (FR), *Paradendryphiella salina* (PS), and two arthropods, *Orthogalumna terebrantis* (OT) and *Neochetina bruchi* (NB). were applied to waterhycinth plants singly and in various combinations (OT, NB, FO, FO+OT, FO+NB, FR, FR+OT, FR+NB, PS, PS+OT, PS+NB). Observations were made on percentage damage to the waterhyacinth. Initial necrotic spots (12% damage) appeared on waterhyacinth treated with FO within first 24 hours and 76% damage was observed by 120 hours. Although delayed disease initiation (3.8% necrosis) was observed in FO+OT treated plants while FO+NB had a comparatively high necrosis (15.6%) after 24 hours, FO+NB and FO+OT treated plants showed enhanced damage percentage (90%) after 120 hours. The disease initiation in PS and FR treated plants were delayed by 72 hours with both chlorotic (23%) and necrotic (12%) marks, respectively. PS had a repulsive effect with weevils causing 59% damage after 120 hours, eventually causing the weevils' death and also delayed disease initiation was observed. The combined effect of PS+OT was 22%, lower than individual effect of PS (23%), and the PS+NB interaction resulted in even lower damage (11.2%) after 72 hours. Damage percentage was higher for FR+OT treatment (95.2%) as compared to FR alone (71%), and for FR+NB the effect was just the opposite (31.2%) after 120 hours. These diverse results indicate that studies on the interaction between *E. crassipes* biocontrol agents should be done prior to their release. The research grant received from SERB, India, is duly acknowledged.

Keywords: Enhancing biocontrol, fungi, insect, interspecific interaction, waterhyacinth

Biological control of parasitic weeds by using strigolactone-degrading fungi (579)

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Root parasitic weeds (i.e. *Phelipanche* and *Orobanche* spp.) are a group of unwanted and highly damaging plants with a unique mechanism of action. They are completely dependent on attaching themselves to the host's roots to consume photosynthates, nutrients and water. Seed germination is a key phase of their life cycle which is stimulated by secondary metabolites, mainly strigolactones (SLs), secreted by the host's roots. Interventions here would be particularly suitable for management of these parasitic weeds because germinated seeds of the parasite can only persist if attached to the host's root. Biological control of parasitic weeds could be approached differently than in the past by using microorganisms, not necessarily phytopathogenic ones, capable of detecting and degrading SLs, thereby preventing seed germination in the weed. These microorganisms could be used as biocontrol agents, as a „physiological" barrier against parasitic plants. To support this hypothesis, four fungi with different ecological functions were considered for their possible ability to metabolize SLs *in vitro*, namely: two strains of *Fusarium* (*F. oxysporum* and *F. solani*), previously reported as biocontrol agents of *Phelipanche ramosa*; one strain of *Trichoderma harzianum*, a potential biopesticide for controlling soil pathogens; and one of *Botrytis cinerea*, a phytopathogenic fungus attaching mainly aerial plant tissues. Experiments were carried out by adding four different SLs (i.e. the natural strigol, 5-deoxystrigol and 4-deoxyorobanchol, and the synthetic GR24) to fungal cultures and culture filtrates, followed by chemical extraction and determination of the SL content by liquid chromatography-tandem mass spectrometry. The strains of *T. harzianum* and *F. oxysporum* were the best in reducing SL content. Considering the whole set of fungi used, 5-deoxystrigol and 4-deoxyorobanchol proved to be the most metabolized SLs (around 73 and 69 %, respectively).

Keywords: Parasitic weeds, strigolactones, weed biocontrol, *Fusarium*, *Trichoderma*

Biological activity of extracts from different pathogens of common ragweed (703)

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Common ragweed (*Ambrosia artemisiifolia*) is a serious invasive weed in Eurasia. Negatively affecting crop yields, this weed also causes human health problems due to allergenic properties of its pollen. The weed shows cross-resistance to some common herbicides and infests both non-arable and arable land. As a result, chemical control, especially in non-crop areas, is problematic and biorational herbicides (mycoherbicides or natural products) could be useful alternatives. In our study 11 strains of fungi isolated from leaves of common ragweed were cultured on both liquid (DMG and Czapek-Dox) and solid media (rice). Metabolites were extracted from the culture filtrate and mycelium of these fungi with ethyl acetate and acetone, respectively. The extracts were tested for phytotoxic activity on leaf segments of common ragweed, perennial sowthistle and couch-grass at the concentration of 5 mg/mL. Antimicrobial activity of the extracts was determined on *Bacillus subtilis* at the concentration of 100–500 µg/disc, and their zootoxic activity was tested on the infusoria, *Paramecium caudatum* at the concentration of 10 and 100 µg/mL. Considerable phytotoxic activity was found in the extracts. Among them, extracts from culture filtrates of *Alternaria tenuissima* 1.75, *Fusarium oxysporum* 4.35, *Acremonium* sp. 16.7, *Pestalotiopsis stevensonii* 59.4 demonstrated the highest activity. All phytotoxic extracts were toxic to the infusorium; *P. caudatum* was extremely sensitive to extracts from *Alternaria tenuissima*, while metabolites of *Phoma* sp. 32.78, and *Fusarium oxysporum* 4.35 had low toxicity. Considerable antibacterial activity demonstrated exo-metabolites of *Colletotrichum gloeosporioides* 13.14, *Phoma* sp. 32.78, *Phoma* sp. 32.149, *Fusarium semitectum* 14.31, *Alternaria tenuissima* 1.74, and *A. tenuissima* 1.75. Generally, endometabolites extracted from mycelium obtained from both liquid and solid cultures were less phytotoxic than the exometabolites of the fungi. Therefore, metabolite complexes produced by fungi isolated from common ragweed possess a wide spectrum biological activity which may have potential as mycoherbicides.

Keywords: Common ragweed, biocontrol, biorational herbicides, extracts

Bioactive substances from *Marsilea crenata* as allelopathic studies (588)

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Plant allelopathy provides sustainable options to manage weeds and considering as a replacement of herbicidal control in present agriculture. *Marsilea crenata*, a fern of Marsileaceae family, was investigated in current research to find out its allelopathic properties and allelopathic active substances. Aqueous methanol extracts of dried *M. crenata* (leaves and shoots) were applied at different concentrations on crops [cress (*Lepidum sativum* L.), lettuce (*Lactuca sativa* L.), alfalfa (*Medicago sativa* L.), rapeseed (*Brassica napus* L.)], and weeds [Italian ryegrass (*Lolium multiflorum* Lam.), barnyard grass (*Echinochloa crus-galli* L.), timothy (*Phleum pratense* L.), sand fescue (*Festuca megalura* Nutt.)] test species. A significant inhibition was observed on the seedling growth of all test species. Inhibitions were increased with increasing extracts concentrations and root growth was more sensitive than shoot growth. The results imply, *M. crenata* may have allelopathic properties and may possess allelopathic substances. The extract was then neutralized at pH 7.0 with 1M phosphate buffer and partitioned against an equal volume of ethyl acetate. The ethyl acetate fraction was subsequently purified by a column of silica gel, Sephadex LH-20, C_{18} cartridge and HPLC with measuring bioactivity in each step. One substance was isolated from *M. crenata* and its structure was identified by spectroscopic analysis as loliolide. Loliolide inhibited shoot and root growth of cress and barnyard grass at concentrations greater than 3 and 30 µM respectively. The concentrations required for 50% inhibition of shoots and roots of cress were 21.3 and 45.9 µM, respectively, and for barnyard grass 176.2 and 55.7 µM, respectively. The result suggests, inhibitory activities of *M. crenata* on test species may be caused by the phytotoxicity of loliolide. Therefore, *Marsilea crenata* could be a representative to develop biological weed control method as well as may contribute to know the crop-weed interactions in allelopathic arena.

Keywords: *Marsilea crenata*, Allelopathy, Loliolide, Weed Management

Plant-associated bacteria as biocontrol agents against weeds (569)

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Resistance to all major modes of herbicide action is increasing in weeds and threatening the efficacy of weed management in agriculture. There is an urgent need to develop novel types of herbicides.The vast majority of microbes in the environment are unknown and represent a major reservoir of new bioactivity including herbicidal activity. The use of microbes with herbicidal activity is a novel approach, which likely involves novel modes of action that do not cause environmental contamination. By definition, biological control methods rely on microbes or natural compounds to reduce population density of another organism. Three different major types are classified: The conservation of natural enemies, the classical biocontrol and the augmentation or inundative approach. The latter method refers to all forms of biological control in which natural enemies are applied periodically at the time when weeds cause the problems analogous to the use of herbicides. The control is usually transient and re-applications are required in the contrast to the classical biocontrol. The success of a biocontrol agent depends on its suitability for mass production and its efficacy in the field. Millions of microbes inhabit the rhizosphere, the phyllosphere and the plant interior, where they form complex microbial communities. The interaction between microorganisms and plant can be mutualistic, neutral or deleterious. Microorganisms may show dose-dependent effects such as some weed-associated microorganisms, which may exert pathogenic effects on their host when present in high cell numbers. Along these lines we isolated plant-associated bacteria from two different weeds (*Ambrosia artemisiifolia* L. and *Lepidium draba* L.) and tested their effects on their hosts. We identified several strains, which reduced germination and growth in weeds. Further experiments on their effects on non-target plants and the mechanisms involved are on-going and will be discussed.

Keywords: Ambrosia, bioherbicide, endophytes

The infection process of *Alternaria sonchi* on *Sonchus arvensis* (383)

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Alternaria sonchi is a fungal pathogen of sowthistle (*Sonchus arvensis*). It causes foliar necrosis and has been evaluated as a candidate biological control agent for this weed. Our research focused on the characterization of the infection process. Leaf discs of *S. arvensis* were inoculated with conidial suspensions of the fungus. Inoculated discs were incubated at 6, 24 and 33°C under high relative humidity (>95%) and different light regimes (continuous dark, dark / light, continuous light). Leaf discs of non-host plants (*Cirsium arvense*, *Arabidopsis thaliana*, and *Elytrigia repens*) were also inoculated. The infection process was investigated by light microscopy from 4 to 48 h after inoculation. The conidia germinated at temperatures of 12–33°C. Under optimal conditions (24°C, continuous dark), the germ tubes had penetrated the leaves of sowthistle 4–8 h after inoculation. Penetration was via the cuticle at the conjunction of epidermal cells. Continuous light exposure and suboptimal temperatures reduced penetration. The conidia also germinated well on leaves of non-host plants; however they did not cause infection. Conidiation on sowthistle leaf discs was observed 48 h after inoculation. Fast death of the host-plant epidermal cells at the penetration sites was the result of phytotoxic compounds produced by the fungus. We showed that the fungus produced a number of phytotoxic compounds in solid substrate culture. In further work we plan to assess phytotoxin production by conidia during germination to clarify the role of phytotoxins in the infection process of *A. sonchi* on sowthistle.

Keywords: *Alternaria sonchi*, *Sonchus arvensis*, biological control of weeds

Striga biocontrol: A readily deployable and inexpensive method for smallholder farmers (839)

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Striga hermonthica (witchweed) is a parasitic weed that attacks and significantly reduces the yields of maize, sorghum, millet and sugarcane throughout sub-Saharan Africa. Low cost management methods such as hand weeding, short crop rotations, trap cropping, or conventional biocontrol have not been effective. Likewise, striga-tolerant or herbicide-resistant maize varieties are higher yielding, but are often beyond the economic means of sustenance farmers. The fungal pathogen *Fusarium oxysporum* f.sp. *strigae* has been the object of numerous studies to develop striga biocontrol. Under experimental conditions this pathogen can reduce the incidence of striga infestation but field use is not extensive, perhaps because it has not been sufficiently effective in restoring crop yield and reducing the soil striga seed bank. Kenyan and US crop scientists with smallholder farmers developed and validated an effective biocontrol strategy for management of striga on smallholder farms. Key components of this research project were: 1. Development of a two-step method of fungal delivery, including laboratory production of primary inoculum on toothpicks, followed by on-farm production of secondary field inoculum in boiled rice enabling delivery of vigorous, fresh inoculum directly to the seedbed; 2. Training of smallholder farmers (85% women, expanding from 30 smallholder famers to a two-season, year-long, 500-farmer paired plot trial) to produce and incorporate the biocontrol agent into their maize plantings in striga-infested soils, including paired control plots and collection of agronomic data; 3. Concerted selection of variants of the pathogen that specifically enhanced virulence to striga via excretion of certain amino acids without harming the crop. This strategy resulted in an average maize yield increase of 56.5% in the long rains season and 42% in the short rains season. The efficacy of the biocontrol agents can be enhanced by selection of amino acid excretion traits.

Keywords: *Striga*, *Fusarium oxysporum*, Biocontrol, Virulence enhancement, Amino acid excretion

Macalpinomyces neglectus and *Ustilago trichophora* as potential agents for *Setaria pumila* and *Echinochloa crus-galli* biocontrol (347)

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Echinochloa crus-galli and *Setaria pumila* are the two most important panicoid grass weeds on arable land in the Czech Republic. During the past 5 years, infestation of the smuts *Ustilago trichophora* on *E. crus-galli* (2011-2013) and *Macalpinomyces neglectus* on *S. pumila* (2014-2015) were observed in selected areas. The frequency of parasitized plants in the population and the effect of mycoparasites on the host plants were recorded. Four locations were found where *U. trichophora* occurred and across these locations the frequency of infested *E. crus-galli* plants was 0.49 %. Usually only the stem of one tiller per plant was infected and the infection did not visually affect the plants' growth or reproduction. In the case of *M. neglectus* occurrence on *S. pumila*, there was a higher frequency of infected plants in 2014 compared to 2015 across the 5 locations where the fungus was observed. While the growth of host plants was not affected, seed production of infected plants dropped to zero as a result of systemic infection of inflorescences. The frequency of infected *S. pumila* plants was 40 – 55 %, but plants of *S. pumila* in neighbouring fields were showing no infection at all. The effect of *U. trichophora* on *E. crus-galli* was relatively low as a result of the low frequency of parasite occurrence and the low effect on the growth and reproduction of the host. Similarly, *M. neglectus* does not affect the growth of its host, *S. pumila*, but in contrast, it did significantly reduce reproduction in this weed. As a potential biocontrol agent, while it would not decrease the competitive ability of *S. pumila*, it would decrease the numbers of this weed's seeds in the field and this could result in fewer seedlings in subsequent years.

Keywords: Biological weed control, weed pathogen, smut, panicoid grass

The potential of the heterothallic leaf-spot, *Mycospharella polygoni-cuspidati*, for control of Japanese knotweed (329)

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Japanese knotweed (*Fallopia japonica*) is a serious invasive weed in North America and across Europe. In the UK, where the costs of control and impacts are considerable, research into a biological management strategy has been underway. The psyllid, *Aphalara itadori*, was approved for release against Japanese knotweed in the UK in 2010, and the fungus *Mycosphaerella polygoni-cuspidati* was also prioritised as a potential second biological control agent for the weed, based on field observations of impact and subsequent specificity screening in quarantine. Ascospores produced in pseudothecia constitute the primary infection pathway of the pathogen and are readily observed on leaf-spotted knotweed leaves in the field in Japan. However, pseudothecial development on artificial media or inoculated plants has not been achieved in the lab so far. In order to elucidate the life cycle of the pathogen, the mating-type genes were investigated in this study. The cloning and sequencing of mating-type genes of the pathogen revealed that each isolate contained either a *MAT1-1-1* or *MAT1-2-1* gene which encoded an α-box or a HMG-box domain, respectively, which suggests that *M. polygoni-cuspidati* is heterothallic. In addition, a multiplex PCR assay using *MAT*-specific PCR primers designed in the present study was established for rapid mating-type determination. Both mating types were naturally distributed, approximately at a ratio of 1:1, in the same population of infected Japanese knotweed. These results will provide valuable information to further pursue the induction of pseudothecia and ascospore production *in vitro* and on inoculated plants. In addition to ascospores as infective propagules, mycelial fragments of *M. polygoni-cuspidati* mass produced in artificial medium have been shown to be infective to Japanese knotweed causing comparable symptoms of disease. Based on these traits of the *Mycosphaerella* leaf-spot, this paper will discuss options for the use of this pathogen as a control agent for Japanese knotweed.

Keywords: *Fallopia japonica*, biological control, plant pathogen, mating type, mycoherbicide

Session 22
HERBICIDE RESISTANCE: Genomics and Cytogenetics

Keynote: Physical mapping of *EPSPS* copies on chromosomes of glyphosate-resistant *Amaranthus* species (726)

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Amplification of 5-enolpyruvylshikimate-3-phosphate synthase (*EPSPS*) gene has been confirmed in several glyphosate-resistant (GR) Amaranthaceae members (e.g. Palmer amaranth and common waterhemp) populations across the US. Furthermore, previous studies reported distribution of amplified *EPSPS* copies throughout the genome of Palmer amaranth, possibly via transposable elements. In this study, we determined the number and configuration of *EPSPS* copies on metaphase and pachytene chromosomes of glyphosate-susceptible (GS) and GR Palmer amaranth and common waterhemp populations from Kansas. Genomic DNA was extracted from young leaves of several plants from these populations. Using SYBR green-based quantitative real-time PCR (qRT PCR) assay, the *EPSPS* copy number was measured by ΔΔCt method with CPS or β-tubulin gene as an endogenous control. Fluorescent in situ hybridization (FISH) was used to determine the chromosomal location and distribution of *EPSPS* copies. The analyses of qRT PCR showed differences in the *EPSPS* gene copy number among the samples; the GS plants of both the species had 1 copy, whereas, the GR population possessed ~4 up to > 100 *EPSPS* copies, depending on the species. FISH analysis performed on prophase and metaphase chromosomes of GS, GR populations exhibited differences in distribution of amplified copies. A faint hybridization site was displayed in GS plants, whereas, a brighter hybridization signal on one pair of homologous chromosomes likely near the centromeric region was found in GR plants of both species with low (4 or 12) *EPSPS* copies. However, GR plants of Palmer amaranth with high (~70 or 90) *EPSPS* copies showed brighter hybridization signal on all the chromosomes throughout the genome. These results suggest that alterations in the *EPSPS* gene copy number in somatic cells of these species initially may occur via unequal recombination (plants with low *EPSPS* copies) and subsequently, possibly via transposon mediated amplification as in Palmer amaranth plants with high *EPSPS* copies.

Keywords: Gene amplification, Glyphosate resistance, FISH analysis, Pachytene, Metaphase

Using multiple sequencing platforms to assemble the genome of *Kochia scoparia* (717)

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Weed biology sits at the crossroads of many lines of research including agronomy, chemistry, biochemistry, ecology, and more recently molecular biology, in part due to the evolution of herbicide resistance. Molecular biology itself is being revolutionized by next-generation and third generation sequencing techniques, allowing us to quickly generate nucleotide databases. To better integrate weed biology in future agriculture challenges, genetic tools including the transcriptomes and the genomes of model weedy organisms need to be developed and made available to the research community. Current "model" plant species do not have the same traits or complexity as many weedy species making them less effective models. Our research team has begun the ambitious effort of sequencing the genome of *Kochia scoparia*, an important weed in the western USA that has evolved multiple herbicide resistance mechanisms. *K. scoparia* is a member of the family Chenopodiaceae, a sister taxon to Amaranthaceae family. *K. scoparia's* relatedness to many other important weedy species (including *Amaranthus* spp.) as well as important crop species (sugar beet and spinach, both in Chenopodiaceae) makes it a good candidate for developing molecular biology research tools. The large, complex, and malleable genome of *K. scoparia* makes sequencing and genome assembly an interesting challenge. It appears that the large genome (haploid size of 1.0-1.3 Gb) is due to a recent polyploidy event in the Chenopodiaceae lineage, resulting in large highly repetitive regions that are difficult to resolve without more advanced approaches to sequencing. We have utilized both Illumina and PacBio sequencing technologies to conduct a hybrid-platform draft assembly of the *K. scoparia* genome. Our initial findings demonstrate the challenges in assembling complex weedy species genome and potential for using cutting-edge molecular tools to improve our understanding of weed biology and weedy traits.

Keywords: *Kochia scoparia*, Genomics, Herbicide resistance, Weed biology, Bioinformatics

Population genomics of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) using genotyping-by-sequencing (GBS) (552)

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Throughout the southeastern and southwestern United States, populations of Palmer amaranth (*Amaranthus palmeri*) have been identified with evolved resistance to the herbicide glyphosate. This project aims to determine the degree of genetic relatedness among a set of glyphosate-resistant and –susceptible lines by analyzing patterns of phylogeography and diversity on an intraspecific level. Seven different lines of Palmer amaranth from different geographic regions were tested against a glyphosate-resistant line from an Arizona locality for glyphosate resistance. The goal is to ascertain whether resistance evolved independently in the Arizona locality, or whether resistance spread from outside to the location. For example, the transportation of resistant seeds in harvesting equipment could be a source of gene flow via seed migration. The accumulation of shikimic acid via the shikimate assay and EPSPS copy number and were tested to confirm resistance. The susceptible lines showed an average of 41 mg/ml shikimic acid while the resistant lines showed an average of 0.1 mg/ml shikimic acid accumulation after exposure to a 500µm solution of glyphosate. Individuals from the Arizona glyphosate-resistant locality had increased copies of EPSPS in the range of 20 – 290-fold. This is the same mechanism previously identified in the Palmer amaranth lines from the southeastern US, therefore it is possible that resistance was introduced from elsewhere. DNA samples were collected for genotyping by sequencing (GBS) to perform single nucleotide polymorphism (SNP) calling, which will be used to determine the genetic structure of the different lines. Currently, neighbor joining trees and principle component analysis are being performed. This information about the evolution and migration of glyphosate resistance will be useful to design better strategies for herbicide resistance management.

Keywords: Palmer amaranth, Herbicide resistance, Glyphosate resistance, Genotyping by sequencing, Genetic relatedness

Functional epigenetic regulation is required for herbicide resistance in *Arabidopsis thaliana* (415)

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Recent studies have shown involvement of epigenetic regulation in resistance to biotic and abiotic stresses. Continuous herbicide use could trigger epigenetic regulation and result in variation of the herbicide effect. The aims of this study are to analyze herbicide effects on epigenetically regulated transcription and sensitivity of *Arabidopsis thaliana* mutants in different epigenetic regulators. The herbicides used were imazethapyr, glyphosate and 2,4-D at sublethal doses of 11, 72 and 81 g L^{-1}, respectively. The first experiment was performed with *A. thaliana* line L5 and heat stress was used as positive control. The second experiment used 15 different mutants associated with specific pathways of epigenetic modifications and the wild type Col-0. The experiments were repeated twice. The herbicide treatments did not lead to global alterations of DNA methylation. However, several mutants affected in DNA and specific histone methylation modifications presented change in herbicide susceptibility. The herbicide effect was increased for the mutants *ros1* and *ibm1*. The *ros1* presented 23%, 27% and 28% ($P < 0.01$) increase in susceptibility to herbicides imazethapyr, glyphosate and 2,4-D, respectively, compared to WT. For *ibm1* the increase in susceptibility ranged between 15-20% ($P < 0.01$). The ROS1 (REPRESSOR OF SILENCING 1) is a 5-methylcytosine glycosylase, a repressor of transcriptional gene silencing. The protein IBM1 (increase in BONSAI methylation 1) prevents the CHG methylation in genes. These results indicate that the evaluated herbicides cannot lead to intense epigenetic alterations, such as heat stress, but can change specific epigenetic pathways, indicating epigenetic control over specific genes involved in herbicide resistance. These results are promising to contribute to understanding mechanisms of herbicide resistance development as well as the regulation of current processes of resistance still not completely understood.

Keywords: Epigenetics, herbicide susceptibility, imazethapyr, glyphosate, 2,4-D

Session 23
HERBICIDE RESISTANCE: Evolution and Climate Change

Keynote: Climate changes increase the risk for herbicide resistance evolution (111)

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Climate changes challenge crop production for the ever-increasing world population. Effect of rising temperatures on crop-plants has been widely studied, but only little is known on the effect it might have on herbicide resistance evolution. In recent years, inconclusive cases of ACCase-resistant grass weeds were reported both from field and greenhouse studies. We tested sensitive populations of *Setaria viridis, Lolium rigidum, Avena sterilis* and *Alopecurus myosuroides*, in response to diclofop-methyl under different temperature regimes [10/16°C and 28/34°C (night/day)]. Interestingly, we noted that temperature elevation increases plant tolerance to the herbicide significantly. Hence, we hypothesize that this temperature-dependent response is due to non-target site (NTS) mechanisms, such as enhanced activity of detoxifying enzymes (e.g., GST and CYT P450). We used the model weed *Brachypodium hybridum* to further examine this hypothesis. NTS ACCase-resistant (BrI-782) and sensitive (BrI-638) accessions were treated with pinoxaden and grown under different temperature regimes (as described above). Regarding the level of resistance, both accessions showed the same trend, as higher temperature elevated herbicide tolerance. Under low temperature (10/16°C) plants from both accessions didn't survive even 1/2X. Whereas, under high temperatures (28/34°C), the sensitive accession survived 1/2X, and the resistant one survived up to 4X of pinoxaden. Expression levels of several candidate genes were examined using RT-PCR. Significantly high levels of two genes, glycosyltransferase and CYT-P450, were found only under the treatment combining high temperature and pinoxaden application. These data indicate that variation between farmers' reports and lab experiments may be due to different environmental conditions. This study points out the increasing risk for the development of weeds with enhanced metabolic herbicide resistance due to the projected global warming. Using the autogamous *B. hybridum* as a model weed may shed light on the NTS mechanisms endowing herbicide resistance and can facilitate the attempts to prevent its expansion.

Keywords: *Brachypodium Hybridum*, *Lolium* spp., ACCase inhibitors, Global warming, Non-target site resistance

Evolution of herbicide resistance in *Apera spica-venti* as a consequence of repeated herbicide applications (163)

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Recent publications have indicated that low dose herbicide usage can rapidly lead to herbicide resistance evolution. Our objective was to test whether repeated application of ALS inhibitors may select for ALS resistance in *Apera spica-venti,* a cross pollinated genetically diverse species. A susceptible biotype (A77) from an organic field with no herbicide application within the last twenty years was treated with 5g of iodosulfuron (0.5x the recommended field rate). Thirty-five percent of individual plants survived the application rate of 5g iodosulfuron. Thirty of these surviving plants were transplanted, grown to maturity and bulk-crossed to produce the A77 iodosulfuron-selected progeny A77-1. In a subsequent dose-response experiment the selected A77-F1 exhibited a decreased sensitivity to iodosulfuron compared to the original A77 population. A second selection cycle using the A77-F1 progeny with 10g iodosulfuron (1x the recommended field rate) resulted in 51% of surviving individuals. Thirty surviving plants were again used to produce the A77-2 progeny and this population was again selected with 10g iodosulfuron in a third selection cycle resulting in the A77-3 progeny. Dose repose experiments using the A77, A77-F1, A77-F2 and A77-3 populations show that the ED_{50} was significantly higher in the two- and three-time iodosulfuron-selected populations than in the unselected susceptible population A77. First molecular analysis of potential target site resistance (TSR) mechanisms show that plants heterozygous for Pro197Asn substitutions were present in the A77-F1 progeny but not in the A77 population. Further analysis will focus on TSR in the subsequent progeny populations. In addition, the A77-3 is currently tested for potential cross-resistance to other ALS chemical groups. First experiments to elucidate the mechanisms underlying resistance using the insecticide malathione as a cytochrome P450 inhibitor indicate that non-target-site mechanisms may be also involved.

Keywords: ALS, Apera spica-venti, selection, herbicide resistance

Effect of crop management on the evolution of herbicide resistance weed populations in field crops (218)

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In semi-arid areas, such as the Israeli Negev, low precipitation limits the farmer's crops and herbicide rotation possibilities. Consequently, rapid evolution of herbicide-resistant weed populations occurs, resulting in significant yield losses. The overall aim of the current study was to examine the effect of different crop management practices (*e.g.*, crop rotation, irrigation regime, tillage, and herbicide application) on evolution of herbicide resistant weeds. A comprehensive weed survey and digital mapping was carried out in the southern part of Israel focusing on several common weeds (*Lolium rigidum, Phalaris* spp., *Aegilops* spp., *Erucaria hispanica* and *Diplotaxis erucoides*). Samples were collected from randomly selected plots (10×10 km^2 grid), as well as from fields suspected to be infested with herbicide resistant populations. For each plot, we collected historical data on the crop management up to ten years. Plant samples were tested for their response to different modes of action herbicides. Out of the 20 populations tested so far, 7 showed resistance to Acetyl-CoA Carboxylase (ACCase) inhibitors, three were resistant to Acetolactate synthase (ALS) inhibitors, and two *L. rigidum* population demonstrated resistance to 5-Enolypyruvyl-Shikimate-3-Phosphate Synthase (EPSPS) inhibitors. Moreover, we identified two *L. rigidum* populations with multiple resistance to ACCase and ALS, and to EPSPS and PPO inhibitors. Interestingly, 30% of the randomly selected plots (3/9) showed resistance to ACCase inhibitors. Meta-analysis of the resistant population dynamics, show that higher proportion of resistant populations was noted in dryland plots as compared with irrigated plots, possibly due to the lack of crop and herbicide rotation in dryland plots. Our results demonstrate the importance of combining different weed management practices to preserve sustainable agriculture systems.

Keywords: Herbicide resistance, integrated weed management, survey, semi-arid

Spatial gradient and fitness cost of enhanced metabolism in ALS inhibitor herbicide resistant *Apera spica-venti* populations in Denmark (49)

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Apera spica-venti (L.) Beauv. is the most important grass weed in Eastern and Central Europe. In Denmark, the first case of ALS inhibitor herbicide resistance for this species was reported in 2011, however the resistance mechanisms, the resistance phenotype of neighboring populations and the fitness has not been assessed. The objectives were to 1) assess the level of ALS and ACCase resistance in populations collected in fields surrounding a known resistant population, 2) analyze these populations for target site mutations in ALS and ACCase gene as well as CytP450 metabolism activity and, 3) estimate the fitness of resistant individuals showing non target site resistance (NTSR). We collected populations in concentric circles surrounding the known resistant population at three locations to determine spatial resistance gradient. Dose response assays were conducted with iodosulfuron, fenoxaprop-P-ethyl and prosulfocarb. Surviving individuals were screened for target site mutations at eight positions in ALS and five in ACCase. Eight populations were subjected to herbicides in mixture with the CytP450 inhibitor malathione to assess NTSR activity. Then, we randomized the genetic background of three ALS NTSR populations over two generations. These F2 were screened for resistance phenotype to ALS. To estimate fitness, a target neighborhood experiment was performed in competitive and non-competitive conditions where vegetative growth, seed production, and pollen viability was assessed. Susceptible and resistant seeds were also germinated at three temperatures. Our results revealed the occurrence of multiple resistant phenotypes with resistance to both ALS and ACCase inhibitors. We observe a resistance spatial gradient at the three locations. Resistance to ALS was due to enhanced activity of the CytP450 family while resistance to ACCase is due to varying frequencies of both NTSR and one mutation in the target gene. Our results showed the absence of a fitness difference between non-target site resistant and susceptible *Apera* populations.

Keywords: ALS inhibitors, Apera spica-venti, metabolic resistance, fitness cost

Session 24
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Weed Control in Plantation Crops

Keynote: Effect of autumn simazine with late-dormancy herbicide applications in matted-row strawberry (29)

Timothy W Miller *(Washington State University, Mount Vernon, United States),* ***Carl R Libbey*** *(Washington State University, Mount Vernon, United States)*

One of the major weeds of perennial, matted-row strawberry (*Fragaria* x *ananassa* Duch.) is common chickweed (*Stellaria media* L.) which, along with other winter annual weed species, thrives during the mild winters of western Washington and adjacent Oregon, USA and British Columbia, Canada. Autumn-applied simazine can provide excellent control of common chickweed, but substantial regional winter rainfall generally contributes to poor weed control during berry harvest if herbicides are not sequentially applied to strawberry in late dormancy. Therefore, trials were conducted at Washington State University Northwestern Washington Research and Extension Center near Mount Vernon, Washington to determine the effectiveness of simazine applied to established ‚Totem' strawberry in November followed by several herbicides applied in February or March of the subsequent year. Visual injury to strawberry foliage from herbicide applications was low both years, averaging 1% or less in mid-April, 2012 and 10% or less in early-May, 2013; foliar injury was no longer apparent at the onset of harvest in June of both years. In 2012, weed control in April was greater than 80% for combinations with isoxaben, indaziflam, and pre-packaged flumioxazin + pyroxasulfone. By June, weed control had declined to less than 80% for all treatments except indaziflam at 146 g ha^{-1} (87%). In 2013, weed control in May was uniformly excellent, and most treatments still exceeded 80% control by June. When averaged across all late-dormancy treatments, simazine increased early season weed control by 6 percentage points in both years, and increased June weed control from 76% to 91% in 2013. Neither total berry yield nor average berry weight was significantly affected by late-dormancy herbicide treatments either year, although application of simazine significantly increased yield in 2012 and berry weight both years.

Keywords: Strawberry, common chickweed, dormant-season herbicides

Can we apply an Integrated Weed Management (IWM) in oregano crop without effect on its quantitative and qualitative characteristics? (393)

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Weeds constitute the greatest obstacle of yield loss in oregano (*Origanum vulgare* spp. *hirtum* L.). Therefore, the aims of this study were: a) to evaluate the efficacy and selectivity of mechanical, chemical and physical means against weeds, b) to investigate their impact on oregano yield and essential oil quality, c) to evaluate their possible use in an IWM program. Field experiments were conducted during 2014 and 2015 in Agrinio (Western Greece) and in A.U.A. The dominant weeds in Agrinio were *Cyperus rotundus* L. and *Sorghum halepense* Pers. whereas in A.U.A. were *Amaranthus retroflexus* L., *Tribulus terrestris* L., *C. rotundus* L. and *Malva sylvestris* L. A randomized complete block design was used in all experiments. In 2014, two pre-emergence herbicide applications, one post-emergence, two glyphosate rates, three flaming propane doses, weedy control and weed-free control (mechanical method) were evaluated. However, in 2015 the examined treatments were the pre-emergence application of metribuzin+pendimethalin at 0.14+1.365 kg a.i. ha^{-1}, the post-emergence application of cycloxydim+metribuzin at 0.3+0.175 kg a.i. ha^{-1}, the post-emergence application of glyphosate at 0.54 kg a.i.ha^{-1} and the propane flaming at the rate of 119 kg ha^{-1}. The treatments were evaluated by determining weed density and their dry matters, oregano herbage and essential oil yields. The results indicated that post-emergence application of herbicide mixture or mechanical means in combination with glyphosate gave similar weed control. In addition, these treatments increased oregano herbage and essential oil yields without any effect on the chemical profile of essential oils. Herbicide residues were not detected in any of the examined samples. In conclusion, the mechanical means combined with a post-emergence application of glyphosate reduced rate is qualified to be used in an IWM program for oregano as it controls annual and perennial weeds, reduces cost of weed control and has less herbicide impact on the environment.

Keywords: Oregano, Integrated Weed Management, Herbicide residues, Essential oil yield

New alternatives for weed management on avocado (*Persea americana* cv. Hass) trees cultivated on slope conditions in Chilean central valley (458)

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Avocado (Persea americana) is a well-consumed fruit nowadays. The last 10 years its consumption and planting area has grown substantially. Due to its increasing profitability and climate conditions requirements, growers prefer planting on slope conditions, which are low cost and frost-free areas. Weed management on these conditions is an important issue mainly for water and nutrients uptake. On this study, several soil residual herbicides were applied, assessing weed control, species spectrum, fruit yield and shoot growth response. Seven herbicides were evaluated; five commonly used by Chilean avocado growers (simazine, terbutilazine, oxyfluorfen, pendimethalin and flumioxazin) and one (indaziflam) not yet register to use on avocado trees. Growth measurements (shoot diameter and shoot longitude) were recorded from 3 to 8 months after treatments (MAT) during two consecutive years (2013-14 and 2014-2015). Results from both growing seasons, showed that indaziflam has a high selectivity to avocado trees. There were not any visible or consistently quantitative damage on leaves, shoots diameter/length or fruit yield. Furthermore, indaziflam reduce significantly the percentage of soil cover with weeds on both seasons, with a 50 (2013) and 80% (2014) less weed presence between 3 and 5 MAT, respect to an untreated control. Adding the broader spectrum of species controlled among all treatments. Such characteristics, convert this herbicide in a good option to solve the scarce labor force issue related to slope conditions.

Keywords: Soil residual herbicide, weed control, shoot growth, selectivity

Weed management in poplar-turmeric based agroforestry systems in Northern India (797)

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Poplar (*Populus deltoides*) is the main agroforestry tree species extensively experimented with seasonal crops in northern India. It is a winter deciduous tree, so during this period of poplar dormancy various winter crops could be intercropped successfully as the trees offer less competition. Poplar-turmeric based agro forestry systems are popular among farmers in this region. However, weeds have become a major production constraint in this agro-forestry system. A field study was conducted to find out the effective and economical approach for control of weeds in turmeric based poplar plantation system. Poplar plants were established in blocks at 5 m x 3 m spacing in Feb during 2013-14 and 2014-15, and turmeric was planted in between the poplar rows in end April. Eight weed control treatments viz. pendimethalin 0.75 & 1.0 kg/ha as pre-emergence (PRE), oxyfluorfen 0.176 and 0.235 kg/ha PRE, atrazine 0.563 and 0.75 kg/ha PRE all integrated with paddy straw mulch 9 t/ha, hand weeding (30, 60 and 90 days after sowing) and weedy check were kept for comparison. Atrazine at both doses caused the mortality of poplar trees and atrazine treatments were not evaluated in 2014-15. Whereas pendimethalin and oxyfluorfen were found to be safe to use in poplar-turmeric based agroforestry system. xyfluorfen 0.235 kg and pendimethalin 1.0 kg ha^{-1} integrated with paddy straw mulch provided similar level of weed control (>63%) to hand-weeding, and increased the yield of turmeric by 32-46%. Integrated use of paddy straw mulch with pendimethalin or oxyfluorfen provided higher level of weed control and higher productivity and profitability than use of straw mulch or herbicides alone during both the years. In addition, pendimethalin and oxyfluorfen were safe to poplar and turmeric. The study concluded that integrated use of paddy straw mulch and herbicides could be adopted for effective control of weeds in poplar-turmeric based agroforestry systems.

Keywords: Agroforestry, Herbicides, Poplar, Straw mulch, Weeds

Session 25
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Glyphosate Reality and Use in Different Crops

Keynote: Facts and myths of glyphosate (734)

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The success of the herbicide glyphosate, a crop protection product commercially used for over 40 years, has been translated into continued worldwide adoptions for weed control in very diverse situations. Glyphosate containing products can be used as foliar sprays to manage weeds in a wide range of arable crops, perennial crops, on grasslands and in gardening but also in non-crop situations including railway tracks, amenity, forestry, aquatic environments and as a tool for management of invasive weeds. The combination of over the top in crop glyphosate applications as selective herbicide with glyphosate tolerant varieties, also referred to as Roundup Ready™ cropping systems, are retained as preferred crop management system by many farmers and farming communities around the world. The same tools are challenged by others. The environmental fate, safety and benefits of glyphosate belong to the most studied topics in the agricultural history and are well understood and documented but still underestimated by many and some of these will be highlighted. Success stories often lead to justified critics but also to non justified myths. Some of these critics and myths related to glyphosate will be addressed during the talk.

Keywords: Weed management, glyphosate

Drivers for glyphosate use in German arable farming (277)

Armin Wiese *(Georg August Universität Göttingen, Goettingen, Germany),* ***Michael Schulte*** *(Georg August Universität Göttingen, Goettingen, Germany),* ***Ludwig Theuvsen*** *(Georg August Universität Göttingen, Goettingen, Germany),* ***Horst H. Steinmann*** *(Georg August Universität Göttingen, Goettingen, Germany)*

In Europe Glyphosate is used as a non-selective herbicide in non-transgenic crops. Thus, patterns of use are different from situations in other parts of the world, where genetic modified crops are grown in herbicide resistant cultivars. German farmers use Glyphosate on roughly 40 % of arable area preferentially after harvest and as pre-seeding application (Steinmann et al. 2012). A public and scientific debate emerged whether this extended use is i) agronomically necessary, ii) sustainable regarding the resistance selection pressure on weeds and iii) affecting field and landscape biodiversity. Therefore, a survey was set up to investigate into farmers glyphosate use patterns, their motivations for use and their attitudes towards glyphosate.
The survey was carried out during winter 2014/15. Online and paper-based questionnaires were sent to professional farmers. 2026 farmers responded and could be included in the analyses. Regression models and clustering was used to identify variables that could explain influence of farm type, soil cultivation regime and labor endowment on glyphosate use patterns. Furthermore, the growing of cover crops, crop rotation structure, dominating weed species and management of resistant weeds were included in the analyses.
Farmers use glyphosate in extremely diverse patterns. Asked directly, 15 % of farmers claim to be a non-user in the respective year. So, a strong proportion of farmers are able to carry out land use without glyphosate. On the other hand, some farmers use glyphosate on 100% of their arable land. Non users are typically running farms with higher share of ploughed land and spent more labor for farmwork than intensive users. Farm scale of non-users is typically below average.
The study was funded by the federal ministry of nutrition and agriculture within the innovation program.

Keywords: Soil cultivation, farm management, weed management, labor costs, weed control economics

Does a glyphosate-induced weed shift exist in northern Germany's winter wheat? (129)

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The increasingly intensive use of glyphosate-based herbicides in the last few decades has lead to measurable changes in agricultural weed communities around the world. Multiple studies conducted in countries permitting the growth of genetically-modified crops (GMCs) have proven the occurrence of weed shifts, which is a shifting of weed community composition that is often marked by the increasing dominance of a few particular species. With a reduced diversity in the weed community, the presence of less sensitive populations poses a challenge for weed management. The aim of our study in northern Germany is to assess whether a weed shift attributable to the inclusion of glyphosate-based herbicides in the weed management strategy within a non-GMC agricultural system can be demonstrated. To this end, weed monitoring is conducted in winter wheat crops in the month before harvest and in the time period between the wheat harvest and sowing of the next crop. Through comparing the weed monitoring data with the field records on herbicide application, trends in weed community composition and possible dominant species will be made for a spectrum of glyphosate product use intensities ranging from no herbicides (organic farming) and herbicide use other than glyphosate products as well as low, medium and high glyphosate product use intensities (with intensities relative to the minimum and maximum use intensities in the study's sample of fields). Results from the first two of a total of three consecutive monitoring seasons will be presented.

Keywords: Glyphosate, weed community composition, weed shift, Germany, winter wheat

Crop rotation and herbicide use evaluated together by structural equation models (391)

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Integrated weed management aims to restrict herbicide use. We used structural equation models to examine effects of crop rotation, intended herbicide intensity level and weediness on herbicide use in multi-year field trials.
Two field experiments were conducted in North-East Germany with coastal climate and sandy soil (set-up 2008) and in Central Germany with continental climate and loamy soil (set-up 2009). The experiments were implemented as two factorial field trials with crop rotation as first and intended herbicide intensity level as second factor.
Winter oilseed rape, winter wheat and maize were combined in four crop rotations with the aim to create different risks for weediness. Crop rotation was described by length, diversity indices and proportion of winter oilseed rape and maize within a rotation. Three intended herbicide intensity levels were established to represent different levels of weediness that farmers can accept: 100 %, 80 % and 60 % of preselected weeds were killed. The weediness was represented by weed density, weed cover and weed density weighted with their damage potential. The dependent variable was the resulting herbicide use measured as TFI (Treatment Frequency Index) and an index that counts for the number of active ingredients applied.
Our research answers the question to which extent crop rotation, intended herbicide intensity level and weediness contribute to the resulting herbicide use intensity and which measured variables have the highest impact.

Keywords: Structural equation models, SEM, herbicide use, herbicide intensity, crop rotation

Session 26
WEED ECOLOGY: Weed Distribution, Surveys and Mapping / Weed Community Dynamics

Keynote: The natural and human-mediated spread of an invasive plant, *Microstegium vimineum* (823)

Emily S.J. Rauschert *(Cleveland State University, Cleveland, United States),* ***David A. Mortensen*** *(The Pennsylvania State University, University Park, United States)*

It is important to understand how invasive species are spread into new areas to better target management efforts. In general, human activities are usually the primary drivers of long-distance dispersal, but the actual mechanisms of this process are often not quantified. We conducted long-distance dispersal experiments to understand the rapid spread in North America of the invasive exotic *Microstegium vimineum* (Japanese stiltgrass) at local and regional scales. Forested roads, along which *Microstegium* grows abundantly, are often unpaved and are subject to frequent maintenance activities such as road grading. We investigated road grading as a likely mechanism of spread along rural roads through a series of larger scale experiments. Small-scale experiments provided the data to model the natural, local spread of *Microstegium.* We then modeled the long-distance spread of the species through a forest landscape using a spatially explicit cellular automaton model. The model was used to examine the contribution of three modes of spread: local, road grading and occasional long-distance dispersal through vehicles. Several management techniques were examined using the model: grading shorter distances, grading less often, and managing buffer areas around ecologically sensitive areas. Not surprisingly, local spread alone was too slow to explain the large-scale invasion; including all three modes of spread most closely mimics the actual invasion of this species. It appeared that the medium-scale dispersal of road maintenance is responsible for the entire roadside being infested; simulations with only long-distance and local dispersal did not result in most of the roadside being invaded. No management strategies examined were effective at stopping or slowing the spread of this species; however, sensitive areas could be protected from invasion by managing a buffer around them or by grading roads less often. These results highlight the need to explicitly address human-mediated spread, often from multiple vectors, when managing invasive species.

Keywords: Invasive species, dispersal, spread, spread modeling

Invasive exotic plants of Carajás National Forest, Brazil (692)

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The Carajás National Forest is a protected area located in the Brazilian Amazon region in the southeast of Para state. It was created by Decree. 2,486 of February 2, 1998, in order to protect an extremely endemic environment of the Amazon ecosystems. With dimensions of 411.948 ha, occupies part of three municipalities in the state of Pará and have inside indigenous groups, mining projects and extractive populations. The creation of the Carajás National Forest had a significant ecological and social relevance in the conservation scenario forming an island of natural vegetation surrounded by disturbed areas down mainly due to the expansion of the agricultural frontier of the country. One of the loss of biodiversity concerns within the Carajás National Forest is the occurrence of invasive exotic plants from different families and genera cataloged in different forest inventories. The most aggressive species had eradication programs in operation. A survey was conducted on cataloging forest inventories carried out by different research institutes under the guidance of North ferrous management miner Vale SA. The most aggressive invasive plants belong to Poaceae family. There were identified the species: *Urochloa brizantha, U. decumbens*, *U. humidicola, U. ruziziensis*, *Melinis minutiflora* and *Panicum maximun*. Other species of importance identified were: *Bidens pilosa* and *Pityrogramma calomelanos.* It was observed a predominance of Poaceae family and based on characteristics of the exotic plants, there is potential for competition with native plants of the Carajás National Forest, causing potential damage to the local biodiversity.

Keywords: Alien plants, Protected area, Biodiversity

A comparison of structure and floristic composition of weed seedbanks within and between different forest restoration systems during three years (676)

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The aim of this study was to evaluate the structure and floristic composition of weed seedbanks within and between different forest restoration systems. This study was conducted in a forest restoration experiment of Embrapa Agrosilvopastoral, Sinop, Mato Grosso, Brazil. The experiment was arranged in a randomized block design with four replicates and seven treatments: eucalyptus + native seedlings; rubber + native seedlings; native seedlings; broadcast seeding of native species; no-till seeding of native species; natural regeneration and native seedlings without exploitation. Four samples composed of three sub-samples were collected manually and randomly at 0-10 cm depth with standard auger in each plot of 60 m x 80 m. The annual collects were done during three years of the forest restoration systems. Fortnightly, the emerged seedlings were identified, counted and discarded during three months. We calculated the relative importance index of weed species identified for each forest restoration system. The five most important species in the experiment were *Hyptis brevipes*, *Eleusine indica*, *Leptochloa virgata*, *Cyperus* spp. and *Alternathera tenella*. At 2012/2013, *L. virgata* was the most important species in rubber + native seedlings, native seedlings, broadcast seeding and natural regeneration, while in others *E. indica* was the most important. In the next year, this species was the most important among the treatments, except at broadcast seeding. On this year, *A. tenella* showed greater relative importance compared to the another years, except with natural regeneration. *H. brevipes* was the main species at 2014/2015 (except rubber + native seedlings) and had higher importance when compared to another years in forest restoration systems. The number of species was reduced along the years in all treatments, except with no-till seeding. The differences related to the importance of weed species on seedbanks were more associated to the year of data collection than with the treatments.

Keywords: Eucalyptus, native seedling, rubber, broadcast seeding, natural regeneration

Understanding weed invasion: a comparison of the functional traits of two populations of *Parthenium* weed and the implications for management (527)

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It is important to understand why certain species become successful invaders while others are not. Comparative studies of individual species, having both invasive and non-invasive populations, is a good way to identify traits associated with invasiveness. As a case study, a focus was placed on *Parthenium hysterophorus* L. (*Asteraceae)*, an invasive species found within Queensland with two distinct biotypes (Clermont; a highly invasive form, Toogoolawah, a non-invasive form) that have invaded the same general environment in Queensland. The study indicated that the Clermont plants were consistently taller, with higher number and longer leaves, more and longer branches, and higher number and larger seeds with faster germination than the Toogoolawah plants. Moreover, the Toogoolawah biotype produced flowers with significantly shorter peduncles, involucre bracts, stamen and corollas, when compared to the Clermont biotype suggesting that its flowers are more likely to be undergo self-pollination, which was further confirmed by self-compatibility test of the two biotypes (i.e. Toogoolawah and Clermont exhibited 72 and 26% self-pollination, respectively). Further research showed the Toogoolawah biotype to be a weaker competitor as compared to the Clermont biotype producing lower biomass and seed output when grown in the presence of pasture plants. Leaf materials coming from both biotypes exhibited allelopathy however the Clermont biotype exhibited a greater inhibitory effect on lettuce seedling growth but not on the four pasture species tested, than the Toogoolawah biotype.

Keywords: Invasive weed, *Parthenium* weed, biotypes, pollination

Session 27
CROP-WEED INTERACTIONS: Parasitic Weeds

Keynote: Striga/sorghum arms race during domestication as revealed by Dual RNA-seq (283)

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Transformation of wild species into elite cultivars through domestication entails narrowing the genetic diversity in crop plants. For sorghum in Eastern and Central Africa, continued selection has greatly contributed to cultivars with a higher susceptibility to the parasitic weed *Striga*, and an increased virulence of the parasite itself. An efficient strategy to build new resistance against *Striga* in cultivated sorghum is to reclaim resistance lost during domestication, while preventing increasing virulence from the parasite. We sought to harness *Striga* resistance genes from wild sorghum genotypes as well as to compare the profile of *Striga* virulence between cultivated and wild sorghum. We obtained 7 supposedly resistant Sudanese wild sorghum genotypes – *sorghum bicolor* subspecies *bicolor, durra*, *aethipicum kafir* and *virgatum* – that coevolved with *Striga* in this region of Africa. For cultivated sorghum, we used the *Striga*-susceptible cultivar 296B. Screening in soil-free root observation chambers (called rhizotrons) confirmed resistance of these wild sorghum genotypes and susceptibility in 296B. We then carried out dual RNA sequencing of wild and cultivated sorghum and their parasites, using Illumina Hiseq. RNA sequencing data were used to determine genes in wild sorghum that are differentially expressed at early and late *S. hermonthica* infection and compared their profile to those of cultivated sorghum. We also compared the profile of differentially expressed genes between *S. hermonthica* infecting wild and cultivated sorghum. Finally, we compared the profile of differentially expressed genes between *S hermonthica* and *S. asiatica* in cultivated sorghum. Our results will identify genes/loci that will provide a platform for enhancing resistance of sorghum to *Striga* using a genetic modification (GM) or a non-GM approach. We will also be able to understand how *Striga* is able to evade, and subsequently overcome the host's resistance. These outcomes are of fundamental importance to developing durable and broad-based resistance against *Striga*.

Greenhouse and open-field testing methods for infection and virulence of broomrape (*Orobanche cernua*) in sunflower (*Helianthus annuus*) (331)

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The parasitic broomrape (*Orobanche cernua*) is one of the most important yield-reducing factors of sunflower production world-wide. Broomrape has many races. In Hungary most of commercial sunflower cultivars are resistant against the most common A-D races (OR4) and also to the common race E (OR5).
This study aimed to demonstrate the comparison of efficiency of greenhouse and open field test methods, the differences between the virulence of common broomrape races and yield loss effect of race E broomrape.
In greenhouse tests 10 sunflower plants per plots were infected at sowing by broomrape seeds. This test was completed for variant races (mixture of races A-D and race E) and for 32 common commercial cultivars in four replications. Infection (yes/no) was recorded and the tubercle-sizes were measured at 42 days after sowing. In open field experiment 40 plants of each 32 commercial cultivars were infected by broomrape seeds of race E at sowing in three replication and experimental-field was maintained without herbicide treatments and without disturbance of broomrape-growth until harvest. Open-field experiment provided the opportunity to follow the whole life-cycle of broomrape. At harvest the number and sizes of adult parasites and the sunflower yield across the different cultivars were assessed. Greenhouse assays confirmed the assumed differences in resistance levels of cultivars and the differences in virulence levels between the races. We also found that resistant cultivars were also infected albeit at a low level. Results confirmed the usefulness of the quicker and lower-cost greenhouse method and the open-field experiment for resistance testing. Additionally, we also concluded on relations between sunflower yield capacity and greenhouse (Pearson correlation= -0.518; $P<0.01$) and open-field (-0.589; $P<0.01$) infection levels.
Our results showed the importance of broomrape-resistance to improve yield capacity and relevance of a greenhouse assay in the detection of resistance.

Keywords: *Orobanche cernua*, resistance-testing, yield-loosing, sunflower, broomrape

Early recognition of broomrape parasitism by physiological measurements and narrow-band spectral signatures (413)

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Broomrape (*Orobanche* and *Phelipanche* spp.) parasitism is a severe problem in many crops worldwide, including the Mediterranean basin. Most of the damage occurs during its sub-soil developmental stage. When broomrape shoots emerge above the soil surface, the damage to the crop is already done. One option to sense early parasitism is through physiological measurements, during the growing season. However, large-scale measurements at the field is complicated and not economical. To date, no agricultural method has been developed for assessing the spatial distribution of parasitism in the field – leading to excess- and indiscriminate-use of herbicides. Nonetheless, in the last decades, hyper-spectral tools were shown to have great potential for fast, repetitive, cheap and non-destructive spatial mapping for agricultural purposes. In the current study, detection of pre-emerged *O. cumana* parasitism on sunflower was investigated. Susceptible and resistant sunflower were planted in infested soil (no-infested control, 5, 10, 15 and 30 mg seeds kg^{-1}). The plants were measured weekly for carbon assimilation rates, stomatal conductivity, transpiration rates and photosynthetic efficiency rates on midday. Narrow-band leaf signatures were simultaneously-taken with a contact field spectrometer. Physiological and spectral measurements taken once a week during host plant development, revealed significant differences between infected and non-infected sunflower plants during early parasitism stage. Furthermore, by applying the advanced Partial Least Squares Regression (PLSR) analysis, correlation was found between specific wavelength changes and physiological changes in sunflower plants. This data demonstrate the potential of early stage detection of *O. cumana* parasitism on sunflower.

Keywords: *Orobanche cumana*, spectral, PLSR

Integrated approach for alleviating the injury of sunflower broomrape (*Orobanche cumana*) in sunflower (499)

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Confectionary sunflower is an important economical crop that is parasitized by the obligatory root parasite *O. cumana*. High infestation levels can cause total yield losses. Recently, a new tolerant confectionary sunflower cultivar ‚Emeq 5' (semi-tolerant to *O. cumana*) was developed in Israel. Additionally, a chemical control system, using foliar application and drip herbigation of imazapic, was successfully developed for *O. cumana* control. In order to reduce the risk for the development of *O. cumana* races with new or increased levels of virulence or herbicide-resistance, we propose to combine crop tolerance and chemical control approaches. Therefore, the objective of this study was to estimate the contribution of the tolerant ‚Emeq 5' variety, chemical applications, and the interaction between the two methodologies to *O. cumana* control. Field studies were performed in the Negev desert (Southern Israel) during 2013-2015 in fields naturally infested with *O. cumana* to examine *the* efficacy of this integrated approach. Two sunflower cultivars were planted: ‚Emeq 5' (*O. cumana* tolerant) and ‚Suprimo' (*O. cumana* sensitive). Chemical control included sequential imazapic applications: a) one foliar application of imazapic at 3.6 g ha^{-1} at the stage of 6 true leaves; b) two applications of drip herbigation (at 7.2 and 0.24 g ha^{-1}, respectively), at the stages of sunflower inflorescences size of 1.5 cm and 5 cm. ‚Emeq 5' exhibited high tolerance to *O. cumana* regardless of the chemical treatments. Three sequential treatments of imazapic effectively controlled *O. cumana* in both cultivars. However, when using ‚Emeq 5', the first two chemical treatments were sufficient to completely prevent *O. cumana* infection and crop damage, whereas in ‚Suprimo' all three treatments were needed. This protocol was validated in a commercial sunflower field resulting in a significant reduction in *O. cumana* infection and increased sunflower seed yield from 630 kg ha^{-1} to 2,500 kg ha^{-1}.

Session 28
HERBICIDES AND APPLICATION TECHNOLOGY: New Product Concepts

Keynote: Using a chlorophyll fluorescence sensor to assess herbicide stress in soybean (298)

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Sensor technologies can be of assistance for agriculture, potentially identifying yield limiting factors while reducing costs. Soybeans [*Glycine max* (L. Merr.)] are known to be sensitive to herbicide-induced stress and often show visual symptoms from herbicide applications. In a pot experiment at the University of Hohenheim, Germany a chlorophyll fluorescence sensor was used to identify and quantify the stress reaction of soybean from herbicide application. The objective of this experiment was to investigate the ability of sensor technology to determine herbicide stress.
A preemergence herbicide treatment, a postemergence herbicide treatment, and a combination of the two were utilized in this experiment. Each treatments used a combination of commercial herbicide products containing some of the following active ingredients: metribuzin, flufenacet, clomazone, dimethenamid, thifensulfuron, bentazon and fluazifop-P-butyl. In addition to the three different herbicide application timings, an untreated control was included for comparison purposes. Four pots per treatment were utilized in this experiment and herbicides were applied at the EC 0.3 or EC 12 soybean growth stage. A Imaging Pulse Aptitude Modulation (PAM) chlorophyll fluorescence sensor (MAXI-PAM, Heinz Walz GmbH) was utilized to quantify chlorophyll fluorescence. Prior to each measurement, soybean plants were dark adapted. Based on the Saturation Pulse Method, two images were taken, one for the minimum chlorophyll fluorescence (Fo) and another for the maximum chlorophyll fluorescence (Fm). Using the proprietary sensor software, mean values in soybean leaves for Fo, Fm and the Maximum Quantum Efficiency (Fv/Fm, Fv=Fm-Fo) were calculated. Measurements were collected every second day for the first week after emergence and once per week afterwards.
The sensor was able to identify stress symptoms in soybean, even classifying different treatments. Treatments were successfully differentiated using data collected from the first measurement. A time graph of recovery time following herbicide application could be generated for these data.

Keywords: Chlorophyll fluorescence, Herbicide stress, Imaging PAM, Soybean

Arylex™ active (halauxifen-methyl): A new herbicide active for post-emergence control of broadleaved weeds in winter oil seed rape (500)

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Oil-seed rape is the second most important oil-seed crop in the world with almost six million hectares grown in Europe. Dow AgroSciences has developed Arylex™ active (halauxifen-methyl), a new and novel arylpicolinate herbicide (HRAC group O, WSSA group 4) for postemergence control of control broadleaf weeds. Two new herbicide concepts are being developed for postemergence use in winter oil seed rape.
Arylex and both new concepts GF-3447 (9.6 g ae/L of halauxifen-methyl + 48 g ae/L of picloram) and GF-3488 (4.8 g ae/L of halauxifen-methyl + 120 g ae /L of clopyralid) were tested in small plot field trials according to EPPO guidelines during the last four years in Europe. Efficacy, selectivity, crop injury and yield were determined. In addition, carryover and crop failure trials conducted.
Arylex is effective at low rates (4.8 g ae/ha) and efficacy increases an adjuvant is included. It controls a broad spectrum of weeds in oil seed rape such as CHEAL, CENCY, DESSO, FUMOF, GALAP, GERSS, LAMSS and PAPRH including biotypes resistant to ALS inhibitors. GF-3447 can be used from crop growth stage BBCH 12 at 0.25 L/ha rate or at BBCH 16 at the maximum rate of 0.5 L/ha. Synergistic control of CAPBP, THLAR, MATSS, and MYOAR was observed. GF-3488 is highly selective from the crop growth stage of BBCH 30 to 50 and at the maximum rate of 1.0 L/ha and due to clopyralid controls additional Asteraceae species such as ANTAR, CIRAR, MATSS, SENVU and SONAR. Halauxifen-methyl rapidly degrades in soil and plant tissues.
Arylex offers effective postemergence control of difficult to control species including herbicide-resistant species at low dose rates, under diverse climatic conditions. GF-3447 and GF-3488 herbicides provide new opportunities for targeted postemergence control in autumn or spring.

Keywords: Arylex, halauxifen-methyl, oil seed rape, new herbicides, broadleaf weeds

Control of *Conyza* species with Arylex™ Active (halauxifen-methyl) (600)

Roger E Gast *(Dow AgroSciences, Indianapolis, United States),* ***Marcos Baez Buchanan*** *(Dow AgroSciences, Buenos Aires, Argentina),* ***Daniel C Cummings*** *(Dow AgroSciences, Bonham, United States),* ***Borja Clemente*** *(Dow AgroSciences, Madrid, Spain),* ***Xavier de Gaujac*** *(Dow AgroSciences, Valbonne, France),* ***Jeffery M Ellis*** *(Dow AgroSciences, Sterlington, United States),* ***Raphael L Frene*** *(Dow AgroSciences, Buenos Aires, Argentina),* ***Peter Nott*** *(Dow AgroSciences, Huntly, Australia),* ***Luiz H. Zobiole*** *(Dow AgroSciences, Toledo-Paran, Brazil)*

Arylex™ active (halauxifen-methyl) is a novel auxin herbicide (HRAC group O; WSSA group 4) from the new arylpicolinate chemical family being developed for postemergence control of broadleaf weeds in cereals and other agronomic crops. Due to its unique weed control spectrum and edaphic characteristics, it is also being developed for burndown application prior to planting certain agronomic crops, such as soybean (*Glycine max*) and corn (*Zea mays*), and also for use in certain orchard crops. Species in the *Conyza* genus have become particularly troublesome weeds in no-till cropping systems as well as in orchards throughout the world due to increasingly high levels of glyphosate and ALS resistance, with few effective alternative herbicide modes of action. Dow AgroSciences conducted numerous field trials Europe, Australia, North and South America from 2012 through 2015 to determine the efficacy of Arylex™ on the three main *Conzya* species (*Conyza canadensis, C. sumatrensis and C. bonariensis*) infesting cereals, soybean and orchard crop growing regions. Arylex™ at 5 to 6 g ae ha^{-1} provided excellent control of all three species when applied at growth stages up to 20 cm. Control was similar for all biotypes, including those resistant to glyphosate and/or ALS herbicides. The tank-mix addition of glyphosate and/or various ALS herbicides did not negatively affect control. Arylex™ will be a valuable new tool for control of problematic *Conyza* species in various cropping systems throughout the world.

Keywords: *Conyza canadensis*, *Conyza sumatrensis*, *Conyza bonariensis*, Arylex, halauxifen-methyl

Restoration of yield loss caused by herbicides using plant growth regulators (85)

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Weed management is the key factor in no-till agriculture which represents almost 90% of the cultivated area in Argentina. In the absence of mechanical practices increased herbicide use has occurred. Dependence on herbicides for weed control has resulted in weed resistance to an increasing number of herbicides. Furthermore, higher herbicide application rates and use of herbicides not always recommended for a given crop have been applied resulting in phytotoxicity symptoms and yield loss. In summary, more focus has been placed on the effectiveness of herbicides for weed control and less attention on the effect of those herbicides on the desired crop. However, recent research has demonstrated that plant growth regulators (PGR) and proper plant nutrition can minimize phytotoxic effects from herbicides. Our objectives were: i) to evaluate the effect of herbicides on crops yields, and ii) to evaluate the effects of PGRs and micronutrients to restore crop yields following phytotoxicity due to herbicide application. Sixteen treatments were applied to corn (*Zea mays*) and soybean (*Glycine max*) fields using different combinations of common herbicides with the goal of causing phytotoxicity. Ten days after appearance of visual phytotoxicity symptoms, 6 different treatments were applied using combinations of Stimulate® (cytokinin 0.009%, gibberellic acid 0.005 %, *Indole-3-Butyric* Acid 0.005 %) and BioForge® (antioxidant: N, N’-diformyl urea) with micronutrients in order to help plants recover from phytotoxicity. Significant losses due phytotoxicity were detected averaging 1352 kg ha^{-1} for corn and 775 kg ha^{-1} for soybean with maximums up to 4600 kg ha^{-1} and 1499 kg ha^{-1} respectively. Application of PGRs resulted in recovery of 99.7% of yield loss on average. In conclusion, application of several common herbicides resulted in phytotoxicity and yield loss of corn and soybean; however, PGR application may be used to minimize crop yield loss due to herbicide application.

Keywords: Corn, Soybean, hormones, phytotoxicity, micronutrients

Session 29
BIOLOGICAL WEED CHARACTERISTICS: Genetic Approaches

Keynote: Potential answers to the question what made *Echinochloa* species a global weed: phenome and genome aspects (267)

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Echinochloa species with diverse ploidy levels from diploid to hexaploid inhabit from tropical to temperate zones and from paddy to upland fields due to their diverse environmental adaptability, which might be acquired by their adaptation to changing cropping system including herbicide use and consequential evolution. Therefore, we tested major *Echinochloa* species inhabiting paddy and upland fields to investigate their biological characteristics and responsible genomic nature.

Three *Echinochloa* ecotypes belonging to either *E. oryzicola* (2n = 4X) or *E. crus-galli* (2n = 6X) were selected and their ecological adaptabilities in their germination, seedling emergence, seedling growth, and competition against rice were tested under various environmental conditions such as soil moisture, soil depth, flooding depth, air temperature, etc.

E. oryzicola is well adapted to flooded paddy condition due to its submergence tolerance for germination and seedling growth, while *E. crus-galli* var. *praticola* well adapted to dry upland condition due to its submergence sensitivity and drought tolerance. *E. crus-galli* var. *crus-galli* showed intermediate adaptability between *E. oryzicola* and *E. crus-galli* var. *praticola*. *De novo* RNA sequencing and transcriptome analysis of these three ecotypes revealed that the gene expression patterns of particular gene ontology categories were notably different among the three ecotypes. qRT-PCR of selected genes revealed that under non-submergence growing conditions, five protein categories (serine/threonine kinase, leucine-rich repeat kinase, signaling-related, glycoprotein, and glycosidase) were significantly enriched in up-regulated differentially expressed genes from *E. oryzicola*. Receptor-like kinases (RLKs)-encoding genes were up-regulated in all cases of control and submergence of *E. oryzicola* compared to two *E. crus-galli* ecotypes.

RLKs-encoding genes significantly up-regulated in *E. oryzicola* ecotype were positively correlated with its eco-physiological responses to flooding stress, suggesting that these genes may be responsible for diverse environmental adaptive diversity in *Echinochloa* species. In addition, their adaptation to herbicide use will also be presented in aspects of their herbicide resistance and mechanisms.

Keywords: *Echinochloa*, RNA sequencing, transcriptome, environmental adaptatibility, herbicide resistance

Multiple loci and epistatic interactions regulate flowering responses of weedy rice to day-length in temperate areas (670)

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Weedy rice (*Oryza sativa*) distributed in temperate areas has lost the requirement for short day-length for the induction of floral initiation during its co-evolution with the conspecific cultivars. Previous research on tropical weedy rice has identified three major loci for photoperiod sensitivity (*Se7.1, Se7.2* and *Se8*) which work together to repress floral initiation under long (>/=14 h) day-length. Our research aimed to determine the genetic mechanisms by which these loci interact to regulate flowering responses to day-length in temperate weedy rice. A population of recombinant inbred lines (RILs), developed from a cross between 'US1' (weedy rice) and 'EM93-1' (cultivated rice), was grown under natural (36.5°N lat., Malden, MO), short (10 h) and long (14 h) day-lengths. The parental lines, US1 flowered (~100 d) later than EM93-1 (~65 d) and both showed little sensitivity to photoperiod. Quantitative trait locus (QTL) analysis detected effects of four loci (*Se7.1, Se7.2, Se8* and *FT6*) on flowering time under the natural and long day-lengths, with all the alleles from US1 delaying floral initiation. These four loci also interacted epistatically with each other to regulate the variation in flowering time from 60 d to >200 d. The effect of *Se8* on flowering time was not significant under the 10-h day-length because the QTL-containing region displayed a dramatic segregation distortion. Only 17 (4%) lines of the 442 RILs were homozygous for the EM93-1 allele at *Se8*, indicating that the weedy line carries a gamete-killer gene that prevents gene flow into conspecific cultivars. This research demonstrated that temperate weedy rice shares a core set of photoperiod sensitivity genes with tropical weedy rice and also discovered a new locus/loci that regulates flowering time under local conditions by various epistasis interactions with the core genes.

Keywords: Weedy rice, flowering time, photoperiod sensitivity, epistasis interaction, recombinant inbred line

Transcriptome analysis during seed dormancy cycling in *Monochoria vaginalis* (246)

Toshiyuki Imaizumi *(National Agriculture and Food Research Organization, Tsukuba, Japan)*

Dormancy cycling is important for many weed species to germinate under favorable environment for seedling establishment. Molecular aspects of dormancy cycling are not clear, which leads to the question of whether different dormant states, such as primary and secondary, are fundamentally similar. In this study, we identified transcriptome during dormancy cycling in a summer annual weed, *Monochoria vaginalis*. *M. vaginalis* is one of the most serious weeds in rice paddy fields in Asia.
Microarrays were used for a global transcript analysis of *M. vaginalis* seeds retrieved from a rice paddy environment. The microarrays with 42,378 probes were designed using Ion PGM next generation RNA sequencing data. The seeds were buried in February 2009 in a rice paddy environment to simulate seed behavior in the soil seed bank and were retrieved every other month from April 2009 to December 2010. We evaluated degree of dormancy by performing germination assays at 25/15C with a 8h light/16h dark daily cycle. Depth of dormancy declined from late winter, then increased from late summer, similar to other summer annual weeds. Microarray analyses revealed that primary dormant seeds had a different type of transcriptome profile than secondary dormant seeds and secondary dormant seeds in 2009 also had a different type of transcriptome profile compared to secondary dormant seeds in 2010. In addition, there were different types of transcriptome profiles during shallow dormant states.
These results indicate that different dormant states are likely to be regulated by different mechanisms.

Keywords: Dormancy cycling, seed dormancy, transcriptome analysis, seed bank

Use of seed dormancy genes as silencing targets to mitigate the risk of gene flow from transgenic into weedy rice (632)

Xing-You Gu *(South Dakota State University, Brookings, United States),* ***Heng Ye*** *(South Dakota State University, Brookings, United States),* ***Alexandra Kena*** *(South Dakota State University, Brookings, United States)*

The risk of gene flow from transgenic crops into wild/weed relatives can be reduced by use of combined transgene containment and mitigating (TM) strategies. This research aimed to develop a TM strategy by linking to a primary transgene with RNA interference (RNAi) structures to silence seed dormancy genes that are functional only in weedy plants. Seed dormancy (SD) is an adaptive trait distributing germination over time. The built-in linkage with reduced SD or increased germination uniformity would make transgene-containing hybrids less competitive in weed populations and also relatively easy to eliminate by agronomic or weed management practices. This TM concept was tested in weedy rice (*Oryza sativa* L.) using the genes *SD7-1* and *SD12* as silencing targets. Both *SD7-1* and *SD12* encode bHLH family transcription factors and their coding sequences were used to design inverted repeat sequences (IRS) as RNAi structures. The IRSs were ligated with the *Bar* herbicide resistance (HR) on the same vectors to transform the cultivar Nipponbare. Transgenic lines with a single copy of the *SD7-1IRS:Bar* or *SD7-1IRS:SD12IRS:Bar* construct were crossed with weedy "red" rice to produce hybrids (F1) and their progeny (F2-F3) lines segregating for the transgene and target loci. As expected, both *SD7-1* and *SD12* were knocked down in the transgenic lines, a complete linkage of HR with reduced SD and white pericarp color was observed in the F2 and F3 generations, and the transgene frequency was much higher in the early germinated than in the late germinated subpopulations. This research proved that the TM strategy worked for the two SD genes under the controlled conditions. Research is being conducted to prove the TM strategy using three SD genes and to evaluate the mitigating effect in field environments. This project was supported by USDA-NIFA/ARS Biotechnology Risk Assessment Grant Program #2013-33522-21097.

Keywords: Gene flow, Trangene, Seed dormancy, Weedy rice, Biotechnology

Session 30
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Weed Management Options for Specific Situations

Keynote: Opportunities and challenges to interseeding cover crops in corn (*Zea mays* L.) (397)

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Penn State University developed a drill-type seeder that can interseed cover crops into growing cash crops. Research has focused on cover crop species, mixtures, seeding timing, and herbicide programs. The objective of this presentation is to share the concept and results from some inaugural experiments. A number of trials were conducted from 2013 to 2015 across a three-state region (Maryland, New York, and Pennsylvania). Most of the trials interseeded cover crops at the V5 to V7 stage when corn was less than 80-cm tall. Most trials collected cover biomass in early fall and corn grain yield. All trials had three or four reps and were repeated over time. The cover crop species included the grasses Kentucky bluegrass (*Poa pratensis L.*), Italian ryegrass *[Lolium perenne L. ssp. multiflorum (Lam.) Husnot]),* perennial ryegrass (*Lolium perenne L.*), orchardgrass (*Dactylis glomerata L.*), and tall fescue [*Lolium arundinaceum (Schreb.) S.J. Darbyshire*] and the legumes crimson clover (*Trifolium incarnatum L.*), hairy vetch, (*Vicia villosa Roth*), red clover (*Trifolium pretense L.*), white clover (*Trifolium repens L.*), and yellow sweetclover [*Melilotus officinalis (L.) Lam*]. Some grass-legume mixtures were included. In separate experiments, herbicides applied at the time of corn planting were evaluated for Italian ryegrass and red clover safety. Herbicides included some corn herbicides believed to be problematic and others that might be safe for cover crop establishment. The results from these trials showed that across sites, red clover was the most successful legume and Italian ryegrass followed by orchardgrass, the most successful grasses. All other grasses and legumes had mixed results. For the herbicide trials, s-metolachlor and mesotrione consistently reduced annual ryegrass or red clover establishment, respectively. Saflufenacil and rimsulfuron allowed cover crop establishment and several herbicides were variable (pendimethalin, dimethenamid-p, acetochlor, and atrazine) and might be useful at lower rates.

Keywords: Interseeding, cover crops, no-till

Control of black grass (*Alopecurus myosuroides* Huds.) by integrated weed management (418)

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The aim of this study is to evaluate how important the choice of cultivar, seed rate and sowing date are to increase the crop competitive ability and possibility to reduce black grass (*Alopecurus myosuroides* Huds) in winter cereals and, therefore, the reliance on herbicides. This study examines crop competitiveness against black grass and other weeds in winter wheat by combinations of **cultivars** (2) with different competitiveness, stand density/ **seed rates** (2) and **sowing dates** (2), totalling 8 combinations. The need for additional chemical control was evaluated in split-plot experiments where **herbicide treatments** (3 + untreated control) were performed across trials plots. The trials were designed as block-trials with four replications intended to be carried out for three years with three trials each year (2013-2016). The results from the first project year (season 2013-14), showed that crop management measures can have a significant impact black grass populations. Of the three tested cultivation factors, sowing date seemed to have the greatest effect. Two weeks later sowing (14 Sep -> 1 Oct) resulted in a 65% reduction of black grass plant number, a 77% reduction of plant weight and also a 77% reduction of ear number, in plots without herbicide use. The effect of choice of cultivar and seed rate showed lesser, but useful, impacts on black grass populations. Results from the second year (season 2014-15), showed similar effects; two weeks later sowing resulted in a 47% reduction of black grass plant numbers, a 60% reduction of plant weight and a 57% reduction of ear number in plots without herbicide use. Delayed sowing resulted in significant yield increases. Crop management measures can be useful tools in sustainable control of black grass.

Keywords: Integrated weed management, *Alopecurus myosuroides*, cultivar, seed rate, sowing date

Herbicidal weed control in wheat under strip tillage system as a practice of conservation agriculture (666)

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Weeds are considered as the major barrier to wheat cultivation under strip tillage system. In Bangladesh, labour shortage and high labour cost is now making manual weed control difficult and therefore herbicidal weed control considered an appropriate option for sustaining crop production under conservation agriculture system. Selection of herbicides with different modes of action is an essential tool to overcome herbicide resistance problem. The present study was conducted at Mymensingh, Bangladesh from November 2014 – March 2015 to examine the weed control efficacy of eight herbicides belonging to six modes of action in eighteen treatments including no weeding and weed free as a control. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The study revealed that herbicide treated plots significantly reduced weed infestation in wheat field under strip tillage system giving up to 227% yield increase over control. Pendimethalin followed by ethoxysulfuron followed by carfentrazone ethyl, Pendimethalin followed by pyrazosulfuron ethyl followed by 2,4-D and pendimethalin followed by pendimethalin reduced weed biomass 97% compared to non treated weedy plot and produced 18-38% higher grain yield than weed free plot. Pendimethalin followed by ethoxysulfuron, pretilachlor followed by ethoxysulfuron followed by carfentrazone ethyl, pendimethalin followed by 2,4-D or (carfentrazone ethyl+ isoproteuron) and pretilachlor followed by pyrazosulfuron ethyl followed by 2,4-D controlled weed biomass 96% compared to non treated control. From the study we concluded that either of these treatments could be a better weed control option for the farmers without sacrificing grain yield and farmer can rotate herbicides which may delay herbicide resistance development.

Keywords: Chemical weed control, Minimum tillage, weed index, Conservation agriculture, Weed management

UK Container grown nursery stock – residual herbicide programmes (250)

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There are few active ingredients available to the UK hardy nursery stock industry, with limited options as summer herbicide treatments. Restrictions on the use of metazachlor, and the loss of oxadiazon have compounded the problem, leaving the industry heavily reliant on isoxaben which does not effectively control common weeds such as groundsel, willowherb, grasses and in some cases pearlwort. Some shrub and many herbaceous species are sensitive to isoxaben, increased reliance on one herbicide will ultimately lead to resistance problems. Research was carried out in 2014 and 2015 to determine crop safety. This research assessed the suitability of seven herbicides as summer treatments; pethoxamid, HDC H25, triallate, napropamide, S-metolachlor, dimethenamid-p + metazachlor and a plant derived product of starch, proteins, oils and lactic acid. Winter treatments were applied in December 2015 and included flumioxazin and napropamide. The industry standard was isoxaben. The experiment was laid out in a randomised split plot design with two treatment factors: chemical treatment and crop species, with three replicate blocks. The majority of species were considered tolerant to herbicides tested by 12 weeks after treatment. Only dimethenamid-p + metazachlor and pethoxamid, resulted in damage on *Olearia* that was susceptible 12 weeks after treatment. *Santolina* treated with isoxaben + napropamide (irrigated in) in August 2015 was moderately susceptible at 12 weeks after treatment. The plant derived starch, proteins, oils and lactic acid product caused no phytotoxic effects on any shrub subjects assessed. The results from these trials are promising, with minimal long lasting damage on most of the species tested. The granular product HDC H25 will be suitable for most shrub species and is likely to be a replacement oxadiazon for use after potting. ADAS thanks AHDB Horticulture for funding the work and Wyevale Containers for hosting the trials.

Keywords: Herbicide, flumioxazin, isoxaben, napropamide, S-metolachlor

Session 31
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Weed Management in Cotton and Soybean

Keynote: Managing herbicide resistance in herbicide-tolerant cotton in Australia: The situation now and planning for future traits (548)

Jeff A Werth *(Leslie Research Facility, Toowoomba, Australia),* ***David F Thornby*** *(Innokas Intellectual Services, Upper Coomer, Australia),* ***James Hereward*** *(The University of Queensland, St. Lucia, Australia),* ***Michelle D Keenan*** *(Leslie Research Facility, Toowoomba, Australia),* ***Bhagirath S Chauhan*** *(The University of Queensland, Toowoomba, Australia)*

Herbicide-tolerant technology has been used in Australian cotton systems for over a decade, with the introduction of glyphosate-tolerant varieties in 2000 and glufosinate-tolerant varieties in 2006. When these varieties were introduced there were no glyphosate-resistant weeds present in cotton systems. Glyphosate-resistant *Echinochloa colona* was confirmed in 2010 in the fallow phase of a dryland cotton rotation. There are now populations of glyphosate-resistant *Conyza bonariensis*, *Chloris truncata*, *Sonchus oleraceus* and *Lolium rigidum* present in fields where cotton is grown. In addition, *Chloris virgata* is becoming a major problem where glyphosate is heavily relied upon.
As a result, the cotton industry approach has changed from preventing glyphosate resistance to managing it. Research has now focused on how to reduce the impact of glyphosate-resistant weeds and determine integrated approaches that are practical for growers to adopt. A systems trial investigating the potential to manage patches of glyphosate-resistant *E. colona* has now been running for four years. This trial is investigating the in-field effectiveness of simulations showing that adopting two non-glyphosate tactics in the cotton crop and in fallow can reduce the seed bank and manage glyphosate-resistant *E. colona* patches. Results have shown this to be an effective strategy for long-term resistance management for species that are not moved by wind.
The introduction of new stacks with glyphosate and glufosinate tolerance, and glyphosate, glufosinate and dicamba tolerance is likely to occur in the next 5-10 years. This will provide benefits to growers, however, make the management of resistance more complex. Research is underway to examine how this technology can best be used to provide effective weed control while mitigating against the risks of resistance to these herbicides. This research includes effective use of residual herbicides, and the incorporation of cover crops to suppress potential weed germination.

Keywords: Herbicide tolerant cotton, Glyphosate resistance

Weed species composition of soybean crops in Hungary is influenced by management and environmental factors (843)

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The goal of this study was to identify factors determining weed species composition in conventional soybean (*Glycine max* /L./ Merr.) crops in Hungary, where its expanding production faces difficult weed problems.
The abundance of weed flora was measured in 262 fields across the country, along with 38 background variables. Using a minimal adequate model containing 24 terms with significant net effects, 21.6% of the total variation in weed species data could be explained.
Plot location (edge vs core position) was found to be the most important explanatory variable which was followed by a set of environmental (temperature, precipitation, altitude, soil texture, pH, Ca, K, Na and humus content), cultural (cultivar maturity, organic manure, fertiliser P and N, row spacing), and weed-management (flumioxazin, pendimethalin, dimethenamid, propaquizafop, bentazon, quizalofop-p-ethyl, quizalofop-p-tefuril, linuron, thifensulfuron) factors. Variation partitioning revealed that environmental variables accounted for about four times more variance than cultural and about two and half times more than weed-management variables. *Chenopodium album*, *Ambrosia artemisiifolia*, *Hibiscus trionum*, *Echinochloa crus-galli* and *Convolvulus arvensis* were the most dominant and frequent weeds but their abundance was influenced by different factors.
The responses of weed species to the studied variables provide new information about their ecological behaviour and our findings also can be used to develop better weed management strategies.
This work was supported by Hungarian Scientific Research Fund (OTKA K111921).

Keywords: Agroecology, non-GM crops, redundancy analysis, weed survey, Glycine max

Bio-efficacy and phyto-toxicity of imazethapyr on control of weeds in groundnut and soybean; and its residual toxicity on succeeding cereal crops (95)

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Weeds pose a serious problem in groundnut and soybean cultivation. Pre-emergence herbicides have certain limitations in their use. Post-emergence herbicides have certain advantages in weed management. However, the knowledge on efficacy and effects of different post-emergence herbicides on control of weeds in groundnut and soybean and their residual effects on succeeding cereals are meager. Therefore, field trials to study the efficacy of different post-emergence herbicides on control of weeds in groundnut and soybean; and their residual effects on succeeding cereals (sorghum and wheat) were conducted at MARS, UAS, Dharwad during 2012-13 and 2013-14. Results of the trials showed that post-emergence application of imazethapyr at 100 g/ha 23 to 30 days after groundnut and soybean sowing although suppressed the growth of both annual broad leaved and grassy weeds, but failed to kill them completely. Annual grassy weeds showed regeneration/ re-growth in the imazethapyr at 100 g/ha treated plots. Post-emergence application of imazethapyr at 100 g/ha although suppressed the weeds in groundnut had resulted in reduced plant height, reduced number of pods/plant, reduced pod weight/plant and reduced pod yield of groundnut over the weed-free treatment. In contrast, such negative effects were not noticed with the soybean crop. Post-emergence application of imazethapyr at 100 to 150 g/ha in preceding groundnut and soybean resulted in 85 to 100 % residual phyto-toxicity on succeeding cereals (failure of sorghum and wheat seeds to germinate and gradual loss of plant population till crop maturity). In contrast, post-emergence application of either propaquizafop at 100 g/ha, or quizalofop ethyl at 50 g/ha and fenoxaprop-p-ethylethyl at 100 g/ha in groundnut crop resulted in complete knock down of annual grassy weeds and did not show any kind of negative effects either on preceding groundnut or on succeeding sorghum and wheat.

Keywords: Imazethapyr 10 SL, Efficacy, Phyto-toxicity, Broad leaved (Dicot) weeds, Annual grassy (Monocot) weeds

Sensitivity of soybean varieties to treatment with pendimethalin, a pre-emergence herbicide (512)

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Soybean is one of the most important field crops in the tropics and has been used for thousands of years to correct nutritional deficiencies. Uncontrolled weed infestation can reduce yields of soybean by 12-80%, depending on the type and density of weeds. Among the methods used for weed control in soybean, pre-emergence herbicides have been found to be very effective. However, differential sensitivity of soybean varieties to herbicides exists. A field experiment was conducted at the University of Agriculture, Makurdi Research and Teaching Farm during the 2013 cropping season to evaluate the sensitivity of six soybean varieties to pendimethalin, a pre-emergence herbicide used for weed control in legumes. The design of the experiment was a randomized complete block with three replications. The herbicide was tested at five different rates: 0, 0.5, 1.0, 1.5, and 2.0 kg ai/ha. The results of the experiment demonstrated the efficacy of pendimethalin to control weeds in soybean at the rate of 1.0 kg ha but only for some of the varieties. For varieties TGx 1945-4F, TGx 1448-2E, and TGx 1951-3F, there was serious injury on the emerged cotyledons and subsequently growth was stunted. There was also reduction in plant establishment and grain yield when herbicide rate exceeded 1.0 kg ha. Among the varieties that were least sensitive to pendimethalin, TGx 1951-4F had the highest grain yield of 1453 kg/ha at 1.0 kg/ha and TGx 1951-3F had the lowest yield at 2 kg/ha. At 0 (no herbicide) and 0.5 kg/ha, soybean plants were tallest, and shortest at 2 kg/ha at 4 wk after planting. Weed density and biomass was highest in the absence of herbicide application and lowest at 1 kg/ha. Soybean variety and herbicide rate had no significant effect on nodulation and seed weight of soybean.

Keywords: Soybean, Sensitivity, Pendimethalin, Glycine max

Session 32
WEED ECOLOGY: Weed Physiology (Genetics)

Keynote: Variation and genetic control of vernalization in *Bromus tectorum* (445)

Ian C Burke *(Washington State University, Pullman, United States),* ***Nevin Lawrence*** *(Washington State University, Pullman, United States)*

Variation in phenology of downy brome (*Bromus tectorum* L.) is a key factor in the success of the species as an ecological invader of natural areas and competitor within agronomic fields. Prior research documented differing vernalization requirements of downy brome collected from different environments, but no previous work has characterized the connection between phenotypic responses and genotypic control of downy brome vernalization. As most variation in vernalization requirements of related species have been attributed to variation of the vernalization gene VRN1 quantifying the expression of a VRN1 orthologue in downy brome may help explain the genetic controls regulating downy brome phenology. A series of common garden experiments was conducted involving 85 accessions of downy brome collected from within small grain production fields of Washington, Oregon, and Idaho. Results of common garden experiments identified differences in time to flowering of up to 19 days and time required for mature seed production of up to 21 days among accessions with little variation among siblings. Eight accessions from the larger collection of 85 were used to quantify vernalization requirements and VRN1 expression. Expression of a VRN1 orthologue was only observed in treatments were flowering did occur, suggesting that the molecular controls of flowering in downy brome are likely similar to related species. From the common garden experiments cumulative growing degree days required for mature seed production for each accession was estimated using non-linear regression. The calendar date when mature seed set occurred was calculated from downscaled climate data covering both a contemporary climate from 1950-2005 and a mid-21st century climate from 2031- 2060. Mid-21st century climate projections considered Global Climate Model simulations for representative concentration pathways 4.5 Wm^{-2} and 8.5 Wm^{-2}. Across all models, mature seed set is expected to occur earlier with changing climate which likely will require earlier control inputs.

Keywords: Downy brome, vernalization, VRN1, climate change

Weedy risks of hybrids between GM soybean (*Glycine max*) and wild soybean (*Glycine soja*) (220)

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With approval of genetically modified (GM) crops increases, risk assessment of gene flow from GM crops to wild relatives is necessary. In case of soybean, there is a possibility of gene flow from GM soybean to wild soybean because wild soybean is the ancestor of the cultivated soybean in Korea and widely distributed in roadsides. Even though outcrossing rates between GM and wild soybean are low, ploidy level is same and wild soybean possesses higher adaptability and has a greater genetic diversity. Therefore, the aim of this study is to estimate a potential weediness of soybeans under field conditions in Korea by investigating viability and reproduction between parent crops and their progenies. We also compared fitness among GM, cultivate, wild and their progenies (F1 and F2 hybrids) soybean for both vegetative and reproductive characteristics. GM and cultivated soybean had the highest vegetative characteristics: plant height, leaf area, leaf diameter and reproductive characteristics: pollen viability while number of flowers is lower than other soybeans. Hybrids had intermediate characteristics between parent soybeans, while F1 hybrids had the lowest pollen viability. Compare to wild relatives, transgenes might increase fitness and weediness. Furthermore fitness cost of soybeans could be predicted through these results and this study will contribute to conduct risk assessment of GM soybean and early-generation hybrids to agro-ecosystem in Korea. This research was supported by Rural Development Administration, Republic of Korea (Project code PJ00837501; Project of LMO Environmental Risk Assessment Center).

Keywords: f1 hybrid between GM and wild soybean, gene flow, fitness test, weedy risk

Ecophysiology of germination and emergence of physalis: a small fruit with high nutritional value (461)

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The cape gooseberry belonging to the Solanaceae family and *Physalis peruviana* L. is the most cultivated specie of the genus. This is a newly explored crop in Brazil and little is known about the ecophysiology of germination and emergence on local conditions. This study aims to evaluate the effect of temperature, photoperiod, sowing depth and seed dormancy on the physalis seedlings establishment. Were evaluated two physalis biotypes from Sertão (RS) and Capelinha (MG). The seeds incubated at 27 and 32 ° C had the highest germination, which are 97.5% and 96.0%, respectively. A reduction in germination when the seeds were incubated at 12, 17, 22 and 37 °C. The starting photoperiod of 8 hours light is better for germination of seeds, and the absence of light considerably reduces the germination. The seeding must be accomplished between 1 and 2 cm depth to better seedling emergence. After 12 months in field burial, 78% of the seeds had germinated and / or been preyed before evaluation. This shows that seeds have little seed dormancy. Thus, the best conditions for the physalis seedlings establishment are sowing between 1 and 2 cm deep, with temperature between 27 and 32 °C and photoperiod more than 8 hours of light with seeds collected over a period of 12 months.

Keywords: Temperature, photoperiod, sowing depth, seed dormancy

Ornamental plants as a source for spontaneous flora of the Czech Republic (749)

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Ornamentals constitute an important source of alien, and potentially invasive species. We studied ornamental plants in the Czech Republic to provide a detailed information on the diversity of taxa grown in cultivation in private gardens. The data can be used as an estimate of the propagule pressure by individual taxa. To make the data comparable across sites, we adopted two-level approach that resulted in producing a detailed list (including all recorded taxa) and an aggregated list (merging closely related and similar taxa). The floristic inventories yielded 1842 taxa on the detailed list, and of the taxa found 77.3% were alien. The ornamental flora consisted of not-escaping aliens, escaping aliens and cultivated natives. Related to the invasion potential of the ornamental garden flora we analysed the recorded taxa with respect to the transient/persistent character of their occurrence. The core part of the flora comprised 29% of the total number taxa and the transient 12% taxa. The “grey zone” between the two included 59% taxa.

Keywords: Ornamenatals

Session 33
AGRICULTURAL, ECONOMIC AND SOCIETAL ASPECTS OF WEED MANAGEMENT: Weed Management Perspectives

Keynote: Western Australia's changing farming systems: the unintended impacts of managing herbicide resistant weeds successfully (539)

Martin J Harries *(Western Australian Government, Geraldton, Australia),* ***Geoffrey C Anderson*** *(Western Australian Government, Northam, Australia)*

The extent of herbicide resistant weed populations in Western Australia is well documented with over 14 million hectares of arable land affected. To combat this challenge an array of integrated weed management techniques have been developed and adopted. The underlying objective of implementing these measures is to drive the numbers of weed seeds in the soil to low levels, which has been a very successful strategy.
The necessity to reduce the herbicide resistant weed seed bank has also influenced crop and pasture rotations used. For example in 1999 grain legumes were sown over 2.1 m hectares and by 2010 the area sown was approximately 0.6 m hectares. Sheep numbers declined from 23 million head to 13.9 million head over the same period and canola production increased from 0.39 to 1.1 m hectares.
With this mind we conducted a survey of commercial fields from 2010 to 2015. A total of 1040 field years of data was sampled from 184 fields. The land use of each field was recorded together with measurements of weed density, herbicide resistance, pasture species composition and biomass, soil-borne pathogen DNA, and soil chemical and physical properties. The dynamics of biophysical variables were related to the crop and pasture sequences employed.
We conclude that there has been a reduction in area sown to legumes and a decline in the productivity of self-regenerating pastures in regions where herbicide resistant weed populations are common. The study also found that cereal soil borne pathogen incidence increased and nitrogen status of many paddocks declined. We discuss these results in regard to the long term sustainability of current farming systems.

Keywords: Herbicide resistance, Western Australia, Rotation

Weed species shifts: Insights from recent and historical data (424)

John Cardina *(The Ohio State University, Wooster, United States)*

Species composition of the weedy flora is altered by biotic and abiotic changes at time scales ranging from months to centuries. The widespread development of herbicide resistant weed biotypes is just the most recent manifestation of this trend. I studied short-term species shifts in field experiments and long-term shifts in the historical literature on weedy species. Field studies showed that the change in a single factor – the time of land preparation or a change in tillage methods – changed the frequency distribution of species, which is likely the first step in a species shift. Historical documents, analyzed from three areas in the U.S., showed changes in weedy species in relation to agricultural practices over 100 years. Data suggest that the identity of species which are considered to be weeds is continually changing. Species considered to be difficult to control at one time are not even recognized as weeds at another time. For example, *Rumex aceotsella* was among the most important weeds in U.S. agriculture in the late 1800s, but is insignificant today. Similarly, *Conyza Canadensis*, *Amaranthus palmeri*, and other species that are the focus of control efforts today, were not recognized as significant weeds a generation ago. A consistent pattern has been the selection, or filtering, of species that are difficult to control within a particular cropping system. Increasing effectiveness of weed management in a stable cropping system has favored species that are increasingly difficult to control. Therefore, weediness is not merely due to a set of biologically based weedy traits, but to the interaction of these traits with existing agricultural practices. Better understanding of these interactions could drive the design of cropping systems with a weedy flora that is less difficult to manage, but early colonizing species will likely require consistent management in any future cropping system.

Keywords: Species shifts, cultural practices, historical records

Effective management strategies for resistant weed species – A global perspective (423)

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Agricultural consultants and their grower clients have struggled with management of resistant pests in crop production systems since the 1960's. In the 1970's and 1980's pests resistant to insecticides and fungicides comprised the major challenges. However over the past 2 decades herbicide resistant weeds have become the most significant pest management problem in global crop production. Managing herbicide resistant weeds poses a complex challenge for several operational and economic reasons. Crop consultants have maintained commercially acceptable control of resistant weed species by incorporating a variety of tactics to develop a systems approach, often unique to their specific geography. Comparison of successful management strategies in the presence of resistant weed species across major agricultural regions of the globe offers valuable insight into the effective components of those strategies.

The Global Alliance of Independent Agricultural Consultants (GAIAC) is a worldwide network of independent agriculture consultants organized to share experience and information. The resulting real time global knowledge base allows members to provide timely and viable solutions to difficult crop production issues, like management of resistant weeds. The authors surveyed GAIAC members in 12 countries on 5 continents to compare weed management strategies for herbicide resistant species. The survey indicated reliance on effective use of available herbicide chemistry, modifying agronomic practices and cropping systems and sanitation as common components of successful strategies across the wide range of geographic locations and production conditions involved. The different governmental entities represented demonstrate the impact of political initiatives on implementation of certain management systems.

Modification of established agronomic practices and cropping systems offer an effective and economically viable strategy to manage resistant weeds. However, the ability to implement those strategies is often impeded by a number of structural, political and market forces. The impact of these limitations and potential options where constraints exist are discussed.

Keywords: Crop consultants, management of resistant weeds, weed control, herbicide resistance, international

Weeds, their impact and management in China (219)

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China is a big agricultural country, agriculture is the foundation of the nation's economy. Various crops have been grown across the country. Over 700 weed species, infesting 94 million ha of crop fields are listed as having agricultural importance. More than 100 of them are considered among the worst weeds, causing 13% crop yield loss annually, which worth of 12 billion RMB. In recent years, with intensified use of herbicides for weed control, weed flora changes have been accelerated to some previously unimportant weeds, such as *Leptochloa chinensis*, *Sagittaria trifolia*, weedy rice, *Alopecurus japonicus*, *Aegilops tauschii*, "weedy wheat", *Acalypha australis*, *Commelina communis*, together with herbicide resistant weeds, for example, *Monochoria korsakowii*, *Descurainia sophia*, *Alopecurus japonicus*, and invasive weed species *Eichhornia crassipes*, *Mikania micrantha*, *Flaveria bidentis*, and *Solanum rostratum*, weed infestations are becoming increasingly problematic to Chinese crop growers. To tackle these new problematic weeds, several projects have been funded by the Chinese Government for integrated weed management in major crops. Research efforts have been placed on understanding weed biology, the occurrence and distribution of weeds, herbicide application, and herbicide resistance. The use of cultural methods integrated with diversified herbicide programs have been encouraged to enhance the ecological advantages in cropping systems for healthy weed management.

Keywords: Weeds, flora change, impact, weed management, China

Impact analysis for the analysis of herbicides based on proposals indicated by EFSA – an industry perspective (387)

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The registration process for plant protection products (PPP) requires demonstration of acceptable risk to the environment. The Guidance for risk assessment in the different areas of ecotoxicology have been subject to revisions by EFSA. For herbicide registration, the risk assessment for non-target terrestrial plants (NTTP) is a key element for authorization and definition of label restrictions (buffer zones, drift reducing technology (drt)). Recently, EFSA published the Scientific Opinion addressing the state of the science on risk assessment of plant protection products for NTTP. In this document, the term NTTP was re-defined from a plant growing outside the field to "all plants growing outside fields, and those growing within fields that are not the intended pesticide target." Further, the use of new endpoints (e.g. reproduction) are proposed to enhance ecological processes. In case no such data are available, EFSA proposes to use extrapolation factors (EF) to derive surrogate values for these endpoints from the standard vegetative endpoints (e.g. biomass). In order to obtain a reproductive ER10 the proposed EF's are 35 and 3 if the standard endpoint is a vegetative ER50 or ER10, respectively. For data sets not allowing the calculation of an HC5 of the standard endpoints an additional EF of 5 should be applied.
An evaluation was done for >30 herbicides (different producers, various target species e.g. *Alopecurus myosuroides, Galium aparine,* and *Chenopodium album*) with standardized endpoints expressed in % of label rate. These endpoints were corrected (divided) for the proposed EF's and used in an off-field risk assessment to estimate whether the PPPs could still be authorized, if yes, which label restrictions would apply. Based on this evaluation herbicides could only be authorized with combinations of high in-field buffers and drt $\geq$ 75%. The results are discussed in light of current regulatory and scientific developments.

Session 34
NON-CHEMICAL WEED CONTROL TOOLS: Cultural Methods

Keynote: Maize tolerance to plant competition: evidence of both progress and opportunity (67)

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Despite the challenges of managing weeds in maize, modern production systems have progressed considerably over the last century. While herbicides have played a role in improving maize productivity, so have advances in crop tolerance to various biotic and abiotic stresses. Recent research demonstrates greater stress tolerance in maize, particularly to plant competition, could be exploited further. With specific focus on sweet corn, over the last decade we have demonstrated 1) wide variability in crop competitiveness among commercial hybrids, 2) strongly competitive hybrids reduce risk of weed control failure, and 3) underlying canopy factors account for a majority of variation in competitive ability among hybrids. Furthermore, we found increasing crop population density of more competitive hybrids improves crop productivity and decreases weed fitness. Ongoing research includes quantifying the extent to which sweet corn tolerance to competition has improved since the mid-19th century. This research uses an 'era of introduction' study approach, where density tolerance is quantified for cultivars introduced as far back as the year 1851. In addition, contemporary transcriptional profiling is being performed on modern sweet corn to examine plant competition at the molecular level. Identifying the different genetic mechanisms of competition-tolerant and competition-sensitive cultivars is shedding new light on crop tolerance to competition. Increasing prevalence of multiple-herbicide resistant weeds and lack of new herbicide modes of action are placing greater burden on non-chemical weed control tools to fulfill weed management objectives. A deeper, more mechanistic understanding of maize tolerance to plant competition may result in new opportunities to further improve maize production systems through the 21st century.

Keywords: Competition, maize, microarray

Intercropping cover crops to unweeded soybean yield in no-till system (542)

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Weed control is the biggest problem in organic farming. Cover crops as oat are very efficient to suppress weeds, but disease, drought and other problems may affect oat biomass, and its weed suppression efficiency. Intercropping different families may create functional biodiversity which may enable greater resistance to these problems. The aim of this work was to evaluate four cover crops and its factorial combination to promote yield of unweeded no-till soybean. The experiment was carried out in Parana State, southern Brazil, in the 2014/15 crop season. The experiment was arranged in a randomized complete block design with five replications. The main plots were the cover crops sowed in April: oat (*Avena sativa*), rye (*Secale cereale*), lupine (*Lupinus albus*), flax (*Linum usitatissimum*) and its factorial combination, including fallow, totaling 16 treatments. The sub-plots were weed control on soybean: weeded and unweeded. Cover crops were managed with roller crimper, and only at this moment there was a full field weed control, just before soybean sowing in October. Mulch did not suppress weed as a weeding treatment. Oat is commonly used as cover crop, and together with rye are the best choices as single cover crop. Used as intercropping both oat and rye resulted in good soybean yield, but not all of them. Lupine and flax as single cover crop were not efficient to outcome a good soybean yield in unweeded treatment. Lupine and flax combination resulted in the worst soybean yield. The fallow also resulted in good soybean yield in the unweeded treatment, probably because weeds emerged before soybean season, and were controlled before its sowing. In conclusion oat and rye are the most efficient mulch for unweeded soybean, and some of oat and rye intercropping can be used with similar results.

Keywords: Organic farming, mulching, cover crop, no-till, soybean

Managing weeds in organic field pea (*Pisum sativum*) with leaf-type cultivar mixtures (365)

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A competitive crop canopy can be used to limit weed growth in the absence of herbicides. While semi-leafless pea has high lodging resistance and yield potential, the larger leaf area of leafed (wild type) pea may be advantageous in competing with weeds. Mixtures of the two leaf types may improve weed control and crop yield compared with single leaf type monocultures by combining their beneficial canopy traits. To test this hypothesis, a replicated field experiment was conducted on weedy, organic land in Saskatchewan, Canada, over four site-years. Mixtures of a leafed and semi-leafless cultivar, CDC Sonata and CDC Dakota, were sown in ratios of 0:100, 25:75, 50:50, 75:25, and 100:0 leafed to semi-leafless pea, at target seeding rates of 88 and 132 plants m^{-2} (conventional and organic recommended). Mixtures containing 25:75 leafed to semi-leafless pea yielded at least 18% higher than either cultivar grown in monoculture. However, no mixtures improved weed suppression compared with either single cultivar. The semi-leafless cultivar was unexpectedly more weed suppressive than the leafed, and mixtures of 50% or more semi-leafless pea were similarly competitive to the semi-leafless cultivar grown alone. Results indicate that mixtures of semi-leafless and leafed cultivars can be used as a tool to increase organic crop productivity. Additionally, this study suggests that crop canopy traits other than leaf type and leaf area may influence competitive ability in field pea.

Keywords: Crop canopy architecture, competition, organic

Effects of management practices on control of docks (*Rumex* spp.) (701)

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Dock (tall species of *Rumex*) infestation is a significant problem in many parts of the world, including Norway where it acts as a challenge in integrated cropping systems as well as a bottleneck in the expansion of organic grassland farming. Experiments, including cultural and direct weed control measures when renewing the grassland, were carried out at different locations in Norway to examine the effect of (i) depth of mouldboard ploughing, (ii) the use of mouldboard plough equipped with a skimmer, (iii) increased grassland competitiveness by cross-sowing and increased sowing density and (iv) the use of a cover crop. Dock root plant and seedling density, cover and above-ground dry weight, and crop cover, dry weight and fresh weight were recorded. Deep ploughing and skimmer use both resulted in reduced dock growth. The effects of increased crop competitiveness, cross-sowing and increased sowing density, most often decreased the number of dock plants but the effect varied between different experiments. Cover crop was in most cases beneficial in reducing dock values. Overall, the best combination of treatments may still not be enough to control dock infestation within a grass crop's lifetime. Thus, and to encourage sustainability, reintegration of grassland and arable farming should be considered as part of an ideal solution.

Keywords: Grassland renewal, *Rumex* spp, Cover crop, tillage, sowing pattern

Session 35
HERBICIDES AND APPLICATION TECHNOLOGY: Formulations, Adjuvants and Tank-Mixtures

Keynote: HPPD Inhibitors in combination with safeners: Modern solutions for sustainable agriculture (592)

Dr. Andreas van Almsick *(Bayer AG, Frankfurt am Main, Germany),* ***Dr. Lothar Willms*** *(Bayer AG, Frankfurt am Main, Germany),* ***Christopher Rosinger*** *(Bayer AG, Frankfurt am Main, Germany)*

Herbicidal inhibitors of hydroxyphenylpyruvate dioxygenase (HPPD) have a long history of use beginning with pyrazolate (Sanbird®, Sankyo, 1980) for the Japanese rice market, followed by several compounds especially for rice, corn and currently for cereals. Development of HPPD compounds was based on the strength of the herbicidal activities, the spectrum of the controlled grass and broadleaf weeds, application timing, and crop selectivity. However, with respect to crop selectivity, selected compounds within the HPPD mode of action work perfectly together with several safeners in different crops. Thus, combinations of HPPD inhibitors with safeners allow for expanded use of HPPD inhibiting herbicides to selectively control major weed problems.

Given the reduction in mechanical weed control, reduced crop rotation, and use of a limited number of different herbicides, herbicide resistance has become one of the most important problems of modern agriculture. Significant examples of resistance to important modes of action are known including weed biotypes resistant to ACCase and ALS inhibiting herbicides. In addition, glyphosate-resistant weed species have become a primary concern in several areas of the world.

The introduction of new, more powerful HPPD inhibitors into different crops with the help of safeners offers new tools to control resistant weed species. Several examples of HPPD inhibitor/safener combinations such as isoxaflutole plus cyprosulfamide and tembotrione plus isoxadifen-ethyl will be discussed in detail, including development, potential applications and meaning. An outlook will outline the further potential and possibilities of future HPPD inhibitor/safener combinations.

Keywords: HPPD Inhibitors, Safener, Resistance, Selectivity, Weed spectrum

Auxin receptor variants as discovery platforms for new auxinics (628)

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Auxins are the basis of one of the most successful classes of herbicide with a commercial history dating back 50 years. The family of auxinic herbicides is broadly-based, is variously selective, has a number of chemical scaffolds and incidences of tolerance have not been widespread or pervasive. Hence there is an interest in novel, commercially relevant actives. The target site for auxins, the auxin receptor known as TIR1, was identified in 2005 and its crystal structure was solved in 2007. Following these discoveries, we are expressing and purifying AtTIR1 and other members of the TIR1 family as the basis of compound activity screens, especially AtAFB5. We are also using structure-led strategies to describe in detail the binding sites and the mechanism of selectivity for auxins. Details of our assays will be presented along with a mode-of-action analysis of new arylpicolinates from Dow AgroSciences. The results will demonstrate our progress towards novel chemistries and the structural basis of selectivity.

Keywords: Auxin, herbicide, receptor, discovery, structure

Cuscuta campestris control with granular pendimethalin in chickpea and watermelon (514)

Yaakov Goldwasser *(The Hebrew University of Jerusalem, Rehovot, Israel),* ***On Rabinovitz*** *(The Israeli Ministry of Agriculture, Kfar Yuval, Israel),* ***Hadar Kuzukaro*** *(The Hebrew University of Jerusalem, Rehovot, Israel),* ***Moshe Sibony*** *(The Hebrew University of Jerusalem, Rehovot, Israel),* ***Baruch Rubin*** *(The Hebrew University of Jerusalem, Rehovot, Israel)*

Field dodder (*Cuscuta campestris*) is an obligatory stem and leaf plant parasite causing major damage in field crops and vegetables in all agricultural regions of the globe. Selective and effective measures to control this parasite are extremely limited. We have proposed that the window of opportunity for effective dodder control is the stage between parasite germination and its attachment to the host. In recent studies we have shown that granular formulations of dinitroaniline cell-inhibiting herbicides applied after crop establishment and before dodder germination may provide effective and selective control of field dodder. The objective of this study was to evaluate the efficacy and selectivity of granular pendimethalin ('Corral' 2.68%, G) in chickpea (*Cicer arietinum*) and watermelon (*Citrullus lanatus*) under lab, greenhouse and field conditions. Petri dish studies have shown that pendimethalin does not affect dodder seed germination rate but reduces shoot elongation from 10 cm in the untreated control to <1 cm using standard application rates. Pot experiments demonstrated that the reduction and distortion of shoot growth leads to complete obstruction of parasite shoot twinning and subsequent attachment to the host stem. In dose-response studies conducted in the greenhouse, we observed that granular pendimethalin at half the recommended rate can be slightly phytotoxic to young chickpea plants but not to young watermelon plants. In a chickpea field trial, granular pendimethalin applied across the seeding bed at the recommended rate was slightly phytotoxic to chickpea plants, but the resulting yields were high and not significantly different from the untreated control. These data indicate that granular pendimethalin can be effective and selective for dodder control in chickpea and watermelon. In future studies we will investigate the efficacy of dodder control and crop selectivity using reduced rates and narrow application bands of Pendimethalin granules applied to watermelon and chickpea under field conditions.

Keywords: Dodder, Parasitic plants, Granular herbicides

In vivo generation of hydroxyl radical by titanium dioxide nano catalyst to break the dormancy of the world's worst weed purple nutsedge (668)

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Purple nutsedge (*Cyperus rotundus* L.) is one of the most invasive perennial sedge weeds, competing with crops for natural resources resulting in losses of crops. Phenols present in the tubers control the germination of tubers. Degrading the phenol break the dormancy and germination of buds present in the tubers. Once tubers are germinated, it can be controlled by either chemical or cultural means resulting in reduced weed seed bank size. The novel titanium dioxide nanoparticles (nano-adsorbent) are quite efficient for degrading phenols present in the *C. rotundus* tubers. A laboratory experiment was carried out at the Department of Nano Science and Technology, Tamil Nadu Agricultural University using Coimbatore to break the dormancy of *C. rotundus* tubers using titanium dioxide nanoparticles by degrading the phenols. The titanium dioxide nanoparticles were synthesized by chemical precipitation method and characterized by Fourier Transform Infrared Spectroscopy (FTIR), X-Ray powder Diffraction (XDR) and Scanning Electron Microscope (SEM). Titanium dioxide nanoparticles at 2.5 g kg^{-1} of tubers had higher phenol degradation (i.e 69.7%) which was similar to 2.0 g kg^{-1} of tubers (i.e. 68.8%). Titanium dioxide nanoparticles degraded phenols by means of Advance Oxidation process (AOPs). In AOPs powerful reactive species like hydroxyl radicals were generated by specific chemical reactions in aqueous solutions. Hydroxyl ions destroyed phenolic compounds and converted them into relatively benign and less persistent end products. Where titanium dioxide nanoparticles were applied, higher germination of *C. rotundus* tubers was observed. Once the tubers were germinated, it could be effectively controlled by several management tactics and a reduction in the weed seed bank was observed.

Keywords: Cyperus rotundus, dormancy, germination, titanium dioxide nanoparticles, weed

Session 36
WORKSHOP ON GRASS WEED GENOMICS 1

Weed genomes as potential sources of new, adaptive agronomic traits: a summary of *Kochia scoparia* research in North America (834)

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Modern weed control based largely on herbicides has increasingly run head on into difficult and significant issues of herbicide resistant weeds, which compromise the utility of some of the best products in the marketplace. Weed biology focused on a variety of weed issues including, resistance, dormancy, competitive ability, traits that ensure weed success, etc., sits at the crossroads of many lines of research including agronomy, chemistry, biochemistry, ecology, and more recently molecular biology, in part due to the evolution of herbicide resistance. To better integrate weed biology in future agriculture challenges, genetic tools including the transcriptomes and the genomes of model weedy organisms need to be developed and made available to the research community not only to improve weed control, but also to mine weeds for desirable traits that could enhance crop productivity. Current "model" plant species do not have the same traits or complexity as many weedy species making them less effective models. Our research team has begun the ambitious effort of sequencing the genome of *Kochia scoparia*, an important weed in western North America that has evolved multiple herbicide resistance mechanisms. This species has desirable agronomic traits such as cold, heat, and salt tolerance, and research over 30 years has shown its wide range of adaptability. The large, complex, and malleable genome of *K. scoparia* makes sequencing and genome assembly an interesting challenge. Our initial findings demonstrate the challenges in assembling complex weedy species genomes and the potential for using cutting-edge molecular tools to improve our understanding of weed biology and weedy traits. This research is part of a longer-term goal of developing a global center of functional weed genomic studies at Colorado State University.

Keywords: *Kochia scoparia*, Weed Genome, Functional Genomics, Agronomic Traits, Crop Improvement

Current state of genomics research in European most important herbicide-resistant weed grasses: a review (841)

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Herbicide resistance is an evolutionary process, and its dynamics and impact are dependent upon many genetic, biological, herbicidal and operational factors (Powles and Yu, 2010). A main prerequisite for managing a weed is that the weed should be well understood. We are far beyond the understanding of weed traits that enable a weed to survive a herbicide treatment under fast changing environmental conditions. In Europe, on the top of the list in herbicide resistant grass weeds are *Alopecurus myosuroides*, *Avena fatua*, *Apera spica-venti*, *Echinochloa crus-galli* and *Lolium perenne*, respectively, in descending order based on the reports available on Heap (2016) website. More than 90% of herbicide resistant cases are associated with just few mode of action groups, predominantly to ACCase and ALS inhibitors. The genomic information for studies in herbicide resistance is limited in most cases. The molecular biology tools are mostly used to study the mechanisms and evolution of herbicide resistance in weed populations. In many cases the whole genome sequences are lacking, markers that can be developed without prior knowledge of the genomic sequences have been used by scientists working with weeds (Baker et al., 2007). Our current understanding of target site resistance strongly supports the idea that parallel genetic changes, and thus genomic constraints, are responsible for convergent evolution of the resistance phenotype (Baucom, 2016). Recent studies (Délye, 2013) have shown that non-target site resistance (NTSR) is more common than it was ever thought. Currently, very little is known about the genetic basis of NTSR, but reports indicate that its control can be either monogenic (Yu et al., 2009) or polygenic (Petit et al., 2010). Many questions remain unanswered about herbicide resistance. There is a potential for utilizing genomic resources developed for crops and model species such as *Arabidopsis*.

Keywords: Barnyardgrass, blackgrass, non-target site resistance, silky windgrass, target site resistance

Strategies for genome sequencing, comparative genome analysis and genomic prediction in grasses (842)

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Many economically important grass species have complex genomes that pose significant challenges in producing high-quality genome assemblies. Additionally, hybridization and many centuries of selective breeding have resulted in agriculturally important grass species that have highly heterozygous and often also polyploid genomes with a high proportion of repetitive DNA. Thus, considerable technical obstacles must be overcome before such complex genomes can be fully assembled.
Lolium perenne (perennial ryegrass) is an outbreeding diploid species with an estimated genome size of approximately 2.2 Gb. It is the principal forage species used in temperate agriculture and therefore a prime candidate for genome sequencing. The first Illumina-based draft genome was published in 2015 (Byrne et al., 2015).
Recent advances in BioNano optical mapping and PacBio long-read third-generation sequencing technologies and new strategies for data integration have made it possible to generate *de novo* assembled grass genomes that approach reference quality. Progress towards generating an accurate high-quality *de novo* reconstruction of the perennial ryegrass genome is presented.
The availability of the perennial ryegrass genome will enable comparative genome analysis, efficient discovery and characterization of genetic variation, and a deeper understanding of the genetic control of important complex traits. This will accelerate the discovery of candidate genes to study herbicide stress response, and the implementation of genomic prediction breeding within forage grasses, leading to better varieties, and more productive and sustainable grasslands.
References
Byrne S, Nagy I, Pfeifer M, Armstead I, Swain S, Studer B, Mayer K, Campbell JD, Czaban A, Hentrup S, Panitz F, Bendixen C, Hedegaard J, Caccamo M, Asp T, 2015. A synteny-based draft genome sequence of the forage grass *Lolium perenne*. The Plant Journal (DOI: 10.1111/tpj.13037).

Keywords: Perennial ryegrass, Genome sequencing, Comparative genomics, Genomic prediction

Session 37
BIOLOGICAL WEED CHARACTERISTICS: Traits of Invasives

Keynote: Identifying the geographic origins for the invasion of *Taeniatherum caput-medusae* (medusahead) in the western United States: evidence for multiple introductions, founder effects and prior adaptation (707)

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Molecular markers can provide insights into the processes that have shaped the genetic diversity of native populations, and can be used to identify an invasive species' geographic origins. *Taeniatherum caput-medusae* (medusahead) is a cleistogamous, diploid, annual grass native to Eurasia that is invasive in the western United States (U.S.). Our objectives were to 1) determine the geographic origins for this invasion, 2) test a multiple introduction hypothesis, and 3) assess the role of founder effects in invasive populations. These objectives were achieved through the combined analysis of native and invasive populations within the same experimental design. Forty-six of 78 native populations contained at least one individual with a multilocus genotype that match those detected in 46 invasive populations. Putative source populations were located in Albania, Bulgaria, France, Greece, Macedonia, Romania, Sardinia (Italy), Turkey and Ukraine. These results are consistent with multiple introductions and indicate that the geographic origins of this invasion occur broadly across the Mediterranean region; with many putative source populations occurring in southeastern Europe. Invasive populations display lower genetic diversity and exhibit higher genetic structure compared with native populations; consistent with founder effects.The second objective of this research was to determine whether the medusahead invasion in the western U.S. occurred through post-introduction evolution, prior adaptation (i.e., pre-adaptation), or a combination of both. This objective was achieved by using allozymes to determine the mating system of ten native and ten invasive populations. The ten native populations were chosen because they are putative source populations. The two different approaches indicate an extremely high self-pollination rate for both native and invasive populations of the grass. High levels of self-pollination within native and invasive populations suggest that this selfing mating system may be a prior adaptation contributing to establishment success and the invasion of medusahead in the Western U.S.

Keywords: Genetic analysis, invasive and native populations, outcrossing rate, prior adaptation, self-pollination rate

Significance of *Heracleum mantegazzianum*: An invasive weed species (52)

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Heracleum mantegazzianum Sommier & Levier (giant hogweed), a perennial broadleaf, belongs to Umbelliferae or carrot family. It is a native of the Caucasian Mountains and southwestern Asia. This species was introduced as an ornamental plant to the United States, Europe, Canada and the United Kingdom. The species colonizes a wide variety of habitats, commonly found along roadsides, in vacant lots, along streams and rivers. Currently, it is found in 15 states in the United States, including nine northeastern states.

Heracleum mantegazzianum reproduces by seed and by tuberous rootstalks. Plants emerge in early spring from rootstocks (as deep as 1 m). Plants can grow up to 4 to 6 m in height. The stem (4.8 to 9.6 cm in diam.) is hollow and usually blotched with purple. Both the leaf stalks and stem produce bristles. The leaves are palmately compound (1.5 m in breadth) with three deeply incised leaflets. Plants flower from June-July. The inflorescence (up to 0.72 m in diam.) has many white florets that form a flat-topped umbel. Each plant potentially can produce as many as 100,000 seeds. Seed dispersal is by wind, water or human activities. Dormancy is limited and seeds remain viable up to 15 years.

Heracleum mantegazzianum has two major impacts: ecological and human health. It suppresses growth of native plants, which has a negative impact on the wildlife that depends on them. The plant exudes a clear poisonous sap. *Heracleum mantegazzianum* can cause phytophotodermatitis, a serious skin inflammation caused by UV photo-activation, resulting in severe burns to the affected areas and severe blistering. Caution should be taken when handling this weed. *Heracleum mantegazzianum* is listed as noxious or invasive weed species in the United States and in many other countries.

Keywords: Invasive weed, Ecology, Phytodermatitis, Biology, Reproduction

Which physical traits of weed seeds determine food preferences of granivorous ground beetles (Coleoptera: Carabidae)? (656)

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Post-dispersal seed predation is a phenomenon that reduces the abundance of weed seeds in the soil seedbank. In temperate zones, granivorous and polyphagous ground beetles (Coleoptera: Carabidae) are considered to be important weed seed eaters. Several previous studies show that carabid beetles are selective and that their seed preferences are based mainly on size and taxonomic constraints. The aim of the current study was to show if carabid selectivity also depends on physical seed traits.
Our analysis was based on seed preferences of two ground beetles — *Harpalus affinis* and *Pseudoophonus rufipes*. The dataset included 63 ranked plant species and for each we searched for several traits (seed mass, volume, total density and shape) in trait databases.
Using a cumulative link model we showed that both carabids tend to prefer seeds of optimal seed mass (0.17 mg/ *H. affinis*; 1.15 mg/ *P. rufipes*) and also react to density and shape. *P. rufipes* prefers denser seeds, in *H. affinis* we observed opposite pattern. Disc- or needle-like seeds are likely more often eaten then seeds with spherical shape. Preferences of carabid seed predators are thus determined by these traits.

Keywords: Seed predation, *Harpalus affinis*, *Pseudoophonus rufipes*, seed density, selectivity

Seed dormancy and dormancy loss contribute to adaptability in the invasive weed species, downy brome (*Bromus tectorum* L.) in Pacific Northwest dryland crop production areas (449)

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Nevin C Lawrence *(Washington State University, Pullman, United States),* ***Ian C Burke*** *(Washington State University, Pullman, United States)*

Seed dormancy is an evolutionary adaptation that prevents germination out of season, even under favourable conditions, and ensures species survival of natural catastrophes. Discontinuous or extensive seed dormancy in weeds ensures environmental plasticity, or the ability to respond to changing biotic and abiotic environmental factors, ensuring germination only in favourable conditions. Extensive crop yield losses in regions of small grain production systems in the inland Pacific Norwest (PNW) are due in part to the vast variability in seed germination of the invasive weed species downy brome (*Bromus tectorum L.*). In a single field location new seedlings emerge throughout the growing season making downy brome one of the most difficult weeds to manage in wheat. Our research explored the central hypotheses that differences in seed dormancy contribute to extensive phenotypic plasticity and adaptability in downy brome in small grain agricultural settings, and that these dormancy differences are regulated by differences in sensitivity to the two plant hormones abscisic acid (ABA; dormancy promoting) and gibberellin (GA; germination stimulating). Phenotypic differences in seed dormancy were measured at physiological maturity utilizing a 132-entry collection of downy brome from six populations across the dryland cropping areas in PNW. Seed dormancy and dormancy release were measured though changes in sensitivity to ABA and GA across an after-ripening time course, and in response to the dormancy breaking treatments dark and cold. Our results indicate 1) there are differences in seed dormancy at physiological maturity within and across downy brome populations, and 2) seed dormancy release occurs as a result of measurable changes in sensitivity to ABA and GA, as well as other environmental cues such as light and temperature.

Keywords: Seed dormancy, Abscisic acid, Gibberellin, Dormancy screen, Downy Brome

Session 38
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Integration of Tactics for Weed Management in Root, Tuber Crops and Vegetables

Keynote: Effect of tillage, irrigation and nitrogen rates on weeds, insects, and sugar beet yields (142)

Don W Morishita *(University of Idaho, Kimberly, United States),* ***Kelli M Belmont*** *(University of Idaho, Parma, United States),* ***Erik J Wenninger*** *(University of Idaho, Kimberly, United States),* ***Howard W Neibling*** *(University of Idaho, Kimberly, United States)*

Most sugar beet (*Beta vulgaris*) produced in the US are grown in conventional tilled soil, which is typically plow, disk and harrow before planting. With the introduction of glyphosate tolerant sugar beet, reduced tillage is now possible. However, much is not yet clearly understood about the interactive effects of tillage level, nitrogen (N) fertilizer application rates, and irrigation amounts in sugar beet production. A field study was conducted in 2013 and 2014 at the University of Idaho Kimberly Research and Extension Center to study the effects of tillage, N fertilizer rate, and irrigation amount on weeds and pestiferous insects, root and sugar yields, nitrates, and conductivity. Three tillage treatments were established: conventional tillage (CT), strip tillage (ST), and direct seeding (DS). Four N fertility rates were applied at 50, 75, 100, and 125% of the recommended rate for CT sugar beet. The irrigation treatments were based on sugar beet evapotranspiration (ET) and were: 50, 100, and 150% of ET. Experimental design was a split split plot randomized complete block design with tillage as the main plot, irrigation as the sub-plot, and N rate as the sub-sub-plot. By the 12 leaf sugar beet growth stage, *Chenopodium album* and *Setaria viridis* densities did not differ between CT, ST, and DS at optimum irrigation and N rate. In 2013 leafminer (*Pegomya betae*) egg and larval densities were greatest in CT compared with DS and ST. Averaged over 2 years, root yield was 8.7 and 6.7 Mg ha^{-1} higher in CT and ST, respectively, than DS, but estimated recoverable sucrose did not differ between CT, ST, and DS. Combined yield and quality results over the 2 years indicated no significant interactions between tillage, irrigation, and N rates suggesting that N and irrigation recommendations do not need to be adjusted for tillage.

Keywords: Conventional tillage, strip tillage, no tillage, direct seed

Integrated weed management for the reduction of weed control cost in cassava (741)

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In Thailand, cassava (*Mannihot esculenta* Cruntz) is an economic crop with plantation area of 1.3 million ha. Weeds are a major constraint to increasing farmers' productivity, particularly in cassava where the cost of weed control is at least 30% of total cost of production. Research on integrated weed management in cassava was comprised of two experiments conducting in eight provinces of Thailand during October 2013 to September 2015. Firstly, five tank mixtures of pre-emergence herbicides and farmer's practices (hoe weeding 3 times) were compared. The results indicated that all five tank mixtures of pre-emergence herbicides, i.e. alachlor+diuron, isoxaflutole+diuron, clomazone+oxyfluorfen, alachlor+metribuzin and s-metolachlor+flumioxazin at the rates of 1.5+1.0, 0.06+1.0, 0.63+0.15, 1.5+0.31 and 1.0+0.06 kg ai ha^{-1}, respectively, provided good weed control. In the second experiment, all participatory farmers preferred a tank mixture of s-metolachlor+flumioxazin at the rate of 1.0 +0.06 kg ai ha^{-1} for large scale field trials. When herbicides were integrated with cultural practices, there was excellent control of weeds for 3 months resulting in rapid growth of cassava plants and higher tuber yields. Clearly, herbicides reduced cost of weed control by 3.2-4.8 folds when compared with hoe weeding. In addition, 98.0% of total 403 farmers from eight provinces were satisfied with weed management and it will be practiced in the following season. Hence, integrated weed management not only minimizes cost of weed control but it also helps cassava farmers to gain higher yields.

Keywords: Integrated weed management, pre-emergence herbicides, cassava, cost of weed control

The evaluation of two weed control strategies in sugar beet and the study of crop-weed interaction in Russia and Germany (211)

Kostyantyn Bezhin *(The University of Hohenheim, Stuttgart, Germany)*

Weed management is a very important issue in sugar beet cultivation. Weed control strategy, based on the application of glyphosate-based herbicides and glyphosate-tolerant sugar beets has proven to be a good alternative to the weed management with selective herbicides. The objective of this study was to compare these two weed control strategies and to analyse the differences in crop-weed interaction between Russian and German cropping conditions by means of empirical models. The following hypotheses have been tested: (i) weed density and composition differ between locations of trial sites due to the difference in climate, soil and weed management practice; (ii) weed control efficacy of conventional strategy is equal to glyphosate-based strategy. Single glyphosate treatment provides less weed control than conventional and two and three applications of glyphosate; (iii) sugar beet yield loss caused by weed competition is higher in Russia than in Germany, (iiii) estimation of sugar beet yield loss based on the early assessment of weed biomass is more accurate than its estimation based on weed density and weed cover assessment. Studies of comparison of weed control strategies consisted of seven field experiments. Crop-weed interaction study consisted of six. The range of weed density was 58-131 weeds m^{-2} in Russia and 20-86 weeds m^{-2} in Germany. Weed cover and biomass provided an accurate prediction of the crop yield loss. Different shapes of the regression lines describe differences in crop reaction to various weed populations. Therefore, models have to be adjusted to the regional conditions. Conventional weed control strategy provided lower weed control than glyphosate-based strategy in four out of seven studies. In five out of seven experiments, single glyphosate application provided the same yield as two and three applications.

Keywords: Glyphosate, weed management, sugar beet yield, crop-weed interaction, relative yield loss

Degradation of different ACCase inhibitors in vegetables (311)

Jaroslav Suk *(Czech university of life sciences Prague, Prague, Czech Republic),* ***Miroslav Jursik*** *(Czech university of life sciences Prague, Prague, Czech Republic)*

The aim of this work was to compare the degradation of four ACCase inhibitors in lettuce, cauliflower, carrot and onion. Small plot trial were carried out during 2012–2014. The propaquizafop, quizalofop, fluazifop and cycloxydim were applied by small plot non residue sprayer Schachtner and the determination of residues was by QuEChERS method and the content of residue was set by liquid chromatography with mass spectrometry. Quizalofop was 10 days after application detected below the threshold of MRL (0.4 mg kg^{-1}) in lettuce and cauliflower. However, the residues were still detected 5 weeks after application (5 % MRL) in lettuce and 6 weeks after application (2 % MRL) in cauliflower. In carrots and onions were always detected small amounts of residues of quizalofop (1-10 % MRL). The greatest concentration of residues were detected in cauliflower, carrots and onions treated by fluazifop. In cauliflower samples were detected 10 and 20 days after application several times higher amount of fluazifop than is the MRL (0.2 mg kg^{-1}) and amount of *f*luazifop decreased below the MRL 6 weeks after application. In carrot samples was detected 2 days after application amount of fluazifop 2 times higher than is the MRL (0.3 mg kg^{-1}). However, at 3 weeks after herbicide application, there was a reduction to 33% MRL and content of residues was just above the detection limit at 5 weeks after the application. In onion, fluazifop content decreased below the MRL 3 weeks after application, but the decrease under the detection limit was three weeks later. Propaquizafop was not detected in any samples of cauliflower and carrots. Also, cycloxydim was not recovered in any samples of lettuce, cauliflower and carrot in all experiments. Hence, those four ACCase inhibiting herbicides are suitable for low residual vegetable production.

Keywords: Herbicide, residue, ACCase inhibitors, vegetable

Session 39
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Invasive Species / Weed Management in Hard Scapes

Keynote: Achievements and challenges in South Africa's environmental weed control programme (275)

Brian W van Wilgen *(Centre for Invasion Biology, Stellenbosch, South Africa),*
Andrew M Wannenburgh *(Working for Water, Cape Town, South Africa)*

South Africa's environmental weed control programme, Working for Water, simultaneously promotes conservation and poverty relief through environmental weed control projects. We trace the programme's history and review the factors that led to its success. These included a sound scientific grounding, a clear demonstration that the weeds are a serious threat to vital and scarce water resources, and a unique opportunity presented by South Africa's transition to democratic government. The programme built on historical precedents for control, and was able to capitalise on a core of dedicated managers that delivered a good-news story, leading to increased funding. The programme has facilitated advances in biological control, raised levels of awareness, enacted legislation, and promoted research. However, it has only treated a relatively small proportion of the estimated invaded area, and assessments of progress towards ecosystem-scale outcomes cannot be made as they are not monitored. The need to operate in a bureaucratic environment, an emphasis on job-creation and relative neglect of environmental goals, and high levels of political interference are significant obstacles to progress.

Keywords: Poverty relief, water conservation, biocontrol, legislation, research

Restoration of areas infested by *Ailanthus altissima* in the Alta Murgia National Park: experience within a LIFE project (730)

Francesca Casella *(CNR – National Research Council, Bari, Italy),* ***Maurizio Vurro*** *(CNR – National Research Council, Bari, Italy),* ***Angela Boari*** *(CNR – National Research Council, Bari, Italy)*

The spread of invasive alien species threatens the conservation of natural ecosystems, being the second leading cause of biodiversity loss. *Ailanthus altissima* (Mill.) Swingle (tree of heaven) is one of the most damaging invasive alien plant species, and the most important one within the Alta Murgia National Park, the second largest park in Europe, containing a great wealth of biodiversity. The species is highly present throughout the park, both in anthropic places such as antique manors and sheepfolds, where farmers intentionally planted *A. altissima* trees for shade, and in natural habitats such as grasslands and rocky soils, fields, woods edges, dry stone walls and roadsides, where they spontaneously grew. The „LIFE Alta Murgia" project, started in 2013, was funded within the European LIFE+ Framework. Its main objective is to eradicate *A. altissima* from the Alta Murgia National Park. Many large areas have been restored by using an eco-friendly and sustainable strategy for tree of heaven control based on stem application techniques able to minimize herbicide use and reduce risks for health and environment. For broad high plant density patches, best results were obtained with one winter treatment with glyphosate followed by one summer completion treatment. Stem applications provided good control with low rates of herbicide and offered many advantages: no drift, no off-target effects, selectivity, minimal need for equipment, the possibility of treatments in urban and natural areas. An official protocol for tree of heaven management will be proposed.

Keywords: Natural areas, sustainable chemical control, invasive alien species, LIFE project, ailanthus altissima

The wild and undesired vegetation in Mediterranean historic sites (431)

Ilektra Kanellou *(Agricultural University of Athens, Athens, Greece),* ***Paraskevi Dimou*** *(Agricultural University of Athens, Athens, Greece),* ***Dionissios Kalivas*** *(Agricultural University of Athens, Athens, Greece),* ***Garifalia Economou-Antonaka*** *(Agricultural University of Athens, Athens, Greece),* ***Maria Papafotiou*** *(Agricultural University of Athens, Athens, Greece)*

A geodatabase was developed using a Geographic Information System (GIS) to obtain information on the wild vegetation in three archaeological sites across Greece; Early Christian Amfipolis (Serres), Kolona (Aegina) and Ancient Messini. Detailed topographic and remote sensing data of the study areas were also included in the geodatabase. Information concerning the spontaneous vegetation was obtained by weed recordings during spring and autumn 2012 using a quadrat (50 x 50 cm) sampling, randomly placed on selected points of a compass star. The number of needed quadrats was determined using a species accumulation curve. In each quadrat, the weed species were recorded using the Braun-Blanquet scale of cover abundance and were identified using the Flora Europaea. In Amfipolis, during spring, 41 different taxa were recorded with the most abundant species *Vicia vilosa* (13% coverage), and most common *Avena sterilis* which occurred in 80% of the quadrat samples. During autumn, 31 different taxa were recorded with *Cynodon dactylon* as the most abundant (24% coverage) and most common species (63%). In Messini, during spring, 50 different taxa were recorded with *Medicago polymoprha* the most abundant species (29% coverage) and *Avena sterilis* the most common species (80%). During autumn, among 34 different taxa, *Cynodon dactylon* was the most abundant (25% coverage), and most common (55%) species. In Kolona, during spring, among 33 recorded taxa *Medicago rubosum* was the most abundant (19% coverage) and most common species (37%). During autumn, among 3 taxa the most abundant (6% coverage), and most common species (10%).was *Convolvulus altheoides.* The vegetation recordings revealed valuable information on species richness per site, their botanical and biological character and the sites coverage % per species. This information was incorporated into the geodatabase and was correlated with topographic characteristics (slope, aspect and distance from ruins).

Keywords: Archaeological sites, geodatabase, weed flora, Greece

Weeds on federal lands in British Columbia (35)

Raj Prasad *(Pacific Forestry Centre, Victoria, B.C., Canada)*

Scotch broom (*Cytisus scoparius*), gorse (*Ulex europaeus*), daphne (*Daphne laureola*) and English ivy (*Hedera helix*), are four prominent, invasive plants that pose a serious threat to Garry oak and associated ecosystems on federal lands in Victoria, British Columbia. These plants colonize disturbed areas quickly forming dense monospecific stands, remain persistent for a long time and defy any easy eradication program. They suppress and inhibit the growth of native plants and ultimately arrest forest succession. Several federal departments including the Department of Environment, Department of National Defence, Department of Fisheries and Oceans, Department of Indian Affairs and Parks Canada have expressed great concerns regarding their rapid incursion, adverse impacts and the resulting degradation of native habitats. With a grant from the Department of Environment and the Department of National Defence, we conducted research to examine the population dynamics, phenology and control methods of these invasive plants on federal lands near Victoria, B.C. Of the several methods of control tested, including manual cutting, application of a registered herbicide (triclopyr), a fungal bioherbicide (*Chondrostereum purpureum*), and a commercial plastic mulch, it was found that mulch and herbicide provided 100% efficacy on resprouting behaviour of all four invasive species. *C. purpureum* produced a variable response when applied under the field conditions. Manual cutting was found to be the least effective. Also a novel prospective bioagent (*Phomopsis* sp. *denovo*) was isolated from dying and dead samples of daphne from the field and results from laboratory, greenhouse and field conditions suggest that it may hold great potential for the control of daphne. Continued and additional research is necessary to determine the appropriate formulations of these bioagents as well as the effectiveness of different and integrated control treatments over a period of years.

Keywords: Alien invasive weeds, bioherbicide, forestry

Session 40
WEED ECOLOGY: Seeds and Soil Seedbank

Keynote: Summer interactions between host and pathogen in the *Pyrenophora semeniperda – Bromus* pathosystem (663)

Phil S Allen *(Brigham Young University, Provo, UT, United States)*

Bromus tectorum and *Bromus rubens* are highly invasive winter annual grasses in the western United States. The ascomycete fungus *Pyrenophora semeniperda* can kill infected *Bromus* seeds, particularly when these seeds are dormant or otherwise germinate slowly. This paper aims to test whether seeds that are infected during early summer and then exposed to intermittent hydration will experience sufficient disease progression to kill seeds, or whether subsequent after-ripening will result in rapid germination that allows infected seeds to escape death. Laboratory experiments were conducted to determine how periodic hydration followed by drying at various storage temperatures (30-60°C) affects mortality of initially infected seeds. Experiments at two contrasting field sites were conducted to allow infected seeds to experience natural temperature and moisture fluctuations. Both laboratory and field data confirmed that *P. semeniperda* kills infected seeds subjected to intermittent hydration episodes followed by drying. An initial infection period of 24 hours resulted in subsequent seed mortality > 60% across all treatments; seeds with an initial infection period of 72 hours experienced higher mortality (>80% and often near 100%). Dry storage of infected seeds led to varying levels of mortality depending on storage duration and temperature. These results confirm that *P. semeniperda* is favored under moisture and dormancy conditions that do not allow for rapid completion of germination. Furthermore, these data support the hypothesis that biological control efforts using *P. semeniperda* may be effective when applied during the summer where precipitation is likely before the completion of seed after-ripening.

Keywords: Seed pathogens, biological control, *Bromus tectorum*, *Bromus rubens*

Density-dependent population regulation in the hemi-parasite, *Striga hermonthica*, on sorghum (91)

Paula R. Westerman *(University of Rostock, group Crop Health, Rostock, Germany),* ***Lia Hemerik*** *(Wageningen University, Wageningen, the Netherlands),* ***Wopke van der Werf*** *(Wageningen University, Wageningen, the Netherlands),* ***Tjeerd-Jan Stomph*** *(Wageningen University, Wageningen, the Netherlands),* ***Tom van Mourik*** *(Helen Keller International, Dakar, Senegal)*

Striga hermonthica is a hemi-parasitic plant species that parasitizes crop species such as maize, sorghum, millet and rice. Density dependence feedback is likely to occur, but has not been fully investigated. Here, density dependence was studied by exposing 80 individual sorghum plants to either 0, 6230, 18710, 37420 or 93520 viable *S. hermonthica* seeds pot^{-1} in a greenhouse experiment. Different expressions of parasite and host performance were evaluated through monthly harvests, and related to the initial seed density, using descriptive models and model selection to determine the shape of the relationships. After three months, direct density dependence was apparent in all developmental stages of *S. hermonthica*, but was most intense during the holoparasitic phase. Prior to the massive elimination of competitors, there was a phase in which the presence of parasites facilitated the initiation of new infections (inverse density dependence). The overall fitness of *S. hermonthica* was not influenced by variations in seed density, as the population growth rate was constant over the range of densities tested, indicating that density dependence was exactly compensating. Knowledge on density dependence can contribute to developing ecologically based management approaches and more accurate population dynamic models capable of forecasting population trends, as aids in combating the parasite in small-holder cereal farming in sub-Saharan Africa.

Keywords: Host-parasite interactions, density dependence

The duration of seed burial in soil and their consumption rates by carabid beetles after exhumation (165)

Pavel Saska *(Crop Research Institute, Prague 6 – Ruzyně, Czech Republic),* ***Alois Honěk*** *(Crop Research Institute, Prague 6 – Ruzyně, Czech Republic),* ***Zdenka Martinková*** *(Crop Research Institute, Prague 6 – Ruzyně, Czech Republic)*

After shedding from the plant and before germination or entering the soil seed bank, predators represent the main cause of seed mortality. Predation of seeds liberated from the soil seed bank is, however, largely unknown. This contribution provides data on the duration of burial in the soil for 26 species of herbaceous seeds, and how it affects the consumption rates and preferences by model species of carabid seed predators, *Pseudoophonus rufipes* (DeGeer), *Harpalus affinis* (Schrank) and *Amara littorea* Thomson. Batches of seeds of each species mixed with fine soil particles spent 1-8 years (8 species) or 1-6 years (18 species) buried in the soil in nylon fabric bags. We used dry stored and frozen seeds as controls. Seeds were presented to the adult predators in a series of experiments. In the first experiment, we presented cohorts of seeds exhumed at particular years to individual carabid species, each species of seeds separately. In the second set of experiments, we presented all species of seeds from the same cohort simultaneously, using frozen control seeds and 6-yrs buried seeds. In general, the consumption of buried seeds was lower compared to controls, but in a few species palatability of seeds after burial increased in the 1st and 2nd year after burial compared to controls. Only in very few species of seeds burial increased the palatability of seeds for carabid beetles. In general we found correlation in both standardized and raw consumption values of control seeds and those buried for 6 years. Supported by the grant 14-02773S awarded by the CSF.

Keywords: Seed predation, granivory, soil seed bank, ground beetles

Weed seed predation in arable crops relates to semi-natural habitats in European landscapes (425)

Marjolein E. Lof *(Wageningen University, Wageningen, the Netherlands),* ***Matthias Albrecht*** *(Agroscope, Zurich, Switzerland),* ***Zita Dorner*** *(Szent Istvan University, Godollo, Hungary),* ***Martin H. Entling*** *(University of Koblenz-Landau, Landau, Germany),* ***Brice Giffard*** *(Ecole Nationale Superieure des Sciences Agronomiques de Bordeaux Aquitaine, Bordeaux, France),* ***Herman Helsen*** *(Dienst Landbouwkundig Onderzoek, Wageningen, the Netherlands),* ***Bart Heijne*** *(Dienst Landbouwkundig Onderzoek, Wageningen, the Netherlands),* ***Philippe Jeanneret*** *(Agroscope, Zurich, Switzerland),* ***John M. Holland*** *(Game & Wildlife Conservation Trust, Fordingbridge, UK),* ***Riina Kaasik*** *(Estonian University of Life Sciences, Tartu, Estonia),* ***Gabriella Kovacs*** *(Estonian University of Life Sciences, Tartu, Estonia),* ***Anna-Camilla Moonen*** *(Scuola Superiore Sant'Anna, Pisa, Italy),* ***Sonja Pfister*** *(University of Koblenz-Landau, Landau, Germany),* ***Jens Schirmel*** *(University of Koblenz-Landau, Landau, Germany),* ***Louis Sutter*** *(Agroscope, Zurich, Switzerland),* ***Márk Szalai*** *(Szent Istvan University, Godollo, Hungary),* ***Eve Veromann*** *(Estonian University of Life Sciences, Tartu, Estonia),* ***Wopke van der Werf*** *(Wageningen University, Wageningen, the Netherlands)*

Greening policies require increased knowledge about interactions between semi-natural habitat (SNH) and ecosystem services such as pollination and pest control that are supported by these habitats at the landscape scale. The EU-FP7 project QuESSA (Quantification of ecological services for sustainable agriculture), aims to quantify how SNH composition and configuration affect weed seed predation levels in arable fields in Germany, Estonia, Switzerland, England, Hungary, Italy, in French vineyards and in Dutch orchards.In each case study (country-crop species combination), 18 fields were selected on separate farms. Landscape context around each focal field was digitized, characterizing all landscape elements wider than 3 m in a 1 km circle. Fields were selected to represent a gradient in the proportion of SNH in the surrounding landscape sectors. Fields had either a woody, herbaceous or no field margin adjacent to the transects, with 6 fields of each type. In each field, eight seed cards covered with a 1-cm wire mesh, containing 20 *Poa trivialis* and 20 *Chenopodium album* seeds were exposed for 7 days on two transects, 10 m apart, at four distances from the field margin. We used GLMs to model the expected seed predation in the fields as a function of variables characterizing the landscape, the margin habitat and distance from the margin. To link habitat and seed predation, a modelling approach was used that assumes that the amount of seed predation at a given target site is the sum of contributions from different sources in the surrounding landscape, according to their area and distance from the target. Semi-natural habitats in the landscape had significant effects on seed predation, but the size and direction of effect varied between studies, species of seed, and habitat type.
This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration.

Keywords: Ecosystem services, field margin, woodland, modelling, land use

Session 41
AGRICULTURAL, ECONOMIC AND SOCIETAL ASPECTS OF WEED MANAGEMENT: Directed Weed Management

Keynote: Participatory action research for weed management (222)

Fernando Pellegrini *(Scuola Superiore Sant'Anna, Pisa, Italy),* ***Ambrogio Costanzo*** *(Scuola Superiore Sant'Anna, Pisa, Italy),* ***Daniele Antichi*** *(University of Pisa, Pisa, Italy),* ***Paolo Barberi*** *(Scuola Superiore Sant'Anna, Pisa, Italy)*

Living mulches may represent an interesting tool for weed control for organic and low-input arable farmers. However, a major challenge is to implement novel practices in a complex agricultural world, where multiple and sometimes contrasting views arise. Our aim was to study the socio-economic issues related to living mulch application, and to trigger the first Participatory Action Research group in the area. In spring-summer 2015 we performed fourteen semi-structured interviews with farmers, technicians and academics, and we set up an on-farm trial to test different living mulch options for common wheat. We organized focus groups with stakeholders with the objectives of defining the trial treatments and periodically assess the results. We found that farmers prefer to adopt innovations using a step-by-step approach, and would adopt living mulch if this practice does not interfere with their economic objectives. Farmers often do not have information on weed management due to the lack of public extension services, and they are undergoing a process of fragmentation. As a consequence, farmers are usually left out of decisions regarding agricultural innovations, hence they considered participatory group activities as important moments for their personal learning process. This experience provides a good indication that universities and extension services need to incorporate more participatory approaches in their agenda, especially when adoption of novel, environmentally friendly practices is sought. Activities that encourage the creation of networks of farmers, technicians and consumers may foster innovation in agriculture.

Keywords: Living mulch, Participatory, Action research, Common wheat, Organic agriculture

Long-term impacts of direct-seeded rice in Punjab State of India: weed dynamics, crop productivity and economic analysis at farmers' fields (328)

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Direct-seeded rice in unpuddled fields (DSR) has been introduced in Indian Punjab, in 2009, as an alternative to conventional system of hand transplanting of rice seedlings in puddled fields (PTR), for effecting labour, groundwater and energy savings. The impact analysis of DSR was undertaken through a survey of local farmers. A questionnaire was prepared and 211 farmers, who had adopted DSR in 21 villages in districts Bathinda, Faridkot and Muktsar, were surveyed during 2013 and 2014. The results indicated that farmers adopting DSR increased from 10 in 2009 to 211 in 2012 in these villages. The continuous adoption of DSR resulted in shift in weed flora from typical aquatic rice weeds to aerobic grasses, and from annual to perennial sedges. The intensity of *Dactyloctenum aegyptium, Leptochloa chinensis*, *Eragrostis* sp., *Cyperus rotundus* increased while that of *Echinochloa crus-galli*, *Echinochloa colona*, *Cyperus iria* and broadleaf weeds decreased over four years. The use of recommended herbicides increased over time; in 2012, 40.7 and 83.4% farmers used recommended pre- and post-emergence herbicides, respectively. The weed shift was relatively slow where farmers used recommended herbicides as compared to when they used un-recommended herbicides. The sequential applications of pre- followed by post-emergence herbicides and spot weeding provided effective control of complex weed flora. DSR recorded some yield penalty in first 1-2 years of adoption as compared to PTR; after that the farmers were able to achieve similar or higher yields than PTR. Farmers skills in sowing techniques and weed management improved over time, which filled the gap in productivity between DSR and PTR. DSR achieved higher net returns (USD 17- 62/ha) than PTR. Grain yields of succeeding wheat were 5.3% higher when it followed DSR than after PTR. The total net returns from DSR-wheat system exceeded PTR-wheat system by USD $80-102/ha.

Keywords: Dry seeding, economics, establishment, weed, wheat

Silybum marianum and *Parthenium hysterophorus*: threat to biodiversity and crop production in Northwest Pakistan (284)

Khan B Marwat *(SBB University Sheringal, Upper Dir, KPK, Sheringal, Upper Dir, Pakistan)*

Invasive weeds are posing the major threat to the biodiversity and crop production globally, including Pakistan. Among several other invasive weeds, Silybum marianum and Parthenium hysterophorus have invaded Agricultural as well as non-cropped areas in many parts of Northwest Pakistan. Due to climatic change, the growth and reproduction of Silybum marianum has been increased by many folds. Thus many farmers use it as fuel and others collect its seed for sale in the market. This way the seeds are inadvertently disseminated to the far flung areas, therefore the plant has taken the shape of invasive weed in Pakistan. Similarly, Parthenium hysterophorus is used in bouquets as cut flower by the farmers and cut flower industry as a source of income. In addition to causing allergy, both the weeds are allelopathic and release toxic materials into the soil and surrounding environment. In addition to the fore-mentioned uses and abuses, both the weeds are threat to biodiversity and will result into monoculture by replacing our desired flora. Experimental data and survey suggest that the spread of these plants should be prevented and farmers should be made aware of the threat posed by such weeds.

Keywords: Invasive weeds, Biodiversity, climate, Utilization of weeds, allelpathy

Improved weed management to increase adoption of conservation agriculture, lift farmers' profits and protect environmental health in the Asian-Pacific Region (553)

Deirdre Lemerle *(Charles Sturt University, Wagga Wagga, Australia),* ***Michael J Widderick*** *(Queensland Department of Agriculture and Fisheries, Toowoomba, Australia),* ***Toni Nugent*** *(Charles Sturt University, Wagga Wagga, Australia)*

Conservation agriculture (CA), incorporating crop residues and reduced or no-tillage **has benefits and costs, including, increased ground cover,** soil conservation and productivity, lower energy and labour costs, and improved sowing time. CA is dependent on herbicides for weed control leading to herbicide resistance, changes in weed species and dynamics, and reduced herbicide performance.

In Australia, CA has been practiced since the 1980s and herbicide resistance is widespread. Herbicides are simple and cost-effective and it is not until farmers 'hit the wall' with resistance that they consider alternative non-chemical options. Leading farmers now are managing resistance and reducing weed seedbanks with diverse crop/pasture rotations that provide more control options.

In contrast, many smallholders in south Asia still practice aggressive tillage with traditional weed control. Low adoption of CA here is due to: lack of knowledge, system complexity, lack of suitable planting equipment, and limited access to herbicides. Recently, rapid increases in herbicide usage due to rising labour costs, is leading to risks of environmental pollution, human and animal safety, and development of herbicide resistance.

As community and political pressures increase for food security, environmental protection and adaption to climate change, government incentives for farmers to adopt CA will increase. Farmers require reliable information on the benefits and costs of weed control technologies. As complex biophysical and socio-economic factors influence adoption, this is more likely if practices lead to systems that are flexible, profitable and reduce risk.

We discuss opportunities and challenges facing weed management in CA as agricultural production intensifies, by integrating 'lessons learnt' in Australia with traditional practices used in other areas. Collaboration, effective communication and sufficient funding will facilitate this process.

Keywords: Conservation agriculture, herbicide resistance, food security, crop intensification, weed management

Session 42
NON-CHEMICAL WEED CONTROL TOOLS: Integrated Approaches

Keynote: How to target weed problems if we are to rely less on herbicides? (465)

Lammert Bastiaans *(Wageningen University, Wageningen, the Netherlands)*

The low labour requirement and high efficacy of herbicidal control has shaped weed management into an activity with a strong focus on the current season, in which weed seedlings appear as prime target. The downside is that, currently, insufficient attention is paid to preventative (or cultural control) measures that focus on life cycle stages other than the seedling stage. Such measures are becoming increasingly important, since the reduction in number of available herbicides, following stricter regulations and herbicide resistance development, undermines the sustainability of current weed control systems. Insufficient knowledge on the true potential of preventative measures makes it difficult to convince farmers of their usefulness. Establishing this potential can, however, be complex, as their contribution to solving instant weed problems is usually less significant than their impact on long-term weed population development. The aim of the current simulation study was to better appreciate the effectiveness of preventative measures. The study centred around a life-cycle-stage weed population model. Population dynamics and steady state seed and plant population density were determined and linked to traits like competitiveness, seed size, seed persistence and dormancy, that together shape the weedy character of a species. The model was then used to establish how intrusion in specific life cycle stages of a range of weed species was effective in decreasing their population density. Marked interactions between weed species and targeted life cycle stages were identified. This implies that the effectivity of cultural control measures is dependent on the composition of the weed community. The same modelling construct provided clues on which preventative measures are likely to generate synergy if applied in combination. Such insights are highly relevant for better exploitation of cultural control measures and for the development of integrated weed management strategies in which preventative measures are skilfully interwoven with chemical control.

Keywords: Cultural control, preventative measures, population dynamics, modelling, life cycle stages

Alternatives for reducing tillage in organic annual grain systems: Implications for weed management (231)

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One of the biggest factors affecting crop performance is interference by weedy species. Tillage and use of herbicides are common ways to combat this issue; however, weeds are adapting and showing herbicide resistance, prompting farmers to use more herbicides and resort to more tillage. U.S. maize and soy production show some of the greatest yield loss due to weeds, while receiving some of the highest herbicide inputs of crops in the United States. Costs associated with herbicides, fuel use from frequent passes through the fields, and erosion from soil disturbance are causing farmers to rethink approaches to fighting weeds through alternative methods. We are addressing some of these concerns by investigating alternative approaches to weed management in an organic grain system that is focused on crop rotation, cover cropping, and reduced tillage. Our previous organic research project showed effective control of weedy species below economic thresholds; however, it also demonstrated agronomic challenges such as inconsistent termination of cover crops, inconsistent establishment of cash crops in high residue, rolled cover crop mulches, and issues with a narrow window for establishing cover crops following cash crop harvest. To address these concerns, we have refined these systems and developed alternative strategies such as relay planting cover crops using interseeder technology, and companion seeding of cover crops in spring into a winter cereal grain. Weed seedbank dynamics, growth, and fecundity are being studied, along with cover crop and cash crop performance. It is our goal to improve cover crop and reduced tillage strategies in organic grain systems in the northeastern U.S. and to use these results to reduce grower-defined production pressures.

Keywords: Organic grain systems, cover cropping, reduced tillage, weed suppression

Cover-crop management to control *Cynodon dactylon* in vineyards: balance between efficiency and sustainability (156)

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The management of cover-crop in vineyards in NE Spain focuses on minimizing soil erosion and compaction. Nonetheless, such practices have shown to influence the weed community in the interrows, especially the spread of *Cynodon dactylon*; thus highlighting the need for investigation of how cover-cropping practices interact with weed control techniques in spatially distinct portions of the vineyard floor. Understanding this impact on weed flora may decrease the need for herbicides and improve sustainability of wine grape production systems.

An experiment was conducted in the Raïmat vineyards (Catalonia, Spain) during the 2015 growing season. The aim of this research was to evaluate the response of *Cynodon dactylon* under the influence of four cover-crop systems: M1: a no-till resident vegetation cover-crop managed by shredding 2-3 times per season; M2: the same as M1, plus regular herbicide application (Glyphosate or Gluphosynate) during the season; M3: forage grass cover-crop (*Festuca arundinacea*) sown in autumn over a tilled interrow; M4: barley cover-crop (*Hordeum vulgare*) sown in autumn over a tilled interrow. The intrarow grape-vine was managed using different herbicides.

Each treatment was monitored in four different 3x10m plots situated in different interrows. To know the evolution of the presence and cover (%) of *Cynodon dactylon,* their population densities were estimated in 120 quadrats measuring 0.5 x 0.5m, on four different dates throughout the season (winter, summer, autumn and the following winter). Data was then analyzed and represented with seasonal maps generated by the JMP program. Furthermore, a three-way analysis exploring agronomic (efficacy), economic (cost) and energetic (carbon footprint) criteria was developed based on the balance between efficacy and sustainability of the different treatments.

Keywords: Cover-crops, Vineyard, Cynodon dactylon, Management, Sustainability

Participatory research on the basic cation saturation ratio approach to soil management: effects on weed communities, soils and crops in an organic grain rotation (434)

Douglas Doohan *(The Ohio State University, Wooster, United States),* ***Warren Dick*** *(The Ohio State University, Wooster, United States),* ***Steven Culman*** *(The Ohio State University, Wooster, United States),* ***Catherine Herms*** *(The Ohio State University, Wooster, United States),* ***Laura Lindsey*** *(The Ohio State University, Columbus, United States),* ***Matthew Kleinhenz*** *(The Ohio State University, Wooster, United States),* ***Subbu Kumarappan*** *(The Ohio State University, Wooster, United States),* ***Alan Sundermeier*** *(The Ohio State University, Bowling Green, United States)*

Our goal is to create a commonly-accepted knowledge base specific to “soil balancing” and its effects on soils, crops, and weeds. Centered on the Basic Cation Saturation Ratio (BCSR) hypothesis, an ‘ideal soil’ should have a saturation ratio of 70% Ca, 10% Mg, and 5% K. In a survey involving 30 organic farmers in Ohio and Indiana, more than 50% expressed a belief that weed problems were related to unbalanced soil. Organic farmers searching for solutions to weed management like soil balancing because it is straightforward and seems to positively affect soils, crops, and weeds. However, it is costly compared to a nutrient sufficiency approach, and potentially damaging to soils. The effects of soil balancing on soil structure and biology, weed control, crop yield and quality are unresolved questions of great theoretical, environmental and economic importance. We established an Organic Farming Research Network in concert with our state-wide organic farming organization (Ohio Ecological Food & Farming Association) to facilitate scientist and farmer collaboration to better understand interactions between soil management and weeds. Collaborative research is documenting farmer experience with soil balancing and weed communities. Four long-term field experiments have been established at certified organic facilities operated by the Ohio Agricultural Research and Development Center. Site-specific sets of treatments were designed to measure costs and impacts of calcium-rich amendments and rotations on soils, weeds and crops. Two years of limestone plus gypsum, or limestone alone applied to a low pH (<6), low CEC (<10) soil increased calcium saturation but did not ‘balance’ the soil. S concentration throughout the soil profile and in crop foliage was enhanced by gypsum. Beneficial effects on soil structure, weed communities and crops were not detected, but are subjects of ongoing investigation that will take place over the next four years.

Keywords: Soil balancing, basic cation saturation ratio, gypsum, limestone, organic farming

Session 43
HERBICIDES AND APPLICATION TECHNOLOGY: Formulations, Adjuvants and Tank-Mixtures

Keynote: Novel high capacity slow release herbicide formulations with new uses (837)

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Rapid leaching from near the soil surface, where they are the most active is a major problem with many herbicides. Creative formulation for placement selectivity improves selectivity and is generally applicable, cost effective and technically feasible for many herbicides.
Delivering herbicides as dry granules avoids foliar uptake and drift. It does but requires uniform distribution and moderation of leaching rates to lower soil levels where crop seeds are placed. We developed a technology based on placing herbicides within a so-called sub-granule. These 30 to 60 µm granules are pressed into a 2 to 4 mm conventionally dimensioned granule for broadcast application.
The first problem to solve with this approach is uniform distribution of the sub-particles given that the granules themselves have only limited coverage with moisture driven granule disintegration. Excipients within the main granule include both gas sources and surfactants that generate stabilised foams following contact with water. Foam formation serves to disperse enclosed sub-particles in response to rain.
Hydrophobic matrices with limited water solubility moderate release from sub-granules, maintaining surface herbicide concentrations and reducing leaching. They can contain micro-nutrients and other water soluble inclusions which are released during particle erosion,. Hi-Cap Formulations has developed such formulations based on biodegradable ingredients including acetyl and methylcellulose that ensure such release of the herbicide effecting weed control. Application of these materials in paddy rice enables the safe and effective use of bleaching herbicides such as sulfentrazone via placement effects. Similarly, the application of these granules containing imazapyr to the seeds of ALS resistant maize for *Striga* control provides for both an increase in stand due to reduced seedling stress from excess early season herbicide exposure as well as extending the duration of *Striga* control due to slower leaching. These factors led to improved, stand, reduced *Striga* emergence and overall higher yield.

Keywords: Slow release, hydrophobic herbicide sub-granules, preventing herbicide leaching, Striga, Rice

Effect of water salinity used in the spray solution on crop tolerance and weed control (450)

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The electrical conductivity (EC) or salinity of well water increased in counties during a recent drought. The increased salinity is a result of salt incursion from the ocean. The water is used for the application of herbicides and other pesticides. The first trial objective was to understand the effect of a single or multiple applications of various spray solutions with increasing electrical conductivity. The second trial objective was to understand the effect of increased salinity on the crop safety and weed control of a single postemergence application. Both experiments were conducted in the greenhouse at the Plant Science Research and Education Unit in Citra, FL. Treatments for the first study were a factorial design with six EC levels and five timings. The six EC levels were 0, 1, 2, 3, 4, or 5 ds m^{-1}. The five timings were zero, one, two, three, or four repeat applications. Treatments were applied to watermelon, green bean, and sweet corn. Injury occurred as necrosis along the edges of the leaves. Three or four application of 4 or 5 ds m^{-1} had greater injury than the nontreated. Treatments in the second trial were a factorial design with six EC levels and four herbicides. The EC levels were similar to the first trial. The herbicides treatments were halosulfuron at 16 g ha^{-1}, metribuzin at 228 g ha^{-1}, and sethoxydim at 128 g ha^{-1}, and no herbicide. Herbicides were different in crop tolerance and weed control. EC levels were not different for crop injury or weed control across herbicides tested. The use of water with high EC levels in spray solutions with repeat applications of fungicides and insecticides may cause injury. Further research is required to determine the impact on EC on fungicide and insecticide efficacy.

Keywords: Salinity, electrical conductivity

Impact of deposition aids on herbicide penetration into crop canopies (421)

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Chase A. Samples *(Mississippi State University, Mississippi State, United States),* ***Greg Kruger*** *(University of Nebraska, North Platte, United States)*

Cotton and soybean crops tolerant to 2,4-D and dicamba have been developed and are commercially available in the United States. While the use of 2,4-D and dicamba provide producers with an additional option for control of glyphosate-resistant Palmer amaranth, off-target movement of these products is a primary concern for U.S. producers. Deposition aids are available to producers and are sold in order to reduce off-target movement of pesticides. Little to no data exists regarding the impact of deposition aids on deposition of pesticides into crop canopies. Therefore, this project was initiated to determine how the use of deposition aids effect deposition of selected herbicides and insecticides into the canopy of cotton and soybean. Experiments were conducted in 2014 and 2015 using a guar gum, a polymer, and an oil based deposition aid with glyphosate and glufosinate to determine the effectiveness of these deposition aids on improving canopy penetration of glyphosate and glufosinate as a model for 2,4-D and dicamba applications. Mylar cards were placed at various locations with the canopy of cotton and soybean crops and immediately after application, each card was collected and placed in a dark container. Mylar cards were evaluated using a fluorimeter to determine level of deposition within the crop canopy. In addition, herbicide and deposition aid combinations were evaluated for droplet size comparison at the wind tunnel facility at the University of Nebraska-Lincoln's West Central Research and Extension Center. Preliminary results regarding canopy deposition were variable. Generally, polymer based deposition aids as well as the addition of glyphosate maximized deposition within the crop canopy. Spray droplet size was greatest in tank-mixtures containing a polymer or guar gum based deposition aid. Further research is needed to determine if deposition aids improve deposition with the crop canopy and to determine the level to which they reduce off-target movement of pesticides, if any.

Keywords: Deposition aid, cotton, soybean

Herbicidal potential of some essential oils vis-à-vis three noxious weed species invading cereals (19)

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Amina Daoud-Bouattour *(Faculty of Sciences of Tunis, Tunis, Tunisia),* ***Zeineb Gammar-Ghrabi*** *(National Agronomic Institute of Tunisia, Tunis-Mahrajène, Tunisia)*

A study was conducted to assess the herbicidal efficacy of essential oils extracted by water/steam distillation from seven medicinal and aromatic plants of the Tunisian flora: *Artemisia herba-alba* Asso., *Mentha pulegium* L., *Rosmarinus officinalis* L., *Salvia officinalis* L., *Lavandula officinalis* L., *Eucalyptus gomphocephala* DC., and *Foeniculum vulgare* Mill.; selected based on ethnobotanical data. In vitro trials were carried out to test the inhibitory activity of these volatile oils against seed germination of three Mediterranean noxious weed species: *Sinapis arvensis* L., *Rumex crispus* L. and *Phalaris minor* Retz., invading grain crops. The same bioassays were conducted concurrently for two winter cereals (wheat and barley) as non-target species. The results revealed a differential response among weed species as well as a disparity across the essential oil activities. Solely oils from *A. herba-alba*, *M. pulegium* and *L. officinalis* drastically inhibited seed germination of *P. minor* and *S. arvensis*. In case of *P. minor*, the inhibitory effect of these oils exposured to the lowest tested concentration C1 = 100 ppm were obvious. Based on their phytotoxic potency (IC_{50}), the most active essential oils could be subsequently ranked as *M. pulegium* > *L. officinalis* > *A. herba-alba*. A phytochemical study using GC/FID and GC/MS was conducted. The abundance of oxygenated monoterpenes might thereby explain the potent inhibitory activity of the oils. *A. herba-alba* essential oil exhibited a distinct chemical composition which would characterize the Tunisian Dorsale. Hence, these promising findings may solve some environmental issues related to pesticide pollution and hold the key to non-chemical weed management.

Keywords: Bio-herbicides, essential oils, seed germination, weeds, cereals

Session 44
WORKSHOP ON GRASS WEED GENOMICS 2

Weed genomes as potential sources of new, adaptive agronomic traits: a summary of Kochia scoparia research in North America (834)

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Modern weed control based largely on herbicides has increasingly run head on into difficult and significant issues of herbicide resistant weeds, which compromise the utility of some of the best products in the marketplace. Weed biology focused on a variety of weed issues including, resistance, dormancy, competitive ability, traits that ensure weed success, etc., sits at the crossroads of many lines of research including agronomy, chemistry, biochemistry, ecology, and more recently molecular biology, in part due to the evolution of herbicide resistance. To better integrate weed biology in future agriculture challenges, genetic tools including the transcriptomes and the genomes of model weedy organisms need to be developed and made available to the research community not only to improve weed control, but also to mine weeds for desirable traits that could enhance crop productivity. Current "model" plant species do not have the same traits or complexity as many weedy species making them less effective models. Our research team has begun the ambitious effort of sequencing the genome of *Kochia scoparia*, an important weed in western North America that has evolved multiple herbicide resistance mechanisms. This species has desirable agronomic traits such as cold, heat, and salt tolerance, and research over 30 years has shown its wide range of adaptability. The large, complex, and malleable genome of *K. scoparia* makes sequencing and genome assembly an interesting challenge. Our initial findings demonstrate the challenges in assembling complex weedy species genomes and the potential for using cutting-edge molecular tools to improve our understanding of weed biology and weedy traits. This research is part of a longer-term goal of developing a global center of functional weed genomic studies at Colorado State University.

Keywords: *Kochia scoparia*, Weed Genome, Functional Genomics, Agronomic Traits, Crop Improvement

Current state of genomics research in European most important herbicide-resistant weed grasses: a review (841)

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Herbicide resistance is an evolutionary process, and its dynamics and impact are dependent upon many genetic, biological, herbicidal and operational factors (Powles and Yu, 2010). A main prerequisite for managing a weed is that the weed should be well understood. We are far beyond the understanding of weed traits that enable a weed to survive a herbicide treatment under fast changing environmental conditions. In Europe, on the top of the list in herbicide resistant grass weeds are *Alopecurus myosuroides*, *Avena fatua*, *Apera spica-venti*, *Echinochloa crus-galli* and *Lolium perenne*, respectively, in descending order based on the reports available on Heap (2016) website. More than 90% of herbicide resistant cases are associated with just few mode of action groups, predominantly to ACCase and ALS inhibitors. The genomic information for studies in herbicide resistance is limited in most cases. The molecular biology tools are mostly used to study the mechanisms and evolution of herbicide resistance in weed populations. In many cases the whole genome sequences are lacking, markers that can be developed without prior knowledge of the genomic sequences have been used by scientists working with weeds (Baker et al., 2007). Our current understanding of target site resistance strongly supports the idea that parallel genetic changes, and thus genomic constraints, are responsible for convergent evolution of the resistance phenotype (Baucom, 2016). Recent studies (Délye, 2013) have shown that non-target site resistance (NTSR) is more common than it was ever thought. Currently, very little is known about the genetic basis of NTSR, but reports indicate that its control can be either monogenic (Yu et al., 2009) or polygenic (Petit et al., 2010). Many questions remain unanswered about herbicide resistance. There is a potential for utilizing genomic resources developed for crops and model species such as *Arabidopsis*.

Keywords: Barnyardgrass, blackgrass, non-target site resistance, silky windgrass, target site resistance

Strategies for genome sequencing, comparative genome analysis and genomic prediction in grasses (842)

Torben Asp *(Aarhus University, Slagelse, Denmark)*

Many economically important grass species have complex genomes that pose significant challenges in producing high-quality genome assemblies. Additionally, hybridization and many centuries of selective breeding have resulted in agriculturally important grass species that have highly heterozygous and often also polyploid genomes with a high proportion of repetitive DNA. Thus, considerable technical obstacles must be overcome before such complex genomes can be fully assembled.

Lolium perenne (perennial ryegrass) is an outbreeding diploid species with an estimated genome size of approximately 2.2 Gb. It is the principal forage species used in temperate agriculture and therefore a prime candidate for genome sequencing. The first Illumina-based draft genome was published in 2015 (Byrne et al., 2015).

Recent advances in BioNano optical mapping and PacBio long-read third-generation sequencing technologies and new strategies for data integration have made it possible to generate *de novo* assembled grass genomes that approach reference quality. Progress towards generating an accurate high-quality *de novo* reconstruction of the perennial ryegrass genome is presented.

The availability of the perennial ryegrass genome will enable comparative genome analysis, efficient discovery and characterization of genetic variation, and a deeper understanding of the genetic control of important complex traits. This will accelerate the discovery of candidate genes to study herbicide stress response, and the implementation of genomic prediction breeding within forage grasses, leading to better varieties, and more productive and sustainable grasslands.

References

Byrne S, Nagy I, Pfeifer M, Armstead I, Swain S, Studer B, Mayer K, Campbell JD, Czaban A, Hentrup S, Panitz F, Bendixen C, Hedegaard J, Caccamo M, Asp T, 2015. A synteny-based draft genome sequence of the forage grass *Lolium perenne*. The Plant Journal (DOI: 10.1111/tpj.13037).

Keywords: Perennial ryegrass, Genome sequencing, Comparative genomics, Genomic prediction

Session 45
HERBICIDE RESISTANCE: Herbicide Resistance Management

Keynote: Crop rotations and cultural practices control wild oat (*Avena fatua*) (184)

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Summer-annual crops facilitate summer-annual weeds. In western Canada where summer-annual crops predominate, summer-annual weeds thrive. There, wild oat control leads to more herbicide applications than any other weed species. Consequently, wild oat resistance to herbicides is Western Canada's most wide-spread resistance issue. Truly integrated weed management strategies are required to slow weed resistance evolution and to preserve herbicide efficacy. A direct-seeded (no-till) field experiment was conducted from 2010 to 2014 at eight Canadian sites to determine crop life cycle, crop species, crop seeding rate, crop usage and herbicide rate combination effects on wild oat management and canola yield. Forgoing wild oat herbicides in only two of five years in exclusively summer annual crop rotations resulted in higher wild oat density, above-ground biomass and seed banks. Conversely, combining 2x seeding rates of early-cut barley silage with 2x seeding rates of winter cereals and excluding wild oat herbicides for three of five years (2011 to 2013) often led to similar wild oat density, biomass, seed density in the soil and canola yield as a repeated canola-wheat rotation under a full wild oat herbicide rate regime. Wild oat was similarly well-managed after three years of perennial alfalfa without wild oat herbicides. Integrated weed management systems that effectively combine diverse and optimal cultural practices against weeds, and limit herbicide use, reduce selection pressure for weed resistance to herbicides and prolong the utility of threatened herbicide tools.

Keywords: Integrated weed management, alternative weed management, combined practices, herbicide resistance, selection pressure

Lime improves control of resistant wild radish (*Raphanus raphanistrum*) and rigid ryegrass (*Lolium rigidum*) in low pH soils in Western Australia (126)

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Herbicide resistance in wild radish and rigid ryegrass is widespread in Western Australia (WA) where soil pH is well below 7. Low soil pH allows the growth of weeds but limits the growth of sensitive crops. A study was undertaken from 2010 to 2014 across three rainfall zones (Eradu, Wongan Hills and Merredin) of WA Wheatbelt to examine the effect of lime applied in acid soil on the growth of herbicide-resistant weeds and performance of wheat and barley crops. All experiments were conducted in a split-plot design with lime in the main plots and herbicides in the sub-plots. Limesand was applied in 2010 on the soil surface and incorporated by planting, increased soil pH by more than one unit at the top soil (0 to10 cm) but the soil pH at the sub-soils (10 to 20 cm or 20 to 30 cm) was still below 4.8. No effect of lime on the density of any weed was observed in the first three years after application but therafter lime reduced the in-crop density of resistant wild radish by 13 to 48% at Eradu (*cf* 120 plants m^{-2} in no lime plots). Increases in lime rate also reduced in-crop density of barley grass (*Hordeum vulgare*) by 67% and resistant rigid ryegrass by 41% to 59%. Herbicide applied in the sub-plots was very effective on all weeds leading to significant increases in grain yield. In the 4th year, presence of lime increased efficacy of herbicide on wild radish at Eradu. Results suggest that limesand applied on soil surface can reduce weed density but it may take 3 to 4 years after application to get the benefit. Although further research is required to understand the mechanism how lime reduces weed density in soil, lime showed potential to reduce density of resistant radish and ryegrass.

Keywords: Herbicide resistance, Lime, Wild radish, Rigid ryegrass, Herbicide efficacy

Management of glyphosate resistant weeds in Australia (114)

Christopher Preston *(University of Adelaide, Glen Osmond, Australia)*

Glyphosate is the most important herbicide in World agriculture and used widely to control weeds in many situations. However, the intensive use of glyphosate has resulted in the evolution of glyphosate resistant weeds. Glyphosate resistance was first identified in *Lolium rigidum* in Australia in 1996. Since then resistance to glyphosate has occurred in a further 10 weed species and over numerous additional sites in Australia. Resistance has appeared across a wide range of situations, including chemical fallows, no-till crop production, in orchards, vineyards, vegetable production, railway rights of way, around structures, in irrigation channels and along road sides. Most of these situations are characterised by: intensive use of glyphosate, limited competition from other plant species, and few other weed management tactics employed. There are many users of glyphosate and different users intersect within the landscape. This means that glyphosate resistant weeds can easily move from one site to another where the management practices will be similar. This situation creates significant challenges to managing glyphosate resistant weeds. In order to address these issues in Australia a multi-pronged approach has been used. This includes the development and communication of practices for management of glyphosate resistant weeds, engagement with all the sectors using glyphosate about resistance, and the delivery of information specific to each sector. A key role has been played by the Australian Glyphosate Sustainability Working Group (AGSWG) in developing and delivering messages about glyphosate resistance. The AGSWG is comprised of representatives from academia, various production industries and chemical companies. Its role is to discuss issues related to glyphosate resistant weeds and their management, to develop clear and consistent messages related to glyphosate resistance, and to foster the communication of these messages to end users. In this way, end users are provided with clear, evidence-based messaging about management of glyphosate resistant weeds.

Keywords: Glyphosate resistance, Chemical fallow, Vineyard, *Lolium rigidum*, Resistance management

Herbicide-resistant weed management must include more than herbicides (36)

Micheal DK Owen *(Iowa State University, Ames, United States)*

Herbicides have been the principal means of weed control in developed countries for approximately 50 years because they are the most cost effective means. Such general use of herbicides has caused weed resistance to herbicides which continues to be a growing problem. The evolution of herbicide resistance to a number of economically important weeds in the Midwest United States is an increasing problem. For example, estimates in Iowa suggest that more than 50% of the fields have *Amaranth tuberculatus* populations with multiple herbicide resistances including 7% of the fields with resistances to five mechanisms of action. Given the dearth of new herbicides with novel mechanisms of action, it appears inevitable that weed management programs will need to be supplemented by use of tactics other than herbicides alone. However, the inclusion of more diversity for weed management also introduces complexity, cost and time constraints to current crop production systems. While herbicides will continue to be the most important strategy to manage weeds, learning to use herbicides in a more diverse manner is paramount. Current herbicide use tactics have not abated the problem and must be improved. Mechanical and cultural strategies should be used as appropriate. Increase the diversity of weed management tactics and provide considerable thought and oversight to individual fields. Furthermore, the social and economic barriers must also be overcome. Management of herbicide-resistant weeds must be approached at the landscape level if programs are to be successful. Community-based efforts must be considered and should be organized and initiatives driven from the "bottom up" rather than the traditional "top down" programs historically delivered by extension and companies. Government incentives are likely to play a major supportive role. How these new ideas are implemented and whether or not momentum can be sustained is a concern.

Keywords: Herbicide-resistant, Cultural, Mechanical, Alternatives, Amaranthus

Glyphosate-resistant *Conyza canadensis* control in a corn/soybean/winter wheat rotation in Canada (168)

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Glyphosate-resistant (GR) *Conyza canadensis* (Canada fleabane) was first reported in Ontario, Canada in 2010 when it was found on 8 farms in one county. Over four years it has spread to 25 counties over a distance of greater than 800 km. Multiple resistant (Group 2 and 9) *Conyza canadensis* has been documented on more than 10% of affected farms. *Conyza canadensis* is an extremely competitive weed and lack of control in corn, soybean and wheat can lead to significant yield losses. More than 50 field experiments were conducted during 2011-2015 to determine the best herbicide options (among registered herbicides in Ontario) for the control of GR *Conyza canadensis* in corn, soybean and wheat. All experiments were arranged in a completely randomized block design with four replications. Among corn preplant herbicides evaluated, dicamba, dicamba/atrazine, mesotrione+atrazine and saflufenacil/dimethenamid-P provided 88, 94, 89 and 91% control of GR *Conyza Canadensis*, respectively. Among corn POST herbicides evaluated, dicamba, diflufenzopyr/dicamba, dicamba/atrazine and bromoxynil+atrazine provided 96, 91, 96 and 91% control of GR *Conyza Canadensis*, respectively. The best herbicide option for enhanced burndown of GR *Conyza Canadensis* in soybean was glyphosate plus saflufancil which provided 77% control. In winter wheat, 2,4-D, dicamba, dicamba/MPCA, dicamba/MPCA/mecoprop-P, clopyralid and pyrasulfotole/bromoxynil provided 89, 91, 94, 92, 96 and 92% control of GR *Conyza Canadensis*, respectively. Based on these results, an integrated weed management program which employs a three crop rotation and multiple herbicide modes-of-action can be used for commercially acceptable control GR *Conyza Canadensis* in corn, soybean and winter wheat.

Keywords: Glyphosate-resistant, rotation, mode of action, Multiple resistant, Canada fleabane

Seed-mediated gene flow in *Kochia scoparia* (15)

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Pollen flow and seed movement are critical factors affecting the spread of herbicide-resistant weeds. Confirmation of glyphosate-resistant *Kochia scoparia* in western Canada generated interest in gaining further knowledge of its seed dispersal. Stems of mature plants breakoff at ground level and thus plants have a tumbleweed seed dispersal mechanism. An experiment was conducted at Scott, Saskatchewan and Lethbridge, Alberta using mature *Kochia scoparia* plants tagged with mini-GPS collars. When wind speeds were sufficiently high (> 20 km hr^{-1}), four plants spaced 50 m apart were released and allowed to move across a farm field to a given distance (ca. 300 m at Scott and 1000 m at Lethbridge). The experiment was conducted three times at each site. Percentage seed drop was calculated by weighing plants before and after the experiment and then utilizing harvest index values previously determined on ten randomly-sampled plants at each site. At Scott, there was a significant relationship between percentage seed drop (*Y*) and the speed of tumbleweed movement (*X*): $Y=1.48X + 8.42$, $R^2 = 0.71$**. At a speed of 25 cm s^{-1}, 50% of seeds per plant dropped over a distance of 300 m. The relationship of number of seeds dropped versus speed was $Y=1500X+4970$, $R^2=0.51$**. Therefore, over 40,000 seeds per plant were dropped at this speed. At Lethbridge, a significant relationship was found between percentage seed drop and distance (*X*): $Y=0.0564X + 30.8$, $R^2=0.69$**. Findings indicate that up to 90% of seeds per plant dropped over a distance of 1000 m. Preliminary results from this study highlight the magnitude and challenge of herbicide resistance gene movement via *Kochia scoparia* seed dispersal.

Keywords: Tumbleweed seed dispersal, *Kochia scoparia*, GPS collars, resistant weed spread

Session 46
BIOLOGICAL WEED CHARACTERISTICS: Dispersal and Survival

Keynote: Seed abscission sensitivity to wind orientation and speed may have evolved to optimise dispersal of wind-dispersed weeds (113)

Michael Renton *(University of Western Australia, Perth, Australia),* ***David Savage*** *(University of Western Australia, Perth, Australia),* ***Catherine Borger*** *(Department of Food and Agriculture, Western Australia, Merredin, Australia)*

Abscission of seeds in some plant species is caused by strong wind gusts that exert sufficient forces to free the seed from its parent. This may be an adaptive feature, as release into stronger wind gusts has been shown to lead to greater dispersal distances, which is likely to have evolutionary advantages. We predicted that similarly individual seeds released into upward wind gusts will, on average, travel further than those seeds released into wind gusts with horizontal or downward orientations and that the preferential release of seeds into upward wind gusts will result in greater distance average dispersal.
As a case study, we studied the abscission dynamics of *Conyza bonariensis* (L.) Cronquist (fleabane), which is an important weed with global distribution.
Using abscission data obtained through a series of seed release experiments, we confirmed that abscission of seeds in *C. bonariensis* is most likely to occur during strong and upward wind gusts. We demonstrated that, for a given wind speed, seeds released into upward wind gusts will, on average, travel further than those seeds released into wind gusts with horizontal or downward orientations. We also showed that preferential release into upward wind gusts has some influence on the distance travelled, but the strength of this influence is dependent on the correlation between wind orientation and wind speed. For this particular study, the sensitivity of release to the horizontal wind speed seemed to have a larger effect on the distance travelled than sensitivity to wind orientation.
Seed abscission sensitivity to wind orientation and speed can have a significant effect on weed seed dispersal distance, and the nature of this sensitivity may have evolved to optimise dispersal of wind-dispersed weeds.

Keywords: Dispersal, abscission, wind orientation, wind speed, fleabane

Grass nodes and meristems of selected grass species as key elements for the explanation of systemic effects of herbicides (486)

Hansjoerg Kraehmer *(Bayer CropScience, Hofheim, Germany)*

External penetration barriers for herbicides have been intensively characterized for decades. Phloem and xylem translocation are also described for many herbicides. Other morphological aspects, however, have been neglected. The anatomy of grass nodes has appeared too complicated in the past to be fully elucidated. The morphology of apical meristems in grasses (targets of systemic herbicides) is also not well explained. To redress this lack of understanding, above and below-ground nodes of different grass species were cut in sequential sections and stained using various technologies. The first obvious findings were that many vascular bundles of these grasses are completely modified as soon as they enter the nodal plexus. These conspicuous swollen vertical conduits are called vasotubuli. Grass nodes can be subdivided in most cases into a lower plexus transition zone, a lower vasotubulus zone, an upper vasotubulus zone, a leaf insertion zone, a funnel zone and/or a pulvinus zone. Nodes of pooid, panicoid and arundinoid grasses may differ to a great extent. Apical meristems are sinks for many herbicides. Vascular bundle formation is initiated within apical meristems. Vascular bundle patterns of grass species may vary considerably. Selected examples of nodes and meristem from different grass subfamilies are presented and explained. After the anatomical characterisation of the node, effects caused by different herbicides are demonstrated within the node after application.

Keywords: Herbicide translocation, grass anatomy, classification of grass nodes

Differences in seed production between self-pollinated and crossed *Cyperus esculentus* plants originating from different regions in Switzerland (650)

Martina Keller *(Agroscope, Wädenswil, Switzerland),* ***Lisa M Eppler*** *(Agroscope, Wädenswil, Switzerland),* ***Lutz Collet*** *(Grangeneuve, Agricultural Institute of the Canton of Fribourg, Posieux, Switzerland),* ***René Total*** *(Agroscope, Wädenswil, Switzerland)*

Yellow nutsedge (*Cyperus esculentus* L.*)* is a serious weed causing high yield losses especially in vegetables. In Switzerland, it was observed for the first time more than 30 years ago and has since spread to all vegetable producing regions. The main means of reproduction and dispersal are soil-borne tubers that are easily spread by machinery. Viable seeds can also be produced. In the literature, *C. esculentus* is reported as an obligate outcrosser. Little is known about its genetic diversity and seed production in Switzerland. In view of its rapid spread, the potential dispersal by seeds was studied in more detail. The objectives of this study were i) to check whether self-pollination occurs and ii) to determine whether there are differences in seed production between self-pollinated and crossed individuals originating from Switzerland. Tubers were collected from 5 different regions in Switzerland, planted in pots and grown in the greenhouse. Glassine bags were used to prevent dispersal of pollen when inflorescences appeared. For self-pollination, single inflorescences were covered with bags; for the crossings two inflorescences from different regions were enclosed in one bag. Number of seeds produced per plant was determined. Self-pollination was observed in the experiment. On average, 48 seeds were produced per inflorescence. Number of seeds produced varied between regions; plants from one region produced 9 seeds per inflorescence, whereas plants from another produced 168 seeds per inflorescence. Compared with self-pollination, crossings resulted in 8 times more seeds (about 400 seeds per inflorescence). Since contractors work more and more in different regions and given the high number of seeds produced if plants from different regions are crossed, it can be expected that seeds will become more relevant as a means of dispersal in the near future in Switzerland.

Keywords: *Cyperus esculentus*, seeds, outcrosser, self-pollination, Switzerland

Endozoochory dispersal and germination of *Lolium multiflorum* resistant to EPSPS-inhibiting herbicides (398)

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Fabiane Q Rosa *(Universidade Federal do Pampa (UNIPAMPA), Uruguaiana, Brazil),*
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Leandro Vargas *(Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Passo Fundo, Brazil)*

Ryegrass (*Lolium multiflorum*) is a winter grass in Southern Brazil with annual cycle used for the production of ground cover under no-tillage and as forage. This species has high dispersion and, therefore, is present in practically all winter crops. Glyphosate herbicide has been used for ryegrass control in no-till fields and perennial crops for over 20 years. The aim of this work was to evaluate the potential of endozoochory dispersion of ryegrass seeds resistant to Glyphosate herbicide and the germination of seeds recovered from the faeces of calves. The seeds (25g, 12 112 seeds) were passed through a tube into the rumen of six calves maintained in metabolic cages. Of the seeds provided to the animals, 9.1% were recovered in the faeces. The recovered seeds in the first three days corresponded to 93% of the total amount of seed recovered. The germination of the recovered seed was lower compared to the germination of the control (66%) and after 48 and 72h, germination was 41 and 37% respectively. For seeds recovered after 96 hours the germination was 17%. The absence of ryegrass seeds in faeces occurred after the eighth day after ingestion suggesting that to avoid endozoochory of ryegrass seeds resistant to glyphosate, calves must remain in quarantine for eight days.

Keywords: Zoochorous dispersion, pasture, ryegrass

Survival of seeds from species of a wild-flowering mixture in ensiling, anaerobic mesophilic digestion and storage of digestate at laboratory scale (151)

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When wild-flowering mixtures are used for biogas-production their seeds can enter the biogas process chain and eventually survive ensiling, anaerobic digestion and storage of the digestate. This poses the risk that they are spread when the digestate is returned to the fields as fertilizer.
In this study, we examined the survival of plant seeds from a commercially available wild-flowering mixture in ensiling, anaerobic mesophilic digestion and storage of the digestate at laboratory scale. From the mixture we chose *Cichorium intybus* (L.) (Common chicory), *Echium vulgare* (L.) (Viper´s Bugloss), *Malva alcea* (L.) (Greater musk-mallow) and *Melilotus officinalis* (L.) Pall. (Yellow sweet clover). Additionally, we tested the survival of *Lycopersicon esculentum* Mill. (tomato) that is a reference species for sanitation of compost according to the German law.
Seeds were ensiled in maize for eight months and exposed to continuous biogas reactors at 35°C for maximum 36 days, afterwards. Further, we stored seeds that have and that had not been in the biogas reactors in digestate for four, eight and twelve weeks. After each step we determined seed viability.
We found the extent of inactivation to be dependent on the hardseededness of the seeds. Ensiling killed the non-hardseeded species *C.intybus*, *E.vulgare* and tomato. The viability of the hardseeded species *M.alcea* and *M.officinalis* was reduced to 20% and 80% by ensiling, respectively, and only slightly by subsequent fermentation at 35°C. Storage in digestate had no effect on hardseeded species while it inactivated the non-hardseeded species irrespective of previous fermentation. We conclude that hardseeded species from the wild-flowering mixture could be spread with the digestate. Further, tomato is not an appropriate species to predict the sanitation of digestate from weeds.
This study was funded by the Fachagentur für Nachwachsende Rohstoffe e.V. on behalf of the Bundesministerium für Ernährung und Landwirtschaft.

Keywords: Wildflowering mixture, seed viability, ensiling, anaerobic mesophilic digestion, storage of digestate

Germination ecology and early growth of *Ambrosia confertiflora* in Israel (374)

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Ambrosia spp. (ragweed) is an invasive plant in Europe, Asia and Australia. The perennial species widespread in Israel is *A. confertiflora* (weakleaf bur ragweed) originating from southern US and Mexico. It is a highly competitive and very aggressive weed, with a very dense subterranean vegetative propagation system producing tall and dense aerial shoots. Geographical Information System (GIS) was used for mapping its spatial distribution throughout Israel. Significant abundance of the species was detected in riverbanks, roadsides and their adjacent cultivated fields and orchards. The weed reproduces from seeds and rhizomes. Seed germination occurs mostly from the soil surface. We examined the development of plant grown under different temperature regimes. Results show that the numbers of sprouts with and without mowing is not significantly different, indicating no apex dominance. Sprout numbers however, are higher under cold temperatures (10/16°C and 16/22°C, n/d) as compared to high temperatures (22/28°C and 28/34°C). Shoot elongation is inhibited by low temperatures and the plants remain in the rosette form. Growth in biomass is higher under warm condition (22/28°C and 28/34°C) and plants are very competitive and cause severe damage to crops. Greenhouse and field studies have shown that the response of *A. confertiflora* to herbicides is age dependent with a high rate of recovery in established plants. We concluded that sequential treatments are required in order to achieve adequate control. This study demonstrates the impact of an aggressive invasive weed on natural and agricultural ecosystems.

Keywords: *Ambrosia confertiflora*, Ragweed, Germination, Biomass production, Invasion paths

Session 47
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND: Invasive and Aquatic Species

Keynote: Trait modulations to irradiance: a key to Ricinus (394)

Neha Goyal *(University of Delhi, New Delhi, India),* ***Gyan Prakash Sharma*** *(University of Delhi, New Delhi, India)*

Cultivated croplands are increasingly posing huge invasion risks through putative propagule escape of crops, crop-associated weeds, and feral crop descendants. *Ricinus communis* L. (Castor), native to East Africa is a classic case of crop plant that has escaped cultivated lands and is rapidly expanding its range across heterogeneous urban landscapes in India. Altered urban landscape owing to an upsurge in developmental activities and associated land use changes provide heterogeneous resource environments to the colonizer. *R. communis* rapidly colonizes open disturbed areas in urban landscapes. Despite enormous range expansion potential of *R. communis* in heterogeneous habitats, there is a limited understanding of species' performance related traits and trait modulations which may facilitate aggressive colonization. We hypothesized that *R. communis* modulates its colonization ability to variable irradiances in urban habitats. To assess colonization ability of *R. communis* at varying levels of irradiance (low- 900 $\mu molm^{-2}s^{-1}$, medium- 1800 $\mu molm^{-2}s^{-1}$, and high- 2700 $\mu molm^{-2}s^{-1}$), plant performance was examined through estimation of key vegetative, reproductive traits and eco-physiological traits. Interestingly, vegetative traits (plant height, the number of primary branches, and node density) did not exhibit substantial modulations. However, reproductive traits (number of inflorescences and infructescences, and reproductive index), and eco-physiological traits (specific leaf area, photosynthetic rate, and water-use efficiency) exhibited significant modulations at different irradiance levels. Modulations in reproductive and eco-physiological traits potentially confer *R. communis*, aggressive colonization ability.

Keywords: Colonizer, Cropland escape, Irradiance, Photosynthesis, Ricinus

Native perennial grasses tolerate reclamation challenges (253)

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David A Mortensen *(The Pennsylvania State University, University Park, United States)*

Domestic development of shale gas is a major component of the United States energy sector. Yet infrastructure has fragmented the landscape with little research on ecological impacts. Interim reclamation could provide wildlife habitat, though highly disturbed soils pose significant restoration challenges. Our objectives are to evaluate weed suppression and invasive weed resistance of native perennial grasses and forbs in compacted soils typical of shale gas well pads. We hypothesize that (1) soil compaction will reduce the growth of native grasses and forbs resulting in greater weed cover and growth, and, (2) that non-native invasive *Microsteium vimineum* growth will be greater in compacted soils due to reduced growth of the native grasses. In 2014, in Pennsylvania, we simulated the soil compaction and interim restoration of a well pad to address these hypotheses. The topsoil on site was removed and stockpiled and the subsoil compaction treatment was created with a vibratory plate compactor. The topsoil was replaced and the site was sown with *Panicum virgatum*, *Sorghastrum nutans*, *Andropogon gerardii*, and *Dichanthelium clandestinum* in a replacement series design, with additional *Monarda fistulosa* plots. *M.vimineum* subplots were sown in the Fall of 2014. Native grass and background weed cover were recorded through the growing season of 2015. Biomass was collected at flowering in 2015. ANOVA was used to determine differences in treatment. Soil compaction did not reduce native grass cover or biomass in monoculture or in the four species mixture, or result in greater overall weed or *M. vimineum* biomass. Plots with *M. fistulosa* had less *M.vimineum* biomass compared with the native grass mix (df=1, *P <0.05). Early results of this research demonstrate that native grasses offer potential for reclamation of highly disturbed and compacted soils typical of shale gas development, and combined with *M. fistulosa* could slow the spread of *M. vimineum*.

Keywords: Restoration ecology, Shale gas, Native perennial grasses, Invasive weed resistance, Microsteium vimineum

Monoecious hydrilla biology and strategies (350)

Robert J. Richardson *(North Carolina State University, Raleigh, United States),*
Justin J. Nawrocki *(North Carolina State University, Raleigh, United States)*

Subterranean turions (tubers) are a key challenge to long-term monoecious hydrilla (*Hydrilla verticillata* L.) management. Tuber densities in situ may exceed 3,000 per square meter on individual sites. These tubers can remain viable for at least 5 years during intensive and successful management operations. Recent research has indicated that monoecious tubers have preformed axillary buds and can resprout following clipping of the terminal shoot after sprouting. Recently sprouted tubers may survive and elongate for at least 56 days in the complete absence of light. Young shoots can also withstand short term exposure to high salinity and long-term exposure to low salinity levels. Management programs must overcome these biological challenges in order to reduce hydrilla infestation levels to low densities, or more rarely, eradicate monoecious hydrilla from a water body. Triploid grass carp (*Ctenopharyngodon idella*) have been an effective long-term management tool for monoecious hydrilla in North Carolina. Triploid grass carp can live for over 15 years in Piedmont Reservoirs and have eradicated hydrilla from small lakes. Fluridone has been documented to reduce hydrilla tuber densities over time on sites where adequate concentrations can be maintained. Contact herbicides can also eliminate monoecious hydrilla biomass, but application timing must prevent new tuber formation. Other management options are available, but typically have greater limitations for long term monoecious population reductions.

Keywords: Aquatic plant management, integrated pest management

A potential new herbicide for invasive annual grass control on rangeland (819)

Derek J Sebastian *(Colorado State University, Fort Collins, United States),* ***Scott J Nissen*** *(Colorado State University, Fort Collins, United States)*

Downy brome (*Bromus tectorum* L.), a winter annual grass, is considered one of the most invasive non-native rangeland species in the U.S. While glyphosate, imazapic, and rimsulfuron are herbicides commonly recommended to control invasive, annual grasses, their performance is inconsistent, and they can injure desirable perennial grasses. Indaziflam is a recently registered cellulose-biosynthesis inhibiting herbicide, providing broad spectrum control of annual grass and broadleaf weeds. Indaziflam is labeled for winter annual grass control in citrus, grape, and tree nut crops, and could represent a new mode of action for selective winter annual grass control on rangeland. Compound light microscopy and seedling root bioassays were used to confirm the cellulose inhibition of indaziflam on monocot and dicot species including downy brome, feral rye (*Secale cereale* L.), kochia (*Kochia scoparia* L.), and Arabidopsis (*Arabidopsis thaliana* L.). In addition, three field experiments were conducted to compare indaziflam to imazapic, rimsulfuron, and glyphosate, three herbicides commonly used for downy brome control. Multiple herbicide application timings were evaluated. At all three sites, glyphosate and rimsulfuron provided less downy brome control than indaziflam one year after treatment (YAT). Percent downy brome control with imazapic decreased significantly 2 YAT (45-64%), and 3 YAT (10-32%). Across all sites and application timings, indaziflam provided the greatest downy brome control 2 YAT (89-100%) and 3 YAT (83-100%). Indaziflam did not significantly reduce species richness. This research provides the first evidence of a potential new tool and mode of action for land managers to control invasive winter annual grasses on US rangeland.

Keywords: Compound light microscopy, downy brome (*Bromus tectorum* L.), imazapic, indaziflam, rimsulfuron

Foloni L. L. (BR): Environmnetal impact of glyphosate use in the control of invasive plant (330)

Luiz Lonardoni Foloni *(Facculdade de Engenharia Agrícola – UNICAMP, São Paulo- SP, Brazil),* ***Edvaldo Domingues Velini*** *(Faculdade de Ciência Agronômicas – UNESP, Botucatu – SP, Brazil)*

This study evaluated glyphosate control of *Urochloa decumbens*, an invasive plant of natural forests, and also its consequences, such as residues, microbial biomass, soil respiration, metabolic soil coefficient, and the seeding (*Pennisetum sp*) after application. A set of environmental impact data were collected prior to recommending glyphosate application in a deactivate gold mine in the Carajás National Park (06 ° 02 ,47, 4 „S and 50 ° 34 ,21.0 WG), in the Amazon rainforest. Two experiments were conducted. One experiment was on a waste dump (worst case), which was subjected to revegetation by hydro seeding in the past, and the second experiment was on natural soil (best case), also with the presence of *U. decumbens*. The experiments were 10 m X 4m, and 7m X 4 m, with mechanical cutting and application of glyphosate at 900 to 1800 g a.e / ha. Results were evaluated during the period of one year. The herbicides were applied with spray CO_2 (40 psi), with 200 L of the solution / ha. Control efficiency indexes visually were made at 20, 40 and 98 days (DAT), and 19, 34, 97 and 219 DAT (second application). A scale of 0% for no control and 100% for full control was used. Among the evaluated parameters, the control efficiency was 100% for the highest rate, after the 2nd application. Results of the residue analyzes performed by two independent institutions, showed no detectable residues. The results of the microbial diversity, made by Disnaturing Gradient Gel Electrophoresis, showed a variation between the samples (* p <0.01) but not significant variation when comparing areas with and without glyphosate (* p> 0, 2). The parameters evaluated in this experiment, in light of current knowledge, allow recommending glyphosate to control *this weed,* with low environmental impact. Acknowledgements: The Vale Co

Keywords: Gliphosate, Environmental Impact, Invasive weed, Uroclhoa decumbens, Amazon rainforest

Suppression of invasive black locust (638)

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Despite many advantageous features, black locust (*Robinia pseudoacacia* L.) is perceived as invasive. As such, it significantly affects biodiversity of natural and semi-natural ecosystems. This is the reason to look for an effective and nature-friendly way to regulate it. Therefore, we followed observations from black locust forests neighboring old botanical gardens (Mlyňany Arboretum in Vieska nad Žitavou, SK and National Botanical Garden in Vácrátót, HU). In both locations, black locust individuals growing in the presence (2.5 and 4.5 fold higher than black locust, respectively) or absence of black cherry (*Prunus serotina* Ehrh.) or common hackberry (*Celtis occidentalis* L.), respectively, were analyzed for growth (height, tree diameter at 1.3 m), stress level (leaf hydrogen peroxide) as well as N-nutrition parameters (leaf chlorophylls, ureides, proteins). We found that black cherry presence had no effect on these characteristics but common hackberry significantly reduced leaf concentrations of chlorophylls and proteins as well as tree height. Similar results were obtained in the lab experiment with application of 1% (w/v) macerate (prepared from leaf and twig powder) on leaf as well as soil (sand + nutritional solution for leguminous species). In both treatments, we found root as well as shoot growth stimulation and less leaf ureides compared to the control (more pronounced in hackberry extract). However, seedlings treated with black cherry extract showed larger hydrogen peroxide concentrations than those treated by common hackberry extract. Altogether, common hackberry seems to be more effective tool for black locust suppression.

Keywords: Black locust (*Robinia pseudoacacia* L.), plant invasions, allelopathy, concurrent tree species, biological control

Session 48
WEED ECOLOGY: Weed Management, Dynamics and Biodiversity

Keynote: Can herbicides affect seed dormancy and viability of flaxleaf fleabane (*Conyza bonariensis*) (661)

Hanwen Wu *(Wagga Wagga Agricultural Institute, Wagga Wagga, Australia),* ***Md Asaduzzaman*** *(Graham Centre for Agricultural Innovation, Wagga Wagga, Australia)*

Conyza bonariensis is a major weed in dryland cropping system in Australia. The weed is difficult to control with any single herbicide application especially when herbicides are applied after booting. Anecdotal evidence suggests that some chemicals might affect fleabane seed viability and/or dormancy as seeds collected from certain paddocks in the summer did not germinate. Experiments under glasshouse and field conditions were conducted to investigate whether various herbicides could sterilize weed seeds and affect seed dormancy. A total of ten herbicide treatments were applied to fleabane plants at two growth stages, ie early budding and late budding, under glasshouse conditions. In addition, 15 different herbicide treatments were applied to mature flowering fleabane plants in the field. The glasshouse results showed that a range of herbicides applied at the early budding stage completely stopped the viable seed production on main stem, while paraquat at 100 g a.i./ha and a pre-packed mixture of MCPA and pyrasulfotole at 250 g + 50 g a.i./ha did not significantly reduce viable seed production. In addition, the pre-packed mixture strongly induced seed dormancy as all the viable seeds were dormant. At the late budding application (24 days after the early budding application), some herbicides reduced seed viability on the main stem by 16-24% and all the treatments significantly increased seed dormancy, with dormant seeds ranging from 11 to 48%, while it was only 4.6% for the untreated control. Field data also showed that a range of herbicide treatments differed significantly in their ability to sterilise seeds, with viable seeds ranging from 23% to 70% as compared to the untreated control of 90%. This study indicates that herbicides can induce seed dormancy and affect on seed viability, depending on the timing of application and herbicides used. The implication of such results on weed management is discussed.

Keywords: Herbicides, Seed dormancy, Seed viability, Germination, Conyza bonariensis

Can low-dose effects of herbicides shift a weed population? – A case study with ALS-inhibitors and *Matricaria inodora* L. (273)

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Weed populations feature within-population genetic differences. Thus, evaluating mean responses in herbicide treated populations may miss ecologically significant individual responses. In the low-dose range, there are two phenomena that are known to vary between individuals of a population, namely 'selective low-dose toxicity' against exceptionally fast-growing individuals and stimulatory effects known as 'hormesis'. The interplay of both low-dose phenomena, *i.e.* whether they occur simultaneously, successively, or independent of each other, is yet unknown and, therefore, it is unsettled if and how their occurrence alters the structure of a population exposed to low-doses of herbicides. Based on this, this study evaluated the occurrence of both low-dose phenomena *in vitro* within a high-density population of *Matricaria inodora* L. exposed to Atlantis WG (mesosulfuron+iodosulfuron). In a dose-response experiment, *M. inodora* was exposed to 12 doses of Atlantis WG in 24 replicates (50 plants/replicate). Root/shoot growth responses were evaluated for the population mean in comparison to the most long-grown (≥90th percentile of the population) and the most short-grown individuals (≤10th percentile) by *Mann-Whitney U* tests and as dose-response relationships. Growth responses were generally biphasic. Slow-growing individuals showed no selective low-dose toxicity and had more pronounced hormesis occurring partially at lower doses as compared to the population mean. Fast-growing individuals were affected by selective low-dose toxicity at doses preceding the hormetic dose range. Hormesis was instead less pronounced and partially shifted to higher doses at the most vigorous growing individuals. Hence, in a dense stand *in vitro* selective low-dose toxicity was only associated with fast-growing individuals, while hormesis was primarily associated with a stimulation of slow-growing individuals. This suggests that both low-dose phenomena can occur in a dose-dependent manner in parallel and have the potential to segregate an herbicide exposed population and alter its sensitivity in the long-run.

Keywords: Biphasic, dose-response, growth stimulation, selective toxicity, sulfonylurea herbicide

The influence of farming and weed biodiversity on seed predation (166)

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In Integrated Pest Management, weeds can also have a beneficial role, as they are part of the agroecosystem and can improve the farmland food web. One interesting aspect is how weed composition can affect seed predation, both qualitatively and quantitatively. Field studies were conducted, at nine different winter cereal fields on the Eastern Swabian Alb (Southern Germany), in 2015. They included three conventionally (CF), three organically (OF) and three extensively (EF) managed fields. Per field we determined (i) the number of weed species, (ii) their abundance and (iii) measured the seed predation using seed cards. The influence of vertebrate and invertebrate fauna was separated from each other with exclosure cages. Measurements were performed before and after cereal harvesting. Different farming types significantly affected the seed predation rate. Before harvest seed predation rate was 44.4% in EF compared to 19.4% and 17.3% in OF and CF, respectively. Farms conducting a late stubble tillage (2 weeks after harvest) showed the lowest seed predation rate (1.9%) compared to the other farms, which carried out this measure directly after harvest (3.6% and 8.7%). In contrast weed species composition and abundance did not affect the seed predation rate. Across all fields seed predation rate of vertebrates was significantly higher than of invertebrates. Vertebrates consumed 48% of the weed seeds directly before cereals were harvested. Invertebrates only reduced 8% of the offered seeds. These rates decreased abruptly after harvest (10% and 5.6%, respectively) until the values of 8.2% and 2.2%, 4 weeks after harvest. In conclusion seed predation is highest when the crop is present and decreases directly after harvest. Extensive farming or fewer disturbances such as stubble tillage seem to promote seed predation. High population density of rodents in the experimental year show the potential of vertebrates in seed predation.

Keywords: Weed biodiversity, seed predation, farming type, winter cereals

Merotto A. (BR): Identification of variability to flooding during germination in weedy red rice (795)

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Weedy red rice (*Oryza sativa* L.) adaption to crop practices could increase the prejudice of this weed to rice production. Increasing infestation of weedy red rice had been identified in rice fields established through the pre-germinated system. The objective of this study was to establish a methodology for selection of weedy red rice ecotypes with tolerance to germinate under high water depth and to identify ecotypes with contrasting flooding tolerance. A greenhouse experiment was performed in a factorial scheme (4x7) where the factor A was the rice genotypes Nipponbare and Irga 410 and the weedy red rice ecotypes AV 31 and ITJ03, and the factor B was the water level above the soil surface of 0, 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 cm. The experiment was carried out twice. The water level that better discriminate susceptible and tolerant genotypes was between 5 and 10 cm. The second study consisted of the evaluation of 165 weedy red rice ecotypes and the rice cultivars Nipponbare and Irga 410 (Factor A) in three water levels above the soil surface of 0, 5 and 10 cm (Factor B). The germination rate of the rice cultivars Nipponbare and Irga 410 was 24.0 e 16.7% under 5 cm of water above the soil, respectively. These cultivars did not germinate in the water level above the soil of 10 cm. Approximately 20% of the weedy rice ecotypes had germination larger than 50% germination under water depth of 5cm. High tolerance to submergence was found for the ecotype ITJ03 ecotypes, which showed emergency 88% under 10 cm of water depth. Several weedy red rice ecotypes presented higher tolerance to flooding during germination than rice cultivars. Large variability to flooding exists in weedy rice indicating different selection pressure caused by crop management and environment.

Keywords: Adaptation, Red rice, Submergence, Water-seeding rice

European grasslands as a source of weeds invading temperate areas worldwide (760)

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A plant species' habitat preferences in its native range determine which habitats are likely to be invaded following its introduction to the new range, affecting whether the invasion will be successful. In our study based on 286 alien species, we classified their habitats in both ranges into broad classes and tested the discrepancy between (i) native-range habitats of species invading from versus into Europe; and (ii) habitats occupied in the native and invaded ranges, using frequency analyses. Species of European grasslands are successful invaders worldwide, however, grassland species from other parts of the world are less successful as invaders in Europe. The preadaptation of European species to human activities and export of European land use are likely causes of this phenomenon. The global spread of European grassland species can be demonstrated on the Southern Island of New Zealand, parts of which (Banks Penninusula, McKenzie Basin) resemble grasslands of central Europe, with dominants like *Agrostis capillaris*, *Anthoxantum odoratum* or *Hieracium pilosella* s.l. and only sparce intrusions of native species. On the contrary, temperate grasslands of North America do harbour native dominants (*Apocynum cannabinum*, *Asclepias* sp. div., *Solidago* sp. div.), however, large areas are massively invaded by European species, such as *Agrostis capillaris*, *Bromus tectorum* or *Cirsium arvense*. The dominance of these species seriously reduces the diversity of native North American species and their community-level impacts are more profound compared to those of North American invaders in Europe.

Keywords: Grasslands, native-range habitats, invaded-range habitats, impacts of invasions, direction of invasions

The impact of *Impatiens parviflora* on native vegetation in oak-hornbeam forests (34)

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Impatiens parviflora DC. is one of the most widespread invasive plant species in central Europe. Nevertheless, the mechanisms of its invasion are still poorly understood. In this paper we studied the impact of *Impatiens parviflora* on native vegetation using removal experiment on permanent plots in oak-hornbeam forests in central Bohemia, Czech Republic. Ten pairs of 1 x 1 m plots were established in invaded vegetation, one plot in each pair stayed invaded and the other served as removal plots and all *Impatiens* individuals were removed from it in August 2011. Phytocenological relevés were recorded in spring and summer 2012-2015 and differences in species composition, numbers and abundances of native species between the plots were tested. Species scores from RDA testing the effect of *Impatiens* removal were correlated with selected plant traits to reveal trait characteristics for species suppressed or supported by the invasion. Significant increase in abundances of native species was observed on removal plots in comparison with invaded plots during the experiment, with the greatest change in the first two years after invader removal. Number of native species was also slightly increasing on removal plots, thought this difference was only marginally significant. Species composition also significantly differed between invaded and removal plots. Species with high affinity to removal plots, i.e. species that are most restricted by *Impatiens'* invasion, were mostly species with small releasing height, early start of flowering and high specific leaf area. Our results indicate that *Impatiens parviflora* has negative impact on native vegetation, but that the vegetation recovers quite quickly after the invader removal. However, further investigations are necessary to confirm the results.

Keywords: Impact, invasive plant, Impatiens parviflora, small balsam, invasion

Session 49
CROP-WEED INTERACTIONS: Allelopathy and Herbicides

Keynote: Mode of action of rice allelochemical momilactone (564)

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Large-scale field screening programs and laboratory experiments conducted in many countries have indicated that rice is allelopathic and releases allelochemical(s) into its environment. A great number of compounds, such as phenolic acids, fatty acids, terpenes and indoles, have been identified as potential rice allelochemicals. However, the studies demonstrate that diterpenoid momilactones are the most important rice allelochemicals, with momilactone B playing a particularly critical role. Rice plants secrete momilactone B from their roots into the neighboring environment over their entire life cycle at levels phytotoxic to other plant species, and momilactone B accounts for the majority of the observed rice allelopathy. In addition, momitactone deficient mutants of rice exhibited significantly reduced allelopathic potential, demonstrating that momitactone serves as an important rice allelochemical. Momilactone also inhibited the growth of *Arabidopsis* and three momilactone high-sensitive and two low-sensitive mutants of *Arabidopsis* were identified. Those mutations were related to the flavonoid biosynthetic pathway. Further, the expressions of the genes involved in the flavonoid biosynthesis were determined by real-time PCR. The results indicate that momilactone inhibits the growth of *Arabidopsis* by regulating the expression of genes in the flavonoid biosynthesis pathway.

Keywords: Allelopathy, Mode of action, Growth inhibition, Arabidopsis, Momilactone

Characterisation of the weed suppressive potential of winter cereal cultivars: the role of above-ground competition versus allelopathy in wheat, triticale and rye (153)

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Current weed management practices in Northern Europe are based primarily on the use of effective herbicides but an increase in the number of herbicide resistant weed phenotypes and a complete lack of new modes of action have led to an urgent need for more integrated weed management tactics. A better understanding of crop-weed interactions would help to achieve this goal. Hence, we studied the weed suppressive potential of 72 commercial cultivars of winter wheat (*Triticum aestivum*), winter triticale (*Triticosecale*) and winter rye (*Secale cereale*) with a specific focus on the relative contribution of above-ground competition and allelopathy. As an indicator of allelopathic potential (AP), the quantity of twelve secondary plant metabolites belonging to the chemical group of benzoxazinoids (BX) were analysed in root and shoot tissue of 33 wheat, 11 triticale and 28 rye cultivars. The total content in root and shoot tissue differed significantly between species with rye containing the highest levels of BX, followed by triticale and wheat with the lowest levels of BX. In addition, the proportion of the twelve BX differed significantly between the species, with rye having the highest levels of non-methoxy-substituted BX and triticale with the highest levels of methoxy-substituted BX. Investigated traits related to above-ground competitive potential (CP) were plant height, ground cover before canopy closure and leaf area index of the cereal cultivars. No stable correlation between AP and CP could be identified and therefore cultivars were assigned to 4 groups: high AP and CP, high AP and low CP, low AP and high CP or low AP and CP, arranged according to descending weed suppressive potential. Finally, 4 cultivars of each cereal species, representing each combination of weed suppressive potential, were chosen for further trials studying their actual weed suppressiveness in the presence of weeds.

Keywords: Cereal, allelopathy, benzoxazinoid, competition, weed

Isolation and identification of allelopathic active substances from *Actinidia deliciosa* roots and leaves (586)

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The young plants of kiwifruit (*Actinidia deliciosa* (A. Chev.) C.F. Liang *et* A.R. Ferguson) do not grow well in the soil where kiwifruits were previously grown. It appears that the roots and leaves of kiwifruit possess allelopathic substances, which accumulate in the soil and inhibit the growth of young kiwifruit seedlings. However, knowledge on the presence of allelopathic substances in kiwifruits is limited. This study was conducted to isolate and identify putative allelopathic substances from the roots and leaves of kiwifruit, cv. Hayward. The root and leaf tissues were separately extracted by aqueous methanol and methanol, respectively. In a parallel study, these extracts showed high inhibitory effects on lettuce and alfalfa. The extracts were then purified by ethyl acetate partition, silica gel column, sephadex LH-20 column, C_{18} cartrige and high-performance liquid chromatography (HPLC). The biological activities of all fractions of each purification steps were determined by cress bioassay. The most active fraction identified in the bioassay was advanced for next separation. Finally, three allelopathically active substances each from leaf and root extracts were isolated. These six substances showed distint retention times in the HPLC analysis, indicating that each of the substances could be different. One of the allelopathically active substances, quercitrin, from leaf extracts was determined by ^{1}H-, ^{13}C-nuclear magnetic resonance and high resolution electro-spray ionization mass spectrometry. Quercitrin may be involved in the allelopathic activity of kiwifruits. Further studies are necessary to identify other substances that likely contribute to the allelopathic potential of kiwifruit. Results from this study will help resolve replant issues in kiwifruit production.

Keywords: Allelopathy, kiwifruit, replant problem

Bioactive compounds with growth inhibitory activity in fruits of *Piper retrofractum* (591)

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Piper retrofractum Vahl. is a medicinal plant belonging to the family Piperaceae. *P. retrofractum* fruits possess multiple medicinal properties and also insecticidal properties, but little has been reported on their allelopathic activity. Therefore, we focused on evaluation of the allelopathic potential in fruits of *P. retrofractum,* and on the isolation and identification of possible allelochemical compounds. An aqueous methanol extract of fruits of *P. retrofractum* strongly inhibited the growth of monocots (alfalfa, cress and lettuce) and dicots (barnyardgrass, Italian ryegrass and jungle rice) at concentrations greater than 1 mg dry weight equivalent extract/mL. The concentration required for 50% growth inhibition (I_{50}) was in the range of 0.3-14 and 0.2-2 mg dry weight equivalent extract/mL for shoot and root growth of test plants, respectively. These inhibitions suggest that the fruit extracts of *P. retrofractum* may contain strong allelopathic compounds. The extract was subsequently separated using several chromatographic runs and three active compounds were finally purified by reverse phase HPLC. Those compounds were identified by spectral analysis to be 3-phenylpropanoic acid, (2*E*, 4*E*)-methyl piperate and (2*E*, 4*Z*)-methyl piperate. 3-phenylpropanoic acid inhibited seedling growth of cress at concentrations greater than 100 µM. (2*E*, 4*E*)-methyl piperate and (2*E*, 4*Z*)-methyl piperate inhibited seedling growth of cress at concentrations greater than 100 and 300 µM, respectively. The growth of treated seedlings decreased with increasing concentrations of the compounds. Results suggest that these compounds may be responsible for the allelopathic activity produced by the fruits of *P. retrofractum*.

Keywords: Piper retrofractum, allelopathic compound, 3-phenylpropanoic acid, (2E, 4E)-methyl piperate, (2E, 4Z)-methyl piperate

Strong indications for allelopathic root interactions between *Fagopyrum esculentum* and *Amaranthus retroflexus* (319)

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The cover crop *Fagopyrum esculentum* (common buckwheat) is known to effectively suppress many weeds, amongst others *Amaranthus retroflexus* (redroot pigweed), during its growth in the field. This can partly be explained by resource competition for light, water, nutrients and space, but allelopathic root interactions might also play an important role. In order to study this question, we developed a method allowing the separation of resource competition from growth repressive root interactions in soil grown plants. Water and nutrient supply were kept constant and in sufficient amounts throughout the experiments, whereas the effect of shading was evaluated by the presence or absence of vertical nets. In the first step, root interactions were studied by separating the rhizospheres of pigweed and buckwheat with impermeable plastic barriers in one condition and by allowing interplant root contacts in the other condition. We observed very strong growth suppression due to both competitive shading effects and root interactions. In the second step, a permeable membrane that allowed water and soluble molecules to diffuse between the compartments was used. Significant growth suppression of pigweed by buckwheat could be observed, suggesting that a diffusible component was responsible for this effect. Collection and characterisation of root exudates is under way. In parallel, the growth repressive effect of shading by buckwheat was tested in field trials over three years. Depending on the environmental conditions of the year, the effect of light competition was predominant or non-significant. However, strong weed suppression could be observed in all years. From our results, we conclude that the roots of the two species must be in close contact for a certain period of time to observe growth repression in the absence of resource competition.

Keywords: Weed suppression, root interactions, allelopathy, *Fagopyrum esculentum*, cover crops

Sorgoleone concentration varies with sorghum hybrid (480)

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Sorgoleone-358 is an important allelopathic component of the oily droplets exuded from the root hairs of sorghum. Previous studies have demonstrated the herbicidal activity of sorgoleone on many small-seeded weeds. Laboratory experiments were conducted to determine the root exudate production potential and sorgoleone-358 concentration of 36 cultivated sorghum, eight shattercane and one johnsongrass cultivars. Using a capillary growing mat system adapted from previous work, root exudates were extracted with methylene chloride and subjected to HPLC analysis to determine the sorgoleone-358 content. Seven to 12 days after the cultivars were seeded, for all 45 cultivars root biomass averaged 18.8 mg $g^{-1}$of seed and ranged from 0.4 to 39.6 mg $g^{-1}$of seed whereas root exudate production averaged 1.23 mg g^{-1} of fresh root weight and was between 0.2 and 4.8 mg g^{-1} of fresh root weight. Sorghum cultivars varied considerably in the amount of sorgoleone produced. Sorgoleone-358 concentration of the root exudate averaged 500 ppm and varied from 129 (for shattercane cultivar S7) to 1,054 ppm (cultivated sorghum cultivar 992123). With respect to the quantity of root biomass produced, sorgoleone-358 concentration averaged 490 ppm and ranged from to 58 (for cultivated sorghum cultivar AAS3479) to 1,463 ppm (for shattercane cultivar S2). Segregation of the commercial sorghum cultivars according to their crop duration group did not show any difference in root biomass and root exudate production but early-maturing cultivars produced on average 18% less sorgoleone-358 compared to medium- and late-maturing cultivars. These results suggest that sorgoleone production potential is genetically constitutive, since environmental conditions were similar for all sorghum cultivars. However, sorgoleone production is also modulated by environmental factors. Therefore, it would be interesting to extend this study to field experimentation and verify if the results obtained here may have potential practical applications in a weed management strategy based on reduced herbicides reliance.

Keywords: Sorghum, Sorgoleone, HPLC

Allelopathy in rice from phenomena to chemicals and regulated genes (671)

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Research on rice allelopathy was started in the United States in the late 1980s. The magnitude of weed problems in rice and increased environmental concerns about pesticide use has made it imperative to find an alternative way of weed control to achieve sustainable rice production. Allelopathic rice offers an integrated weed management tool with substantially reduced herbicide usage. In this research, a bioassay of rice root exudates was conducted using a modified equal-compartment-agar-method, and the non-allelopathic and allelopathic rice cultivars Dongjinbyeo and kouketsumuchi. Additionally, assays for cinnamic acid 4-hydroxylase (CA4H) activity and identification of 14 active phenolic compounds in the rice cultivars were conducted by Bradford method and HPLC analysis, respectively. Further, gene chip and bio-informatics techniques were used to analyze and select the genes regulating allelopathic activity in rice for the allelochemicals reported. The results showed that the use of rice root exudates is a good method for laboratory screening tests, which used 0.3% agar as the medium coupled with the elimination of competition for nutrients among different species. The activities of CA4H and 14 phenolic compounds in the rice cultivars showed that there is a close relationship between allelopathic potential and the phenolic compounds identified. Gene chip and bio-informatics analysis revealed that there are about 8,060 genes involved in response to the stress condition, in which 4,970 and 3,080 genes were up- and down-regulated, respectively. About 40 genes were related to the synthesis/metabolism of phenolic acids and steroids. The findings suggest that phenolic acids and steroids are the most important chemicals contributing to the allelopathic potential of rice. The results also provide a theoretical basis for the identification of genes involved in rice allelopathy.

Keywords: Rice, allelopathy, chemical compounds, regulated genes

Session 50
NON-CHEMICAL WEED CONTROL TOOLS: Direct Methods

Keynote: Precision harrowing using a bi-spectral camera and a flexible tine harrow (293)

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Mechanical weed control strategies can provide an additional solution to chemical weed control. Yet these weed control strategies need to adopt the capabilities of new technologies, in order to compete with conventional herbicide applications.
In the given study a novel automatic harrowing system is presented and tested. An automatic harrow can increase or decrease the harrowing intensity during operation. It can achieve that by decreasing the tine angle relative to a perpendicular axis of the field surface, attaining increasingly more aggressive intensity levels. A bi-spectral camera has been used in order to identify weeds or crops within the field. The image deriving from the sensor was used to determine the crop and weed variability of the field. This was performed with image analysis algorithms, and separation of the outcome based on shape features. Monocot, dicot and perennial weed density and coverage can be calculated from the image data. A Decision Support System based on fuzzy logic used this information to trigger an appropriate tine angle movement. Thus, areas with high crop and weed densities were applied with more aggressive harrowing treatments and areas with lower weed densities with a gentler treatment.
A winter barley field was adopted to evaluate the suitability and effectiveness of the system at the University of Hohenheim, Germany. A harrow application was conducted with or without the automatic harrowing system with different speed levels (2, 4, 8 kmh^{-1}) during autumn. A herbicide treatment and an untreated control were included. Weed counting was performed prior and after application, along with biomass cuts in order to estimate treatment efficacy. The on-time adjustment of the system and its restrains were examined. The online system performed well, providing similar results with the non-automatic harrowing, but with lower intensity levels. No difference was found between mechanical and herbicide treatments.

Keywords: Bi-spectral camera, Site specific harrowing, Shape feature analysis

Evaluation of direct-fire steam for soil disinfestation in California strawberry (137)

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Steam has long been used for soil disinfestation including control of weed propagules. Response to increasing geographic restrictions on use of soil fumigants near schools and hospitals, i.e., sensitive sites, requires the development of non-fumigant soil disinfestation methods at field-scale. Development of field-scale steam applicators to treat large soil volumes quickly and efficiently is difficult. Steam can be a component within an integrated set of fumigant and non-fumigant practices for control of weeds such as *Cyperus esculentus* as well as soil pathogens. Steam used side-by-side with fumigants may facilitate sustainable strawberry production into the future by allowing growers to steam in sensitive sites where they cannot fumigate. Previous field steam applicator designs have required 2 to 3 days to treat 1 hectare. Recent advances in steam generator technology may make it possible to overcome some of the limitations of steam application. We are currently evaluating a direct-fire steam generator and tractor-towed steam applicator that injects steam and hot air into the soil to a depth of 30 cm. Direct-fired steam generators are >90% fuel efficient and avoid the hazards of steam pressure vessels used in traditional steam boilers. Estimated costs of custom steam application are about \$12,350 ha^{-1} which is comparable with current costs of methyl bromide fumigation in California. Steam treatment of field soils reduced the viability of propagules of *C. esculentus, Polygonum aviculare*, *Portulaca oleracea* and *Stellaria media* by over 90% and performed similarly to chloropicrin plus 1,3-dichloropropene fumigation. Control of *Capsella bursa-pastoris*, P. *aviculare*, *Poa annua*, and S. *media* in the field with steam was comparable to methyl bromide at >90%. Steam is a very effective non-fumigant method of soil disinfestation and it likely has a role in a future California strawberry production system that must use less fumigant than was allowed previously.

Keywords: Steam, soil disinfestation, weed seed, strawberry

Weed control with flaming and cultivation in maize and soybean (178)

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Propane-fueled flame weeding and mechanical cultivation are common tools for weed control in agronomic crops. Therefore, the objective of this study was to evaluate the effectiveness of cultivation alone, flaming alone, and various combinations of cultivation and flaming combined in a single operation for weed control in maize and soybean. Field experiments were conducted in 2010-2012 utilizing flaming equipment developed at the UNL delivering propane doses of 20 and 45 kg/ha for the banded and broadcast flaming, respectively. Weed control and crop response was evaluated visually at 14 and 28 days after treatment (DAT), while yield and its components were collected at crop maturity. In general, corn and soybean exhibited excellent tolerance to heat from flaming conducted at the above selected growth stages. A single application of any of the weed control treatments did not provide satisfactory weed control regardless of the application stage. At least two applications of weed control treatments were needed for acceptable level of weed control. Maize treated twice (eg. V3 and V6 stages) with the combination of cultivation and banded flaming had 27% higher yield compared to the plots cultivated twice (12.6 t/ha vs. 9.9 t/ha). Cultivation and banded flaming applied in a single operation at the V3 and V6 stages of maize exhibited the greatest level of weed control (> 95%) in both years. Similar results were observed in soybean. Cultivation and banded flaming combined in a single operation and conducted twice (at VC and V4 stages) provided about 75% weed control and the best yield (3.3 t/ha) in both years. Flaming, with or without inter-row cultivation, can provide acceptable level of weed control in maize and soybean when conducted at least twice (VC and V4 in soybean, and V3 and V6 stages in maize).

Keywords: Maize, soybean, flaming, heat, cultivation

Effect of strip tillage systems on weed suppression in sugar beets by utilizing different cover crops (7)

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Field studies were conducted at the University of Hohenheim. The goal was to investigate weed suppression ability of cover crops planted in autumn, and the resulting mulches during sugar beet vegetation in spring. Six different treatments were investigated: untreated control, 3 cover crops in mono-cultivation and 2 cover crop mixtures (CCM). CCMs were chosen, because they have the ability to adapt in various environmental stresses (e.g. pests), which can reduce the output of a monoculture, significantly. Sugar beets were sown in a Strip Tillage (ST) system at the beginning of April. We observed, if single and mixture cultivation, of cover crops resulted in similar weed control density in autumn and in spring during the sugar beet growing season; if CCMs lead to a faster canopy development, and yielded in higher biomass (in autumn) and mulch (in spring) compared to mono-cultivation. Weed densities in the field experiment ranged from 20 to 300 plants m^{-2} with *Chenopodium album* L. and *Stellaria media* L. Vill. as predominant species. During winter season, mustard, fodder radish, spring vetch and the different CCMs resulted in an up to 80% weed suppression compared to the control. Mustard and a CCM showed a significantly faster emergence and canopy development than spring vetch and fodder radish. Highest biomass yields were observed in the mustard mono-cultivation. In spring, before sugar beet planting, mustard provided the highest amount of plant residues, biomass and the highest soil coverage (65%). In sugar beets, measurements prior to the first herbicide application showed that cover crop mulches have a weed control efficacy by 60% and 55% in mono- and mixture cultivation. No significant differences in yield were detected. This study has proven a potential of cover crop (mulches) to reduce weeds before herbicide application including a faster crop development at the early stage of the crop.

Keywords: Cover crops, mixtures, mulch, strip-tillage, sugar beets

Searching for new substances with potential herbicidal action in the Mediterranean medicinal flora. From Hippocrates Medicinal School till nowadays (651)

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Medicinal plants (MP) contain the main component of the “phytochemical pool” in the Mediterranean basin. Actually, some of the MPs produce essential oils characterized by high content of bioactive compounds. In ancient era, Hippocrates (460 -370 BC) established in Kos island (Greece) the famous Medicinal School using certain MPs such as *Hypericum hircinum* L, *H. empetrifolium* Willd, *Crithmum maritimum* L and *Artemisia arborescens* Vaill., for therapeutics aims. Nowadays, these species still occur in small populations in the island. Additionally, two other MPs, *Origanum vulgare spp. hirtum* L. and *Salvia officinalis* L. are known in Mediterranean countries for their medicinal characteristics. The aim of this study was to evaluate the phytotoxicity of the aforementioned MPs focusing on their potential herbicidal use. According to our methodology, plant tissues (leaves, inflorescences) were collected at full blooming, were air dried and subjected to hydrodistillation and chemotypical analysis of their essential oils. The derived hydrosols after dilution in water to the following concentrations, 50%, 25%, 12.5%, 6%, 3%, 1.5%, 1%, 0.5% v/v, were bioassayed two times for their inhibitory action using the bioindicators *Lemna minor* L. and *Avena sativa L*. as well as the weeds *Cyperus rotundus* L and *Lolium multiflorum* Lam. In petri dishes incubating assays (with 3 replications), the seeds germination and radicle growth of *Avena* and *Lolium*, the tubers vegetation of *Cyperus* and the fronds growth of *Lemna* in aqueous culture, were measured daily for 10 days. Estimating the Inhibitory Index($I_{50\%}$) based on dose response curves, *Origanum* hydrosol showed the highest phytotoxicity in *Avena, Lolium* and *Cyperus* bioassays, followed in reduced rank by *Artemisia, Crithmum*, *Salvia* and *Hypericum* hydrosols. Noticeably, in *Lemna* assays *Salvia* showed the highest phytotoxic effect. The differential phytotoxic response of bioindicators may be attributed to the different chemotypical specificity of the tested MPs (research in progress).

Keywords: Medicinal plants, hydrosols phytotoxicity, bioidicators, weeds

Evaluation of safflower (*Carthamus tinctorius* cv. Koseh) extract on germination, antioxidants enzyme activity, cell membrane damage and induction of α-amylase activity of wild mustard (*Sinapis arvensis*) seeds (515)

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This research was carried out in order to evaluate possible allelopathic effects of safflower (*Carthamus tinctorius* L. cv. Koseh) on seed germination and induction of α-amylase of wild mustard (*Sinapis arvensis* L.). The experimental design was arranged in a completely randomized design with six replications. Treatments were different safflower extract concentrations (0, 5, 10, 15 and 20%). Results showed a decrease in seed germination, lipid peroxidation malondialdehyde (MDA) concentration, seedling fresh weight and seedling length of wild mustard when safflower extract concentration increased. However, the mean germination time decreased. Safflower extracts also inhibited the induction of α-amylase in target seeds and the inhibition increased with increasing extract concentration. The lowest induction of α-amylase was obtained with 15 and 20% safflower extract (5.1 and 4.7 nmol $seed^{-1}$ min^{-1}, respectively).

Keywords: Allelopathy, germination, mda, antioxidant enzyme

Session 51
HERBICIDES AND APPLICATION TECHNOLOGY: Affects from Herbicide Applications

Keynote: The auxin uptake carrier AUX1 does not carry most classes of auxinic herbicide (649)

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Auxins are the basis of one of the most successful classes of herbicide with a commercial history dating back 50 years. The family of auxinic herbicides is broadly-based, is variously selective, has a number of chemical scaffolds and incidences of tolerance have not been widespread or pervasive. Hence there is an interest in what contributes to the modes-of-action and elements of selectivity of different actives. The principal route for cellular auxin uptake is by the activity of the proton-coupled auxin uptake carrier AUX1. Models have shown that a factor referred to as diffusion is also important, but selectivity in uptake is conferred by the AUX1 protein. Using both root growth bioassays with *aux1* mutants and accumulation assays using tobacco BY-2 cell cultures, we have mapped the structure-activity relationship of AUX1. We have developed mathematical models for accumulation of 2,4-D and competitive inhibition of 2,4-D uptake, yielding both accurate IC_{50} values and insights into the relative importance of AUX1-mediated uptake versus diffusion. We have used a wide panel of auxins and analogues to give a new cheminformatic map of AUX1 substrate selectivity. Amongst the results we will show that major families of auxinic herbicides are not carried by AUX1 and reflect on how this affects our understanding of auxin selectivity as herbicides.

Keywords: Auxin, herbicide, transport, model, competitor

Rabinovitz O. (IL): *Phelipanche aegyptiaca* control in processing tomatoes by weekly drip chemigation of imazapic at low application rates (268)

On Rabinovitz *(The Israeli Ministry of Agriculture, Kfar Yuval, Israel),* ***Yaakov Goldwasser*** *(The Hebrew University of Jerusalem, Rehovot, Israel),* ***Hadar Kuzukaro*** *(The Hebrew University of Jerusalem, Rehovot, Israel),* ***Baruch Rubin*** *(The Hebrew University of Jerusalem, Rehovot, Israel)*

Laboratory and field experiments were conducted to evaluate drip chemigation of imazapic (Cadre®, (240 g ai/L) for *Phelipanche aegyptiaca* control in processing tomatoes. The recommendation for *Phelipanche aegyptiaca* management is three applications of 6 g/ha imazapic per application every two weeks starting 45 days after tomato transplanting. The objective of this study was to evaluate the effect of weekly applications of reduced doses of imazapic to improve *P. aegyptiaca* control and enhance tomato plant selectivity. Experiments were conducted using two commercial processing tomato fields in the Upper Galilee of Israel in which herbicide applications were made by farmers. Weekly tomato growth estimations and *P. aegyptiaca* inflorescence counts as well as final tomato yields were determined for the following treatments: non-treated control, weekly imazapic application, and imazapic application every two weeks. Soil samples to determine imazapic levels in the soil were collected 1 and 7 days after initial imazapic application and 13 days before tomato harvest. weekly applications of imazapic resulted in 37- to 41-fold reductions in *P. aegyptiaca* infestation compared to the non-treated plots. Additionally, a 21- to 23-fold reduction in *P. aegyptiaca* infestation was observed following bi-weekly imazapic application compared to the non-treated plots. Tomato yields following weekly imazapic application were 1.4-3.3 fold higher compared to the non-treated plots at one field and 3.3 fold higher than the two week interval treatment in one field. However, tomato yields were not different following the two week interval treatment of imazapic yield in the second field compared to yields following weekly application of imazapic. Imazapic levels in soil samples is currently being evaluated. Weekly interval drip chemigation of imazapic is more efficient for *P. aegyptiaca* control compared to two week imazapic application intervals under commercial field conditions. Application timing and rates should take into account soil texture, climate, crop, and parasite development conditions.

Keywords: Broomrape, Parasitic plants, ALS herbicides

Detection of herbicide effects on pigment composition and PSII photochemistry in *Helianthus annuus* by Raman spectroscopy and chlorophyll a fluorescence (783)

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Impact of herbicides from three mode-of-action groups: protoporphyrinogen oxygenase (carfentrazone-ethyl) inhibitors, carotenoid biosynthesis (mesotrione, clomazone and diflufenican) inhibitors and acetolactate synthase (amidosulfuron) inhibitors were studied for control of sunflower plants (*Helianthus annuus*). Raman spectroscopy, chlorophyll fluorescence (ChlF) imaging and UV screening of ChlF were combined in order to monitor changes in pigment composition, photosystem II (PSII) photochemistry and non-photochemical quenching in plant leaves at six days after herbicide application. Raman signal of phenolic compounds, carotenoids and chlorophyll was monitored and differences in their intensity ratios were observed. Strong enhancement of relative content of phenolic compounds were registered in the case of amidosulfuron-treated plants, with simultaneous decrease of chlorophyll/carotenoid intensity ratio. The results were confirmed by *in vivo* measurement of flavonols using UV screening of ChlF method. Herbicides from the group of carotenoid biosynthesis inhibitors decreased both maximum quantum efficiency of PSII and non-photochemical quenching parameter determined by ChlF. Resonance Raman imaging (mapping) data with high resolution (150,000- 200,000 spectra) are presented, showing distribution of carotenoids in leaves of *Helianthus annuus* treated by two of the herbicides acting as inhibitors of carotenoid. Clear signs of carotenoid depletion within sunflower leaves induced by the treatment were observed. The different spatial pattern of the depletion was registered, dependent on the type of herbicide applied, i.e., clomazone and diflufenican, respectively. This study was supported by the Ministry of Agriculture (NAZV), project number QJ153037 and NPU I grant of Ministry of education, youth and sport (grant number LO1415)

Keywords: Herbicides, Raman spectroscopy, Chlorophyll fluorescence, UV screening

Rainfastness enhancement effect of adjuvants on glufosinate ammonium herbicide for weed control at high rainfall intensity in immature oil palm environment (740)

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A common concern for herbicide application is the efficacy could be reduced if rainfall occurred shortly after spraying especially in the immature oil palm plantations. Incorporating of adjuvants as tank mix with herbicide is the usual solution to overcome these problems. However, in high rainfall area with high rainfall intensity, not many adjuvants are capable to enhance the rainfastness of the herbicide. A study was carried out to evaluate 14 adjuvant products (MIRACLE, ACTFAST (ACTIVATOR), EMERY609, WET & STICK, MYTRON, DS747, SILWET408, BOND, AQUAREX, ALBAROL WHITE OIL, EMERY610, SILMAX 100, KAO134 and ACTIRON) on its capability to enhance rainfastness of glufosinate ammonium herbicide in controlling general weeds in immature oil palm. The study was conducted in 4 stages in a specially built rainfall simulation system in an immature oil palm planting field in Banting, Selangor, Malaysia. Results showed that only adjuvant SILMAX 100 at 0.1% v/v and KAO134 at 0.1% v/v incorporated with glufosinate ammonium 13.5% in the spraying tank prior to spraying was capable to enhance the herbicide rainfastness and provide satisfactory control of general weeds after heavy rainfall simulation of 31 mm/hour rainfall intensity post-treatment. Thus, the usage of SILMAX 100 and KAO134 is recommended to be used as tank mix with herbicides prior to spraying in the oil palm plantations that is having high frequency of raining days and high rainfall to reduce losses of herbicide efficacy due to rain wash off. However, based on 0.1% v/v dosage, SILMAX 100 will incur an additional chemical cost of around RM1.12 per 16 L spraying pump while additional cost of RM1.44 at 0.1% v/v dosage will be incurred for KAO134. Estimated cost over benefit ratio is 1:4.14 for SILMAX 100 and 1:3.22 for KAO134.

Keywords: Adjuvant, Rainfastness, Glufosinate ammonium, Rainfall intensity, Immature Oil Palm

Integration of allelopathic solutions and herbicides for control of *Sorghum halepense* (L.) Pers. (646)

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Ilhan Uremis *(Mustafa Kemal University, Faculty of Agriculture, Hatay, Turkey)*

Johnsongrass (*Sorghum halepense* (L.) Pers.) is a troublesome weed which has evolved resistance against many herbicides and is one of the plants with autotoxic properties. Such autotoxic properties can be used to control this weed. This study was aimed at using water extracts of mature johnsongrass alone and in integration with lower doses of herbicides. Two doses of johnsongrass water extracts (JGWE: 2% and 4%) alone and in combination with lower doses of foramsulfuron and clethodim were applied as post-emergence spray. A non-treated control was included in the experiment for comparison. Thirty days after the treatment' application, the plant height of johnsongrass plants were recorded in each treatment, the plants were harvested to record fresh and dry weight. Results indicated that JGWE (2 and 4%) provided a satisfactory reduction in fresh weight (37-46%), dry weight (46-60%) and plant height (30-39%) of johnsongrass over control. Half doses of herbicides (foramsulfuron and clethodim) or a combination of herbicides + JGWE provided a weed control statistically similar with that of allelopathic water extracts. The results of our studies conclude that allelopathic JGWE possess the potential to suppress the johnsongrass plants, however, their combination with herbicides could not significantly improve the control of johnsongrass compared with individual use of these two methods.

Keywords: Sorgaab, *Sorghum halepense* (L.) Pers., foramsulfuron, clethodim, reduced dose

Bio-efficacy of fluazifop-*p*-butyl against grassy weeds in cotton (*Gossypium herbaceum* L.) and its residual effect on succeeding blackgram crop (528)

S Rao Atluri *(Acharya N.G.Ranga Agricultural University, Guntur, India)*

A field experiment was conducted during the rainy season of 2010-11 and 2011-12 at the Regional Agricultural Research Station in Lam, Guntur – 522034, Andhra Pradesh, India to evaluate the bio-efficacy of fluazifop-p-butyl against grassy weeds in cotton and its residual effect on succeeding blackgram crops during the winter season. Postemergence treatments were applied 23 days after sowing (DAS) including fluazifop-p-butyl at 100, 134, 167, 335g/ha (for phytoxicity) in comparison with paraquat at 600g/ha, pendimethalin at 750g/ha (preemergence), hand weeding at 20, 40 and 60 DAS and a weedy check. All treatments were replicated three times in a randomized block design. Results indicate that postemergence application of fluazifop-p- butyl at 167g/ha reduced grassy weed growth which resulted in greater crop dry weight, yield components and seed cotton yield compared to lower application rates of fluazifop-p-butyl (100 and134 g/ha). Results following application of fluazifop-p- butyl at 167g/ha were similar to those following application of fluazifop-p-butyl at 335 g/ha in both years. No application rate of fluazifop-p-butyl, including the highest dose (335g/ha), resulted in cotton injury. In the field experiment, residual carryover of fluazifop-p-butyl to subsequent blackgram crops following fluazifop-p-butyl applied at 100 to 335 g/ha was evaluated. No significant differences in blackgram plant population, plant height, crop dry weight and seed yield were observed indicating that there was no residual effect of fluazifop-p-butyl in soil after cotton harvest. It is concluded that postemergence application of fluazifop-p-butyl at 167 g/ha is effective in controlling grassy weeds without any crop injury and residual effect on the succeeding crop.

Keywords: Fluazifop-p-buytl, Grassyweeds, Cotton

POSTERS

Session 1
HERBICIDE RESISTANCE

Herbicidal performance of different ALS-inhibitors on black-grass (*Alopecurus myosuroides* Huds.) – Impact of non-target-site-resistance (802)

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The introduction of the Clearfield®-production system enables farmers for the first time to use an ALS-inhibitor in Winter Oilseed Rape for post-emergence control of broadleaf weeds. Additional grass weed activity observed with imazamox on sensitive populations of *Alopecurus myosuroides* Huds. raises the question, whether such a use does have an impact on the selection pressure for resistance already caused by ALS-graminicides in cereal crops. In a resistance monitoring program, conducted during 2010 – 2012 on *Alopecurus myosuroides* Huds. a total of approx. 200 populations from different European countries were tested on their susceptibility against different ALS-inhibitors, including products with active substances of different chemical classes: imazamox (imidazolinone), mesosulfuron/iodosulfuron (sulfonylurea) and pyroxsulam (triazolopyrimidine). All products were used at 2x, 1x and ½x of their maximum registered dose rate including their recommended adjuvant. Efficacy results from greenhouse trials were used to classify the resistance level in comparison to a sensitive standard using the 4 class system (S, R?, RR, RRR) developed by S. Moss (1999). In a total of 42% of the tested populations, different levels of resistance against mesosulfuron/iodosulfuron were observed, with half of them showing no point mutation at Pro197 and/or Trp574. In a direct comparison of the tested ALS-inhibitors on the resistant population without a target-site mutation, a stronger decline in herbicidal activity of imazamox compared to the other two ALS-graminicides was observed. The use of imazamox containing herbicides in Winter Oilseed Rape within the EU started with the introduction of the Clearfield®-system in 2012. As such, the tested populations were hardly exposed to imazamox, with the current level of non-target site resistance most likely caused by the established products used in winter annual crop rotation. Non-target site resistance in *Alopecurus myosuroides* Huds. already achieved a level, which is higher than the activity potential expressed by imazamox.

Keywords: Imazamox, mesosulfuron, pyroxsulam, *Alopecurus myosuroides*, non-target site resistance

The poster in a PDF version is available here.

Quinclorac absorption and translocation in cross and multiple resistant barnyardgrass (*Echinochloa crus-galli*) populations from Brazil (727)

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In South Brazil, multiple resistant barnyardgrass has become a difficult-to-control species. Barnyardgrass populations (ECH77 and ECH141) cross-resistant to imazethapyr and bispiribac-sodium and resistant to quinclorac were used to study mechanisms of quinclorac resistance. Absorption and translocation of [^{14}C]quinclorac in ECH77, ECH141 and in a susceptible (SUS) biotype were determined. Maximum absorption was estimated to occur at 48 HAT for SUS, compared to 54 and 57 HAT for ECH77 and ECH141, respectively. Time required for 90% of maximum absorption (t_{90}) was estimated in 29, 34, and 10 HAT for ECH77, ECH141 and SUS, respectively. At 72 HAT, more [^{14}C] remained in the treated leaf of SUS (47%) compared to ECH77 and ECH141 (27% and 23%, respectively). Translocation was predominantly below the treated leaf in SUS with less than 1% and 0.5% of [^{14}C] detected above the treated leaf and in the root, respectively. At 48 HAT, 6%, 13% and 10% of absorbed [^{14}C] had been translocated below the treated leaf in SUS, ECH77 and ECH141, respectively. At the same evaluation time, 1%, 9% and 14% of absorbed [^{14}C] had been translocated above the treated leaf in SUS, ECH77 and ECH141, respectively. At 48 and 72 HAT, less than 0.5% of [^{14}C] was detected in the roots of the resistant biotypes. Levels of [^{14}C] increased below and above the treated leaf of ECH141. At 72 HAT, 15% and 17% of [^{14}C] was detected below and above the treated leaf of ECH141, respectively. The greater total translocation in ECH77 and ECH141 compared to SUS, the [^{14}C] distribution pattern across plant parts, as well as cross and multiple resistance present in ECH77 and ECH141, lead to the hypotheses: 1) the greater [^{14}C] translocation in the resistant biotypes might be [^{14}C]quinclorac metabolites, and 2) resistance is primarily metabolism-based. Therefore, metabolism studies are being conducted.

Keywords: Metabolic resistance, radiolabeled herbicide, auxinic herbicide, cross-resistance, rice weeds

The poster in a PDF version is available here.

Butachlor inhibition of plant growth in *Oryza sativa* involves ROS-mediated oxidative damages and malfunctioning of antioxidant defense system (208)

Faisal Islam *(Zhejiang University, Hangzhou, China),* ***Jian Wang*** *(Zhejiang University, Hangzhou, China),* ***Muhammad Ahsan Farooq*** *(Zhejiang University, Hangzhou, China),* ***Rafaqat Ali Gill*** *(Zhejiang University, Hangzhou, China),* ***Jinwen Zhu*** *(Zhejiang University, Hangzhou, China),* ***Weijun Zhou*** *(Zhejiang University, Hangzhou, China)*

Growth inhibition and biomass reduction are general responses to herbicide stress in crop plants. The interest in understanding the toxic effects of herbicides on crop growth and physiology has increased in last decades. Butachlor is a systemic herbicide, used extensively in paddy fields. In this study, we investigated the different physio-biochemical and molecular changes in two rice cultivars Zhejing 88 (ZJ 88) and Xiushui 134 (XS 134) being subjected to different concentrations (0.5, 1, 2 mM) of butachlor. The herbicide toxicity showed negative impact on photosynthesis, as revealed by decrease in chlorophyll contents, carotenoids, chlorophyll fluorescence and alternations in chloroplast ultra-structures. A significant increase in oxidative stress as evidenced by enhanced production of malondialdehyde, reactive oxygen species (H_2O_2, $O_2^{\cdot}$) and electrolyte leakage was observed in cultivar ZJ 88 as compared to XS 134. Higher activities of antioxidant enzymes and their related gene level were also observed in XS 134 than ZJ 88 under butacholar treatments. Surprisingly, proline accumulation and pyrroline-5-carboxylate synthase transcript level were more pronounced in ZJ 88, suggesting its ameliorative role under butacholar induced oxidative stress. Significant changes in soluble sugar, protein, phenolic, phenylalanine ammonia-lyase and putative fatty acid elongase transcripts were also found in XS 134 as compared to ZJ 88. In addition, butachlor exposure produced swelling in the chloroplast, increased number of plastoglobuli, disrupt thylakoid patterning, disintegrated mitochondria and produced turbid nucleoplasm. Thus, cultivar ZJ 88 was shown to be more sensitive under butachlor toxicity as compared to XS 134. The present work extends current knowledge of antioxidant defense system and transcriptional regulation of stress responsive genes in rice plants and provides valuable insights into aspects of butachlor detoxification and acquired tolerance.

Keywords: Chlorophyll fluorescence, pyrroline-5-carboxylate synthase, phenylalanine ammonia-lyase, ultra-structure, Oxidative stress

The poster in a PDF version is available here.

Target-site- and non-target-site-resistance mechanisms are both involved in resistance to fenoxaprop-p-ethyl in American sloughgrass (*Beckmannia syzigachne*) populations (255)

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American sloughgrass (*Beckmannia syzigachne*) is one of the main grass weeds that harm wheat production in rice-wheat areas in China. Fenoxaprop-*p*-ethyl is the main herbicide used to selectively control grass weeds in China. American sloughgrass has evolved resistance to fenoxaprop-*p*-ethyl due to continuous application. Samples from 31 field populations in partial rice-wheat areas in China were collected and treated with fenoxaprop-*p*-ethyl to determine whether the populations were resistant to fenoxaprop-*p*-ethyl. The results show that ten of the 31 tested field populations evolved a high level of resistance to fenoxaprop-*p*-ethyl. A portion of the ACCase gene was amplified, sequenced and aligned. The well-known Ile-1781-Leu, Ile-1781-Val, Ile-2041-Asn, Asp-2078-Gly and Gly-2096-Ala mutations were identified in 5 resistant populations. None of the known substitutions endowing ACCase-inhibitor resistance were identified in the other resistant populations. Our research shows that the TSR mechanism and NTSR mechanisms are both likely involved in American sloughgrass; thus, it is more difficult to control American sloughgrass efficiently using different ACCase-inhibiting herbicides.

Keywords: ACCase, resistant mechanism, *Beckmannia syzigachne*, amino acid substitution, non-targetisite resistance

The poster in a PDF version is available here.

Inheritance patterns for resistance to clethodim in *Lolium rigidum* populations from Australia is variable (130)

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Lolium rigidum is a major weed of agriculture in Australia and has developed resistance to many herbicides. Clethodim was the last in-crop herbicide available for its control. Clethodim resistance has now occurred in *L. rigidum* populations across Australia. The inheritance of clethodim resistance was studied in 5 clethodim-resistant populations (A61, A91, E2, F4 and FP). Reciprocal crosses between resistant and susceptible populations were made and a dose response conducted on the F_1 individuals. Within 4 crosses (all except A61), the response of reciprocal F_1 families were similar to each other, indicating clethodim resistance is encoded on the nuclear genome. The level of dominance ranged from partial to complete across the herbicide dose range used. In A61, the response of F_1 from the maternal and paternal parents was different, indicating resistance is inherited through the female parent, with a minor proportion through pollen. F_1 individuals from four of the populations were crossed with susceptible individuals to create backcross (BC) progenies. All BC populations segregated in a different manner. The FP population fitted a single gene model (1:1), whereas A91 and E2 populations did not. A complete dose-response analysis on BC progeny of A91 fitted a 1:3 inheritance model, indicating two genes, one dominant and one recessive, contributed to resistance. For E2 the data fitted a 3:1 inheritance model indicating two dominant genes contributed to resistance. For A61 the BC populations responded similarly to the female parents. Where the maternal parent was susceptible (F_1♀S) the BC progeny were susceptible and where the maternal parent was resistant (F_1♀R), the BC progeny were resistant. This confirmed maternal inheritance of clethodim resistance in this population. The results of this study indicate different patterns of inheritance of clethodim resistance exist among *L. rigidum* populations, which indicates multiple resistance mechanisms may be present in these populations.

Keywords: Inheritance, clethodim, segregation, *Lolium rigidum*

The poster in a PDF version is available here.

AHAS single nucleotide polymorphism Asp376Glu in *Lolium perenne*: impact on herbicide efficacy, growth traits and enzyme activity (237)

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Recently the acetohydroxyacid synthase (AHAS, EC 2.2.1.6, formerly EC 4.1.3.18), single nucleotide polymorphism Asp376Glu (numbering standardised to *Arabidopsis thaliana*) was detected in a *Lolium perenne* population originating from France. This is the first report of an AHAS Asp376Glu genotype in *Lolium* species. Plants of the mentioned population were cultivated under greenhouse conditions and 150 individuals where genetically characterized by sequencing the AHAS-gene between nucleotides 122 and 654. Plants bearing the Asp376Glu single nucleotide polymorphism were multiplied by repeated tiller propagation for herbicide efficacy trials and growth trait studies. All selected Asp376Glu genotypes were heterozygous and showed no other single nucleotide polymorphisms in the AHAS- and ACCase-gene. Furthermore all selected genotypes were sensitive against ACCase inhibitors (aryloxyphenoxy-propionates, cyclohexanediones and phenylpyrazolines), and thus the probability for masked NTSR mechanisms biasing the resistance profiles of the selected genotypes can be excluded. A sensitive reference genotype was selected out of the same initial population as well as two resistant reference genotypes bearing the Trp574Leu hetero- and homozygous. In addition genotype specific AHAS activity and herbicide induced AHAS inhibition was studied in vitro, using recombinant *Arabidopsis thaliana* DNA. *L. perenne* plants bearing the Asp376Glu mutation were highly resistant against mesosulfuron+iodosulfuron, pyroxsulam, and propoxycarbazone, whereas against imazamox only moderately increased tolerances for dosages below 140 g a.i. ha^{-1} were observed. Below ground biomass of the Asp376Glu and Trp574Leu genotypes appeared to be significantly reduced by up to 60% compared to the AHAS genetic wild type. The AHAS enzyme study could show that AHAS enzyme rate of Asp376Glu genotypes appeared to be reduced by 48% compared to the AHAS genetic wild type. The observed pleiotropic effects of the Asp376Glu mutation are providing a first indication that plant fitness is hampered.

Keywords: AHAS, target site resistance, fitness costs

The poster in a PDF version is available here.

Confirmation and mechanism of glyphosate resistance in tall windmill grass (*Chloris elata*) from Brazil (840)

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The overreliance on glyphosate as a single tool for weed management in agricultural systems in Brazil has selected glyphosate-resistant populations of tall windmill grass (*Chloris elata* Bisch.). Two *C. elata* populations, one glyphosate-resistant (GR) and one glyphosate susceptible (GS), were studied in detail for a dose-response experiment and for resistance mechanism. The dose causing 50% reduction in dry weight (GR50) for GR was 620 g a.e. ha^{-1} and 114 g ha^{-1} for GS, resulting in an R/S ratio of 5.4. GS had significantly higher maximum ^{14}C-glyphosate absorption (Amax) into the treated leaf (51.3%) than GR (39.5%), a difference of 11.8% in maximum absorption. GR also retained more ^{14}C-Glyphosate in the treated leaf (74%) than GS (51%), and GR translocated less glyphosate (27%) to other plant parts (stems, roots, and root exudation) than GS (36%). There were no mutations at the Pro106 codon in the gene encoding 5-enolpyruvylshikimate-3-phosphate synthase (*EPSPS*). There was no difference in *EPSPS* genomic copy number or *EPSPS* transcription between populations GS and GR. Based on these data, reduced glyphosate absorption and increased glyphosate retention in the treated leaf contribute to glyphosate resistance in this *C. elata* population from Brazil.

Keywords: Copy number, gene amplification, gene mutation, herbicide absorption, herbicide translocation

The poster in a PDF version is available here.

QWERT® – a innovative system to reduce weed resistance in-season (274)

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Farmers and consultants often report about weed populations surviving herbicide applications which in previous years proved to be effective. In Germany, herbicide-resistant populations of *Apera-spica-venti* L. Beauv. and *Alopecurus myosuroides* Huds. are widely spread, causing significant financial losses for farmers. The QWERT®-System will help farmers to identify herbicide-resistance directly in the field and provide additional information from the lab, giving them the chance to control these weeds in-season. This prevents yield losses and stops propagation of herbicide-resistant weed seeds. The QWERT®-System is developed by several companies as a tool to reduce costs and problems associated with herbicide-resistant weed populations. It provides a precise in-season diagnosis system, using in-field chlorophyll-fluorescence imaging and PCR-technologies. In-field measurements using a PAM-fluorometer show reduced herbicide effects 4-5 days after treatment, already. In order to calibrate the PAM-fluorometer data from all over Germany was collected and evaluated. After measurement, analyses of target site resistance (TSR-analyses) on suspect leaf samples performed by IDENTXX give precise information about kind and zygosity of mutations causing resistance within plants. Together with data from field history, farmers can find solutions to work out strategies to avoid and overcome the problem of herbicide-resistant weed populations in crop rotations. Big sized field studies using the QWERT®-System are conducted in order to demonstrate its effectiveness to discover resistant grass weeds in-field shortly after using different herbicide-treatments and control-strategies.

Keywords: Herbicide resistance, control-strategie, QWERT®, TSR-analyses

Differential proteomic analysis of glyphosate resistance in horseweed (*Conyza canadensis*) (3)

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The emergence of herbicide resistance in weeds is an increasing threat to the viability of farming enterprises and global food security. An understanding of the molecular basis for herbicide resistance is necessary in guiding the design of new molecules to combat these weeds. In the case of the herbicide glyphosate, mutation of key residues in the target protein has been reported as an effective resistance mechanism, which has evolved in some weeds. However, target site mutation has not yet been found in glyphosate-resistant horseweed (*Conyza canadensis*) biotypes. Instead, there is clear evidence that herbicide translocation within the plant is curtailed as the compound is sequestered into cell vacuoles. The key components of this resistance mechanism have not yet been identified. We have adopted a proteomic approach to identify differentially expressed proteins in glyphosate resistant and susceptible biotypes of horseweed. Plants were treated with glyphosate and samples for protein extraction harvested prior to the onset of cell death. Profiling of shikimic acid accumulation and ABC transporter gene expression were used as molecular markers to confirm the differential response to glyphosate in the 2 biotypes. Two dimensional difference gel electrophoresis (2D-DiGE) and tandem mass spectrometry led to the identification of proteins, whose response to glyphosate differed between the 2 biotypes. Here we reveal the protein network deployed after exposure to glyphosate and discuss new insights into the molecular response triggered by glyphosate.

Keywords: Glyphosate, resistance, horseweed, proteins, 2D-DiGE

Enzymatic properties and ryegrass resistance mechanism to iodosulfuron-methyl-sodium herbicide (230)

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Ryegrass (*Lolium multiflorum*) is one of the most worrisome species with regard to herbicide resistance. This study aimed to characterize the acetolactate synthase (ALS) site of action of inhibiting herbicides of ryegrass, biochemically comparing resistant biotypes (NC and AR) and susceptible biotypes to iodosulfuron-methyl-sodium (iodosulfuron) herbicide. Varying concentrations of pyruvate (1, 10, 20, 40, 60, 80 and 100 mM), of iodosulfuron (0 to 100 µM for the resistant biotypes and 0 to 0.5 µM for the susceptible biotype) and concentrations of valine, leucine and isoleucine (0, 0.001, 0.01, 0.1, 1, 10 and 100 mM) were used for the in vitro characterization. According to the results, the Michaelis constant (Km) values (pyruvate) for the biotypes assessed were similar. In the presence of iodosulfuron, resistant biotypes needed 395 to 779 times more herbicide, to inhibit 50% of the enzyme activity, compared to the susceptible biotype. This confirmed a sensitivity modification to the ALS enzyme in the resistant biotype. The resistant biotypes were less sensitive to the inhibition of the enzyme activity in the presence of the three amino acids. It was concluded that biotype resistance was due to the enzyme insensitivity to iodosulfuron herbicide.

Keywords: Acetolactate synthase (ALS), *Lolium multiflorum*, Amino acids, Sulfonylurea

Rough sprangletop (*Leptochloa scabra* Ness) resistance to propanil (141)

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Greenhouse experiments were conducted in order to determine the resistance of *Leptochloa scabra* Ness to propanil, which is the selective herbicide with longer use (> 50 years) in Venezuelan rice fields. For that purpose, seeds of ten accessions collected in traditional rice farms, considered putative resistant, and from another one collected on the campus of the Central University of Venezuela (Maracay, Aragua), used as susceptible control, were sown in plastic pots of 10 cm diameter with 500 grams of soil, approximately. Propanil treatments were applied to seedlings at two- to three-leaf growth stage and aerial biomass per pot was measured 21 days after application. From bioassay detection, seven accessions survived propanil at 2880 g ai ha-1 (commercial rate). To verify and quantify the degree of resistance to *L. scabra*, a whole-plant dose-response experiment was done using a survivor accession (LS 287P), and the susceptible check (LS 395A). Propanil treatments were 0, 180, 360, 720, 1440, 2880, 5760, 11520 g a.i. ha-1 for the accession resistant (R) and 0, 45, 90, 180, 360, 720, 1440, 2880 g a.i. ha-1 for the susceptible (S). The data were fitted to the log-logistic model using SigmaPlot statistical software (version 11.0, Systat Software, Inc., CA, USA). The average effect dose (ED50) for S was 535 g a.i. ha-1, while for R was 1784 g a.i. ha-1. The resistance index (ED50R/ED50S) of accession LS 287P was 3.3, corroborating the resistance of *L. scabra* to propanil. This is the first known case of herbicide resistance of this weed species.

Keywords: Oryza sativa L, Venezuela, dose-response, cola de zorro

Unravelling EPSPS regulation mechanisms in glyphosate-susceptible and -resistant *Amaranthus palmeri* populations (577)

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The herbicide glyphosate functions by inhibiting the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) in the biosynthetic pathway of aromatic amino acids (the shikimate pathway). *Amaranthus palmeri* is one of the most important weeds where populations with resistance to glyphosate have been described by amplification of the EPSPS gene. In this study a population from North Carolina (U.S) with this resistance mechanism (NC-R) has been physiologically studied and compared to a susceptible population (NC-S). Plants of both populations were grown in aerated hydroponic culture and sprayed with glyphosate at one time (1x = 0.84 kg ha^{-1}) and three times (3x) the recommended field rate. Plants were harvested 3 days after the application of treatment. Quantitative real-time PCR confirmed that relative EPSPS gene copy number was greater in NC-R than in NC-S (47.5-fold). Immunoblotting showed that, in both populations, the EPSPS protein increased after glyphosate treatment, suggesting a transcriptional regulation. EPSPS *in vitro* activity increased with glyphosate dose in NC-R population, but not in NC-S, where a slight decrease was detected. Free amino acids content was higher in both populations after glyphosate exposure, although the detected increase was much lower in NC-R plants. In the NC-S population each relative aromatic amino acid (AAA) content and the sum of three AAA contents were increased after glyphosate application, in a dose-dependent manner. In NC-R plants, AAA content was in general not affected after glyphosate treatment, with only a slight variation with the highest dose in leaves. These results indicate a post-transcriptional regulation at the level of EPSPS, whose signal remains unknown but cannot be AAA content. A tight control of EPSPS activity takes place *in vivo*, where transcriptional and post-transcriptional regulations are coordinated.

Keywords: *Amaranthus palmeri*, Aromatic aminoacid content, EPSPS, Glyphosate

The poster in a PDF version is available here.

Sulfonylurea (SU) herbicide resistance mechanism of some acetohydroxy acid synthase (AHAS) mutants and new designed herbicides specific to the mutants (769)

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Sulfonylurea (SU) herbicide-insensitive form of AHAS mutants in weeds is one of the biggest problems in global agriculture. The mutation rate of proline in the position 197 (Pro197) in AHAS is highest among SU herbicide-resistance mutants. Therefore, it is significant to investigate the resistance mechanism for the mutation and to develop the herbicides specific to the mutants. SU herbicide resistance mechanism of the mutants, 197Ser, 197Thr and 197Ala, in AHAS were targeted for designing new SU-herbicide. We did molecular dynamics (MD) simulation for understanding SU herbicide-resistance mechanisms of AHAS mutants and designed new herbicides with docking and MD evaluations. Mutation of residue Pro197 caused a significant conformational change in the residues 196, 197, 198, 199 and 200. The conformational change by mutation to 197Ala and 197Ser enlarged the entrance of the active site, making the herbicide unsuitable for complementary binding, while that by mutation to 197Thr contracted. Map of the root mean square derivation (RMSD) and radius gyrations (Rg) for each mutant revealed the domain indicating the conformation for herbicide resistant. Based on our investigated mechanism of the enlargement and contraction of active site entrance, we designed new herbicides with substitution at the heterocyclic moiety of a SU herbicide, chlorimuron ethyl, for the complementary binding to the changed active site entrances of mutants, and designed new herbicides. We characterized the herbicide resistance mechanism in terms of the flexibilities of the active herbicide-binding pocket for both wild and mutants, and designed new herbicide to minimize the resistant. We confirmed that our screened new herbicides bonded to both AHAS wild type and mutants with higher affinity and more stable binding conformation than the existing herbicides.

Keywords: Herbicide resistance, Acetohydroxy acid synthase (AHAS), Molecular dynamics (MD), Herbicide designs

Temperature effects on chlorophyll fluorescence of *Alopecurus myosuroides* (107)

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Chlorophyll fluorescence measured by sensors is becoming a common method for plant stress detection. A new portable imaging system has been introduced into the market. It can perform, on plants, image measurements of the maximum quantum efficacy yield (*Fv/Fm*), of the photosynthetic system (PS-II). This sensor has proven its potential in separating herbicide stressed from non-stressed plants. Yet more research needs to be performed taking into account various environmental factors that can affect the sensor output. Our aim was to measure how temperature, and other relevant weather conditions affect the *Fv/Fm* values. Herbicide stressed and non-stressed blackgrass plants (*Alopecurus myosuroides*) were measured daily in the first week after treatment. An ALS inhibitor and an ACCase inhibitor were selected as herbicides. Moreover, weather data were obtained, like sunlight, precipitation and temperature information like minimum, mean or maximum daily temperature or mean temperatures of various depths below ground (2, 5 and 10 cm) and above ground. Field measurements were conducted at winter and spring of the 2014 – 2015 vegetation period, at the University of Hohenheim, Germany. Fluorescence measurements were correlated with the corresponding weather data, above and below ground temperature and their possible combinations.

We found a positive correlation between *Fv/Fm* measurements and the below ground temperatures of the same day. The adjusted R^2 was between 0.1 and 0.54 for the winter period and between 0.43 and 0.73 for the spring period. The *Fv/Fm* values of the ALS inhibitor had the best correlation with temperature data, and the ACCase inhibitor the worst. Highest correlation was found between the *Fv/Fm* measurements and the soil temperatures 5 and 10 cm below ground. These results can be used to improve the distinctive effect between stressed and non-stressed plants, by specifically excluding the underlying temperature effect.

Keywords: Blackgrass, chlorophyll fluorescence, herbicide stress, imaging sensor, PSII, temperature

The poster in a PDF version is available here.

New plate assay for rapid detection and characterization of herbicide-resistant weeds (185)

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Annual bluegrass (*Poa annua*) is among the most troublesome weeds in managed turfgrass in Mississippi. Acetolactate synthase (ALS) inhibitors are most commonly used for annual bluegrass control. However, repeated usage of these herbicides resulted in resistance, as reported in Alabama and Tennessee. In Mississippi, our group was the first to confirm and report an annual bluegrass population (Reunion) resistant to foramsulfuron (ALS-inhibiting herbicide). The objective of this study was to develop a rapid agar plate assay for the herbicide resistant trait, which can then be used for confirming resistance of any annual bluegrass sample from residential or commercial turfgrass in less than two weeks. This study uses annual bluegrass as a model to demonstrate the feasibility of the plate assay. Greenhouse dose response studies revealed Reunion to be 45 times more resistant to foramsulfuron than the susceptible population. Reunion requires 331 g of foramsulfuron ha^{-1}, whereas the susceptible population only requires 7.2 g of foramsulfuron ha^{-1}, to achieve 50% control. Mutation of the ALS gene resulting in an amino acid substitution, Trp_{574} to Leu, was identified as a possible mechanisms of resistance in Reunion population. For the plate assay, plants were grown in Murashige and Skoog (MS) medium, and three inoculation techniques were tested. The seed, and root tip inoculation proved to be the most effective in discriminating between resistant and susceptible populations. Total time involved from planting of seed to confirming resistance was about 2 weeks (only 1 week to express injury symptoms). Daily non-destructive root scans were able to identify changes in root characteristics (number of laterals, root length, root area, and root growth rate) between resistant and susceptible populations. This plate assay can potentially be used with any weed species to effectively detect resistance traits, and can be combined with molecular assays to further confirm resistance.

Keywords: Resistance detection, Agar plate, Murashige and Skoog medium, Root phenotyping, Weed

Lolium spp. in New Zealand show resistance to glyphosate through two mechanisms and resistance to glufosinate and amitrole (27)

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Plants of *Lolium multiflorum* and *L. perenne* were recently found to have survived applications of glyphosate in several vineyards in New Zealand. Live plant samples from the vineyards were sent to Massey University to confirm resistance. The plants were multiplied by dividing into three-tiller plantlets and growing on for several weeks prior to conventional dose-response testing with glyphosate, amitrole and glufosinate using control plants from new pastures never exposed to glyphosate. These tests confirmed that *L. multiflorum* from two sites and *L. perenne* from three sites showed 10-31 fold (R/S ratio) resistance to glyphosate, 0-13 fold resistance to amitrole and 0-6 fold resistance to glufosinate. Interviews with vineyard managers revealed that all three herbicides have been used repeatedly at most sites. Possible resistance mechanisms for glyphosate were investigated using both ^{14}C-labelled glyphosate to examine translocation within the plant and DNA analyses to look for changes at the molecular level. Recovery of ^{14}C-glyphosate revealed that uptake was not affected but all the resistant plants moved lesser amounts of glyphosate toward the meristem region compared to susceptible plants, indicating it is altered translocation that confers resistance in these plants. The DNA analysis looked for changes to target-site modification in the EPSPS (5- enolpyruvylshikimate-3-phosphate synthase) enzyme, specifically at codon 106. A mutation at this site was found in one of the resistant *L. perenne* plant lines. This line also had the highest level of resistance, being three times more resistant than any of the other resistant biotypes. The conclusion is that repetitive use of a limited range of herbicides in the vineyards has led to the evolution of these *Lolium* species with multiple resistance and that one plant line shows resistance to glyphosate by two quite different mechanisms. The Ministry for Primary Industries and Foundation for Arable Research funded this study.

Keywords: *Lolium perenne*, *Lolium multiflorum*, Glyphosate, Resistance, Mechanism

The poster in a PDF version is available here.

ALS inhibitor resistance mutations in *Myosoton aquaticum* (L.): comparison of ALS enzyme and plant growth characteristics (155)

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Acetolactate synthase (ALS-) inhibitors are widely used herbicide to control broadleaf weeds in wheat fields in China. Recently, more *Myosoton aquaticum* populations in wheat field have been identified as resistant to these herbicides. Previous studies have elucidated the mechanism of resistance and *in vivo* response of ALS to ALS inhibitors. This research investigates the effect of various ALS resistance mutations in *M. aquaticum* on ALS functionality and plant growth. The enzyme kinetics of ALS from four purified *M. aquaticum* populations, each homozygous for the resistance mutations Pro197Ser, Pro197Leu, Pro197Ala, and Pro197Glu, were characterized and the effect of these mutations on plant growth was assessed via relative growth rate analysis. All the resistance mutations populations express similar extractable ALS activity to wild populations, while the Pro197Ser resistance mutation resulted in higher extractable ALS activity. In addition, all tested mutations have no significant effect on ALS kinetics. The Pro197Leu mutation remarkably increased sensitivity to feedback inhibition by isoleucine and valine. The Pro197Glu mutation slightly increased sensitivity to feedback inhibition by isoleucine. Moreover, all four mutations exhibited no significant effects on relative plant growth rate. However, all four purified *M. aquaticum* populations showed lower seed germination rate than wild populations (Pro197Pro > Pro197Ser > Pro197Glu> Pro197Leu >Pro197Ala). This study provides baseline information regarding ALS enzyme response and plant growth characteristics of *M. aquaticum* biotypes resistant and sensitive to ALS inhibitors.

Keywords: Acetolactate synthase (ALS-) mutation, enzyme kinetics, herbicide resistance, *Myosoton aquaticum* (L.)

Changes of endogenous polyamines responding to paraquat in goosegrass (*Eleusine indica* L.) seedlings (152)

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Polyamines (PAs) are ubiquitous, polycationic compounds that are essential for the growth and survival of all organisms. The aim of this study was to investigate the changes of endogenous polyamines in resistant (R) and susceptible (S) biotype of Goosegrass (*Eleusine indica* L.) seedlings after paraquat spraying. Seeds were germinated in plastic boxes with a 2:1 mixture of peat: sand in a growth chamber. Seedlings of both biotypes at the 6-7 leaf stage were sprayed with paraquat (Syngenta, China) of 0.6 kg.ai·ha^{-1}. The aboveground parts were taken from both untreated seedlings and treated seedlings sprayed with paraquat for 0, 30, 60, 90, 120 and 180 min after treatment, respectively. And then, the free putrescine (Put), spermidine (Spd) and spermine (Spm) were extracted and determined using high performance liquid chromatography by standard. The content of Spd was 59.7, 56.5, 57.3, 59.6, 57.5, and 56.7 μg·g^{-1} after 0, 30, 60, 90, 120 and 180 min by paraquat spraying, respectively, but Put and Spm was 0 in seedlings of S biotype. The content of Put was 5.04, 4.58, 5.97, 9.17, 4.78, and 4.81 μg·g^{-1}, Spd was 58.4, 59.9, 56.5, 52.3, 54.8, and 56.8 μg·g^{-1}, Spm was 0, 0, 59.2, 172.0, 89.3, and 0 μg·g^{-1}, after 0, 30, 60, 90, 120 and 180 min by paraquat spraying, respectively, in seedlings of R biotype. We suspect that the Put and Spm maybe play an important role in R biotype of *E. indica*.

Keywords: Polyamines, Paraquat, *Eleusine indica* L.

Rate of absorption and metabolism of the herbicide iodosulfuron-methyl-sodium in resistant and susceptible ryegrass biotypes (228)

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Increased metabolism resulting in rapid detoxification of the herbicide is the second most common mechanism of resistance to ALS (acetolactate synthase) inhibitors. The objective of the study was to assess the rate of absorption and metabolism of the herbicide iodosulfuron in ryegrass biotypes that are resistant and susceptible to the herbicide. Two experiments were conducted to determine herbicide absorption rate and to compare the herbicide metabolism between the biotypes resistant to iodosulfuron (NC and AR) and susceptible (S). To assess the absorption rate, samples were collected from 0 to 10 hours after herbicide application, and the collected amount of herbicide in water was quantified by Ultra Performance Liquid Chromatography (UPLC®). To assess metabolism, plant collections were performed from 0 to 20 days after herbicide application and extracted using Accelerated Solvent Extractor (ASE™) and then quantified by UPLC. Biotypes NC and S have herbicide absorption rates of 2.2 and 2.1% per hour, respectively. The amount of absorbed herbicide was not significant for biotype AR and the average absorption was 12%. The maximum absorption was found at 10 hours for biotypes NC (37%) and S (33%), both differing from biotype AR. The differences between biotype metabolism were observed up to 6 days after herbicide application, with lower metabolism for biotype S. The time required for the biotypes to degrade 50% of the herbicide was approximately 1 day for the resistant biotypes and 4 days for biotype S. It can be concluded that resistant biotypes AR and NC more rapidly metabolize the herbicide, compared to the S biotype. No differences in absorption between biotypes indicated that absorption was not a resistance mechanism.

Keywords: Acetolactate synthase (ALS), Lolium multiflorum, Detoxification, Sulfonylurea

Synergists for indirect exploration of non-target-site herbicide resistance mechanisms in different *Alopecurus myosuroides* populations (206)

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Non target-site resistance (NTSR) is one of the main challenges in current herbicide based weed control systems in many crops. To study the resistance mechanisms an indirect method is the use of malathion as inhibitor of cytochrome-monooxygenase (CYPs). However, modern tools like transcriptomic approaches showed that also other enzymes can be involved in enhanced metabolic resistance mechanisms. The question is, if other synergists can bind to these enzymes. The aim of the study was to investigate the potential of different chemicals as synergists to improve herbicide performance in different NTSR ALOMY populations and on wheat. Plants were grown in a greenhouse and sprayed in the 2-leaf stage. Herbicide application was done without potential synergist, spraying a synergist 24 h before herbicide treatment and in a tank mixture synergist + herbicide. 21 days after treatment plant fresh weight was measured. As synergists the insecticide malathion, 4-Chloro-7-nitrobenzofurazan, malathion + 4-Chloro-7-nitrobenzofurazan and the fungicide prothioconazole were used. All herbicides and synergists were also sprayed on wheat plants to investigate their selectivity. Results showed that malathion had the strongest effect in increasing the herbicide efficacy. However, also 4-Chloro-7-nitrobenzofurazan and prothiocanazole showed some synergistic potential. There were interactions between herbicides, the application timing, and ALOMY population. For example 4-Chloro-7-nitrobenzofurazan showed no effect on pinoxaden performance at population '710', but a significant efficacy increase on meso- + iodosulfuron. While malathion reduced the selectivity of meso- + iodosulfuron in wheat, prothioconazole and 4-Chloro-7-nitrobenzofurazan did not. Results showed that there are some potential synergists besides malathion which might address other herbicide degradation mechanisms than CYPs. Furthermore they are more selective in wheat than malathion. A method might be developed to screen resistant weed populations for presence of different herbicide metabolic pathways in addition to other more direct methods.

Keywords: Malathion, 4-Chloro-7-nitrobenzofurazan, prothioconazole, mesosulfuron, pinoxaden

Possible mechanisms conferring glyphosate resistance to *Paspalum paniculatum* biotypes from Costa Rica (776)

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Paspalum paniculatum is a perennial herbaceous grass species originating from South America. It is of economic importance as a weed in plantation crops where glyphosate is widely used in its control. Reduced control by glyphosate at its recommended field rate (840 g ae ha-[1]) has been observed in palm (for hearts) and banana crops in the Caribbean region of Costa Rica in fields exposed to multiple glyphosate applications per year for more than a decade. The objective of the study was to characterize glyphosate resistance mechanisms in confirmed resistant (R) biotypes. Greenhouse dose–response bioassays carried out in 2012-2014 confirmed that putative resistant plants with 5 leaves to 3 tillers were indeed three- to eight-fold less sensitive to glyphosate than known susceptible (S) plants. Glyphosate absorption and translocation measured with radiolabeled C^{14} glyphosate and phosphorimaging were similar in both R and S biotypes. Plants from representative individuals of S and R biotypes, were treated with glyphosate (0.72 kg ha-[1]) and shikimic acid was extracted 6, 24, 48, 72, 96 and 144 h after treatment (HAT). The S plants accumulated between five and eight times more shikimic acid than did the R plants at 6 and 144 HAT. Glyphosate and AMPA, its main metabolite, were quantified in R plants treated with 1.0 kg ha-[1] glyphosate and nontreated (control) plants, by LC-MS/MS. High levels of glyphosate were found (25 to 33 ppm) in all treated plants, but no AMPA was detected, indicating that differential metabolism of the herbicide does not confer resistance. The *EPSPS* gene copy number was not different between R and S plants. Preliminary partial sequencing of the *EPSPS* gene suggests that resistance is related to target site mutation in glyphosate-resistant *P. paniculatum* biotypes from Costa Rica.

Keywords: Glyphosate, *Paspalum paniculatum*, Resistance mechanisms

The poster in a PDF version is available here.

Control and cross-resistance of barnyardgrass to ALS- and ACCase-inhibitors in rice fields in Korea (489)

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Barnyardgrass (*Echinochloa crus-galli* var. *crus-galli*) is the most difficult-to-control weed that infests rice fields in Korea. The objectives of this research were to confirm ALS (acetolactate synthase)- and ACCase (Acetyl-CoA carboxylase)-inhibiting herbicide-resistant barnyardgrass in Korea and to determine sensitivity and efficacy of rice herbicides applied for control of resistant and susceptible barnyardgrass biotypes. The putative seeds of ALS- and ACCase-resistant barnyardgrass biotype were collected from rice fields in fall 2010. The response of barnyardgrass biotypes to 10 rates (0 to 10×) of ACCase inhibitors, cyhalofop-butyl and metamifop, and ALS inhibitors, priminobac-methyl, penoxsulam and flucetosulfuron, was evaluated in a dose–response bioassay in a greenhouse. On the basis of the values at GR50 (concentration of respective herbicides required for 50% inhibition of dry weight), the analysis showed about 19- to 42-fold resistance depending upon the type of ALS- and ACCase-inhibiting herbicides being investigated and susceptible biotype used for comparison. The resistant biotype had a reduced sensitivity to ALS- and ACCase-inhibiting herbicides. These results suggested a cross-resistance between ALS- and ACCase-inhibiting herbicides that resulted in ineffectiveness for control of barnyardgrass. Barnyardgrass biotypes were effectively controlled (≥ 90%) with mefenacet and fentrazamide by 2 leaf stage, whereas oxadiazon, thiobencarb and butachlor provided over 90% control by l leaf stage of the resistant biotype.

Keywords: Barnyardgrass, control, herbicide, resistance

The poster in a PDF version is available here.

Development of a standardised test system for detection of resistance against pre-emergence herbicides (381)

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Herbicide resistance is often caused by non-target site based resistance mechanisms (NTSR). Apart from the impact of NTSR on the efficacy of ALS and ACCase inhibiting herbicides, occasionally thiocarbamates, dinitroanilines and oxyacetamides seem to be affected by NTSR as well. Due to the lack of molecular markers for quick detection of NTSR, extensive glasshouse based herbicide efficacy studies are inevitable. However, adsorption of the mentioned compounds to humic substances and clay minerals as well as particle bond transport due to irrigation water makes glasshouse based resistance test systems for pre-emergence herbicides highly biased and unreliable. The aim of the presented test system is 1) to increase detection accuracy by replacing the common soil substrates by chemically inert growth media and 2) to reduce the time required for resistance testing. Pre-germinated seeds of a sensitive blackgrass reference population as well as of five known NTSR populations were cultivated in plastic containers filled with quartz sand and nutrient solution. On top of the pre-germinated seeds a 0.5 cm thick agarose cover was placed. The agarose cover contained the pre-emergence herbicides pendimethalin, prosulfocarb, flufenacet, and metazachlor in descending dosages. In a second approach pre-emerged seeds were directly grown on herbicide-agarose growth medium. Herbicide efficacy evaluation in the first approach was evaluated ten days after treatment by determination of photosynthetic active leaf area, based on chlorophyll fluorescence measurement. For the second approach, herbicide efficacy evaluation was evaluated by bi-spectral image based root growth analysis. The results of the developed test systems were compared with glasshouse based standard herbicide dose-response trials. Both test systems were able to detect resistance against all tested herbicides with high accuracy. Furthermore the potential for automated herbicide efficacy assessment makes these two new test systems favourable in terms of cost efficiency, user safety and detection accuracy.

Keywords: Pre-emergence herbicides, herbicide efficacy assay, herbicide resistance

The poster in a PDF version is available here.

Situation of multiple resistance in barnyardgrass (*Echinochloa crus-galli* L. Beauv.) across the rice fields of Thailand (742)

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Several rice farmers in central plain of Thailand have recently complained on herbicide failure of barnyardgrass (*Echinochoa crusgalli* L. Beauv.) control. In 2014, a random survey was conducted in pre-germinated wet-seeded rice fields across central and lower north of Thailand to establish the situation of multiple-resistance in barnyardgrass. A total of 280 rice fields were visited to collect barnyardgrass seeds. Resistance to three ALS-inhibiting herbicides, i.e. bis-pyribac sodium, penoxsulam and pyribenzoxim, were screened in both laboratory and glasshouse conditions. In addition, resistance to other herbicides with five different modes of action i.e. butachlor (cell division inhibitor), fenoxaprop-p-ethyl (ACCase inhibitor), propanil (PSII inhibitor), quinclorac (cellulose inhibitor) and oxadiazon (PPO inhibitor), were tested in those populations under glasshouse condition. The results from both laboratory and glasshouse confirmed that 85.5% of total barnyardgrass populations exhibiting cross-resistance to ALS inhibiting herbicides. In addition, 97.6% of total populations showed multiple-resistance to fenoxaprop-p-ethyl and quinclorac. However, those populations were completely controlled by butachlor, propanil and oxadiazon. In conclusion, resistance to ACCase inhibitor, ALS inhibitors and cellulose inhibitor was commonly found in barnyardgrass populations across central Thailand. Therefore, through diversity in herbicide use and with cultural management, it is possible to maintain barnyardgrass populations at a low level and/or minimize herbicide resistance evolution.

Keywords: Multiple-resistance, barnyardgrass, *Echinochoa crusgalli*

The poster in a PDF version is available here.

Investigations on *Apera spica-venti* (L.) P. Beauv. (loose silky-bent grass) resistance against herbicides from different HRAC- classes in the federal state Hesse, Germany (598)

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In the summer of 2014, panicles from loose silky-bent grass were collected at 109 sites (from established spraying windows and loose silky-bent grass patches, which became obvious at time of harvest within cereal fields) across the federal state Hesse, to analyze the status of resistance against herbicides from different HRAC-classes. In December 2014 the loose silky-bent grass seeds were seeded into pots, which were mounted on tables in the greenhouse of plant protection service Hesse. The seedlings were sprayed (repeated) with the following compounds: 0,6* (flufenacet 400*** + diflufenican 200*** (HRAC: F1/K3)); 0,3* + 0,6** (mesosulfuron 30*** + iodosulfuron 6*** (HRAC: B)); 0,13* + 0,6** (pyroxsulam 68*** + florasulam 23*** (HRAC: B)); 0,2* (mesosulfuron 7*** + iodosulfuron 47*** + mefenpyr 213*** (HRAC: B)) and 0,9* pinoxaden 50*** (HRAC: A). Herbicides were applied at a speed of 3,6 km/h and a pressure of 3,0 bar with an experimental sprayer which was equipped with Teejet XR 8002 VS nozzles. Applications took place at BBCH-stages, who prevented optimal efficiency conditions for each individual herbicide. Efficiency factors were rated. Biotypes were tested for mutations of well-known genetically positions, which modify acetolactate-synthase (ALS) and acetyl coenzyme a carboxylase (ACCase). The herbicide from HRAC class F1/K3 reached very high efficiency factors up to 100% against nearly all biotypes. Also, the herbicide from HRAC-class A reached high efficiency factors in most cases. However, all herbicides from HRAC class B showed very low efficiency rates. Only 12 biotypes could be controlled with an efficiency rate of more than 90%. 45 biotypes contained several mutations, which cause ALS-resistance. Only one biotype contained one mutation, which can cause ACCase resistance. The results will be used to develop guidance information to prevent further increase of resistance.
*application rate compound (l,kg/ha), **application rate adjuvant (l, kg(ha) ***active ingredient (g. a.i.*l-1 / kg-1)

Keywords: Target site resistance, Apera spica-venti, ALS-resistance, Mutations, Loose silky-bent grass

The poster in a PDF version is available here.

From field experiments to modelling of herbicide resistance evolution (404)

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The continuous spread of herbicide resistance urges the implementation of Integrated Weed Management (IWM) to establish more sustainable cropping systems. An important question is whether application of IWM strategies can provide a sufficient level of weed control, and in addition, favour a reversion of the resistance evolution process. The PURE project tackled this issue through a combination of experiments and modelling. Two case studies were considered: *Echinochloa crus-galli* resistant to ALS inhibitors in maize and *Alopecurus myosuroides* resistant to ACCase inhibitors in wheat. Field and greenhouse experiments showed that the resistant (R) biotypes of the two species had different fitness costs. In *E. crus-galli* a delay in plant development and lower seed production were registered for the R biotype. Instead, in *A. myosuroides* a delay in speed of seed germination and seedling emergence rate was observed, in particular under stress conditions. The implications of these fitness costs were investigated using a generic model for simulation of annual weed population dynamics in monoculture cropping systems. Simulations were performed to investigate the dynamics of weed populations in herbicide-free field situations and the potential of IWM to replace herbicide-intensive weed management, thereby reversing the selection for herbicide resistance. For *E. crus-galli*, the R fitness penalty in reproduction resulted in a stable population density with a population growth rate close to zero, under the assumption that other still effective herbicides generated effective control (98%- 99%). Whereas for *A. myosuroides*, the slight fitness penalty detected in emergence rate resulted in no perceptible difference in population growth rate between the biotypes, implying that a herbicide-free cultivation approach would not help to control the R biotype. The combination of experimentation and modelling proved effective in translating detailed observations on fitness costs at plant level to agronomic implications at field level.

Keywords: Echinochloa crus-galli, *Alopecurus myosuroides*, IWM, herbicide resistance, modelling

The poster in a PDF version is available here.

Alien invaders in space: adding the spatial dimension to models of weed populations (112)

Michael Renton *(University of Western Australia, Perth, Australia),* ***Gayle Somerville*** *(University of Western Australia, Perth, Australia)*

Weed management is an essential part of every agricultural system. However, weed management is difficult because the dynamics of weed populations are influenced by a mix of interrelated factors, many of which may be hard or impossible to observe directly and/or play out over long periods of time. Computational simulation modelling provides an important tool for integrating existing knowledge in order to help understand, predict and manage weed population dynamics. However many weed population models have treated weed populations as spatially homogeneous, ignoring the possibility of spatial heterogeneity in environments, management, densities and genetics. We hypothesise that in many situations accounting for spatial heterogeneity is essential. This presentation will describe some examples where spatially explicit modelling of weed populations has been used to address real world weed management issues. The examples include predicting spread of invasive weeds in urban bushland and agricultural landscapes; evaluating whether occasional strategic inversion (mouldboard) ploughing can slow the evolution of herbicide resistance; and investigating whether accounting for spatial heterogeneity changes predictions of how quickly resistance will spread through a weed population and impact crop yields. In each of the examples, the results show that including the spatial dimension is essential for properly understanding and predicting the issue or question being examined. While space may not be the final frontier in the war against weeds, it is an important step in overcoming the green invaders. Spatial heterogeneity should be considered when using computational simulation modelling to help understand, predict and manage weed population dynamics.

Keywords: Modelling, spatially-explicit, herbicide resistance, spatial heterogeneity

Competitive ability of ryegrass cultivars in relation to glyphosate resistant and susceptible to glyphosate (86)

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Cultural management is used across time as a way to suppress the establishment and development of weeds. Around the world ryegrass (*Lolium multiflorum* Lam.) is an alternative cover crop to protect the soil. We aimed with this work evaluate the competitive ability of ryegrass cultivars on volunteer ryegrass susceptible or resistant to glyphosate. Six trials were conducted based in the method replacement series, in which the treatments consisted of combinations of plants proportions of ryegrass cultivars Barjumbo; Ponteio and Le 284 with competitor plants of ryegrass susceptible and resistant to glyphosate herbicide. The proportions used were: 8:0 (eight ryegrass cultivar and zero ryegrass volunteer, 100:0%); 6:2 (six ryegrass cultivar and two ryegrass volunteer, 75:25%); 4:4 (four ryegrass cultivar and four ryegrass volunteer, 50:50%); 2:6 (two ryegrass cultivar and six ryegrass volunteer, 25:75%); and 0:8 (zero ryegrass cultivar and eight ryegrass volunteer, 0:100%). We used completely randomized design with four replications and used a t-test ($P < 0.05$). None of the ryegrass cultivars tested had higher competitive ability than volunteer ryegrass susceptible to glyphosate, which not is worrying, since this biotype is easily controlled by glyphosate application. However the Barjumbo cultivar has higher competitive ability than volunteer ryegrass resistant to glyphosate expressed by the dry matter suppression, which shows the alternative of cultural management such as cover crops to suppress ryegrass populations resistant to glyphosate.

Keywords: *Lolium multiflorum* Lam, replacement series, resistance, cultural management

Distribution of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* S. Wats.) in Nebraska, U.S. (493)

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Amaranthus palmeri S. Wats. is an annual, C4 and dioecious weed in the Amaranthaceae family that is native to North America. It has a rapid growth habitat, an extended germination period, efficient photosynthetic capacity and prolific seed reproduction that enables the species to survive in different environmental conditions and rapidly evolve resistance to weed management tactics. Palmer amaranth is an aggressive weed in cropping systems in the U.S. Yield losses up to 79% have been reported in soybeans (Bensch et al. 2003) and up to 91% in corn (Massinga et al. 2001). Several Palmer amaranth populations have been reported resistant to ALS inhibitors, Microtubule assembly inhibitors, Photosystem II inhibitors, EPSP synthase inhibitor, and 4-HPPD inhibitors in the U.S. The objective of this study was to investigate the susceptibility of Palmer amaranth populations from Nebraska to glyphosate. Palmer amaranth populations were sampled in Nebraska and were subjected to a glyphosate-dose response study, in which different rates of glyphosate (0, 4, 39, 217, 434, 868, 1736 and 3472 g ae ha^{-1}) were applied to 12 cm tall plants using a single nozzle research track sprayer calibrated to deliver 94 L ha^{-1} with a Teejet AIXR95015EVS nozzle at 414 kPa. Visual estimations of injury and above ground biomass were recorded 21 days after treatment. Data were fitted to a non-linear regression model with the drc package in R 3.1.2. The I_{50}, I_{90}, GR_{50} and GR_{90} values were estimated for each population using a four parameter log logistic equation: y =c+(d –c/1+exp(b (log x –log e))). The results confirm the presence of glyphosate-resistant Palmer amaranth in Nebraska. Identifying the distribution and the level of glyphosate-resistance is an important part of the integrated weed management (IWM) and a key factor for the successful control of Palmer amaranth in Nebraska.

Keywords: Herbicide resistance, EPSPS inhibitor, Amaranthaceae, Integrated weed management

The poster in a PDF version is available here.

Rice weed resistance in Portugal (313)

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In Portugal *Echinochloa* species are the major troublesome weeds in rice (*Oryza sativa* L.) being *E. crus-galli* ssp. *hispidula*, and *E. phyllopogon* (Stapf) Koss (syn=*E. oryzicola* Vasing) the most economically important weed species. One hundred percent of paddy rice producing area (30 000 ha) is treated annually with herbicides, namely ALS- and ACCAse – inhibitors. In spite of high selection pressure, no problems of resistance in weed grasses have been reported to those herbicides. Populations of *Echinochloa* spp. resistant to propanil were confirmed in 2008 but this herbicide is no longer in the market due to environmental issues. Recently rice grower's complaints of lack of control of *Echinochloa* were monitored in Tagus and Sorraia river valleys (South Portugal). Seed samples were collected from 12 rice fields and tested for ALS-Resistance. Species identification in the *Echinochloa* complex is crucial for assessment of herbicide susceptibility and resistance confirmation. Biometric characteristics of cariopse allowed distinguishing between *E. crus-galli* ssp. *hispidula* (3 populations) and *E. phyllopogon* (9 populations) – identification was further confirmed with classic taxonomy. After the first screening of 12 populations, penoxsulam efficacy to six *Echinochloa* spp. populations was assessed in greenhouse dose-response bioassays (1/16N-8N, N=40 g ha^{-1}) to confirm resistance. Cross resistance to profoxydim (1/8-2N, N=100 g ha^{-1}) were also analysed. A log-logistic model was fitted to fresh weight and mortality for ED_{50} and ED_{90} determination. One population of *E. phyllopogon* was confirmed resistant to penoxsulam and presented no cross resistance to profoxydim. ED_{50} and ED_{90} values for penoxsulam were 99.35 g $ha^{-1}$and 262, 4 g ha^{-1}, respectively and ED_{50} for profoxydim was 32.9 g ha^{-1}. This is the first reported case of ALS-Resistance in *Echinochloa phyllopogon* in Portugal.

Keywords: *Echinochloa phyllopogon*, penoxsulam, ALS-resistance

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Resistance to penoxsulam and quinclorac in *Echinochloa crus-galli* in double cropping rice area of southern China (280)

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Echinochloa crus-galli (L.) Beauv. (barnyardgrass) is amongst the most problematic weeds in rice fields of China. The steady reliance on the different herbicides for control of these weeds has led to resistance to herbicides. We collected 51 biotypes with suspected resistance from rice fields in Hunan, Anhui and Jiangxi province of China and investigated their sensitivity to penoxsulam, an acetolactate synthase (ALS) inhibitor, and quinclorac, Hormone quinolinecarboxylic acid herbicide. Whole-plant experiments showed that 13 biotypes were highly resistant (higher than 100-fold), 11 biotypes were moderately resistant (10-and 100-fold), 6 biotypes were lowly resistant (3-and 10-fold), and 21 biotypes were sensitive (lower than 3-fold). On the other hand, 7 biotypes showed resistance to penoxsulam and quinclorac. The expression levels of *ALS* were higher in the multiple-herbicide resistant biotype than sensitive, which were lower in resistant biotypes only to penoxsulam than susceptible biotypes. The differential expression among examined biotypes was more prominent for multiple-herbicide resistant biotypes. Differences in their relative expression levels could influence the occurrence of resistance to penoxsulam and quinclorac in *Echinochloa crus-galli*.

Keywords: *Echinochloa crus-galli* (L.) Beauv, Resistance, penoxsulam, quinclorac

Resistance to ACCase-inhibiting herbicides in a keng stiffgrass (*Pseudosclerochloa kengiana*) population in China (154)

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Keng stiffgrass (*Pseudosclerochloa kengiana*) is a troublesome weed in winter wheat field rotated with rice in China. The repeated use of ACCase-inhibiting herbicides to control grass weeds has selected for resistance in keng stiffgrass. Seeds of one suspected resistant population were collected from a wheat field in Yutai County of Shandong province, where fenoxaprop had been used annually at least 10 years. Dose-response experiments demonstrated that the Yutai population had evolved high-level resistance to fenoxaprop, clodinafop, sethoxydim, clethodim and pinoxaden. Partial gene of CT domain was cloned and sequenced to confirm the molecular mechanism of resistance to ACCase-inhibiting herbicides. An Asp-2078-Gly mutation was found in Yutai population according to the sequencing result. In addition, two partial homoeologous plastidic ACCase genes (*Acc1;1* and *Acc1;2*) were isolated from both the sensitive and resistant populations. All two of these ACCase genes were transcribed, with each able to carry the Asp-2078-Gly mutation. To determine the sensitivity to alternative mode of action herbicides, assays were conducted at the single recommended rate of each herbicide. Based on the results, both the sensitive and resistant keng stiffgrass populations were effectively controlled by the herbicides pyroxsulam, isoproturon and glyphosate. This study established the first report of Asp-2078-Gly substitution in ACCase-resistant keng stiffgrass and potential herbicides to control this resistant weed.

Keywords: Herbicide resistance, keng stiffgrass (Pseudosclerochloa kengiana), ACCase gene, mutation, cross resistance

The poster in a PDF version is available here.

Herbicide resistance in wheat lands in China (64)

Guo-qi Chen *(Nanjing Agricultural University, Nanjing, China),* ***Jun Li*** *(Nanjing Agricultural University, Nanjing, China),* ***Li-yao Dong*** *(Nanjing Agricultural University, Nanjing, China)*

Since the first report in 1996, herbicide resistance poses serious threats to weed management in wheat production in China. Currently, 166 populations of 11 weed species occurred in wheat fields in China have been reported to be herbicide-resistant with reduced sensitivity > 4 fold according to whole-plant bioassays. These 11 weed species include 6 grasses (*Beckmannia syzigachne*, *Alopecurus japonicas*, *Alopecurus aequalis*, *Aegilops tauschii*, *Sclerochloa kengiana* and *Polypogon fugax*) and 5 broadleaf weeds (*Descurainia sophia*, *Capsella bursa-pastoris*, *Myosoton aquaticum*, *Galium aparine* and *Lithospermum arvense*). Among these 166 populations, 47.0% were collected from Jiangsu province with 2.1 out of 24.1 million ha wheat planting areas in the whole country. Nevertheless, herbicide resistance in some wheat planting areas has not been reported. Moreover, these 166 weed populations showed resistance to either ACCase (Acetyl-coenzyme A carboxylase)-inhibitors or ALS (Acetolactate synthase)-inhibitors. Target site resistance (TSR) mechanism on ACCase-inhibitor resistance in different populations referred to 9 mutations of 8 amino acid sites including Arg-1734-Gly, Met-1738-Leu, Thr-1739-Ser, Ile-1781-Leu, Trp-1999-Cys, Trp-1999-Leu, Trp-2027-Cys, Ile-2041-Asn and Asn-2078-Gly. TSR mechanism on ALS-inhibitor resistance in different populations referred to 6 mutations of 2 amino acid sites including Pro-197-Gly, Pro-197-Ala, Pro-197-Leu, Pro-197-Thr, Pro-197-Ser and Trp-574-Leu. Non-target-site resistance (NTSR) was also confirmed in *Beckmannia syzigachne* by the use of cytochrome P450 inhibitors. Besides revealing the resistance mechanisms and fitness shifts of resistant populations, some fundamental works are urgently needed, including 1) founding the systematic baselines of sensitivity/resistance for principal weed species to major herbicides; 2) Knowing the relatively accurate distribution patterns of herbicide-resistance in weeds and improving publically-available databases of herbicide resistance; and 3) understand the distribution patterns of NTSR in weeds. This research was funded by Special Fund for Agro-scientific Research in the Public Interest (201303031).Corresponding author: Li-yao Dong (dly@njau.edu.cn).

Keywords: ALS-inhibitor resistance, ACCase-inhibitor resistance, review, Weed, wheat land

The poster in a PDF version is available here.

The distribution of ACCase-inhibiting resistant American sloughgrass (*Beckmannia syzigachne*) in China wheat fields (336)

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American Sloughgrass (*Beckmannia syzigachne*) is one of the most important grass weeds in wheat in China. To detect the distribution of resistant weed, seeds of 47 American Sloughgrass populations were collected from wheat fields where farmers complained that they could not be controlled effectively by fenoxaprop-p-ethyl. Pre-germinated American Sloughgrass seeds were planted into 12-cm-diam pots containing moist loam soil and maintained in the greenhouse at 15-25 C. The seedlings were thinned to 15 evenly sized plants per pot before herbicide application. Fenoxaprop-p-ethyl, 69 g/L emulsion oil in water, at 0 and 160 g a.e. ha^{-1}, clodinafop-propargyl, 15% wettable powder, at 0 and 67.5 g a.e. ha^{-1} and pinoxaden, 50 g/L emulsifiable concentration, at 0 and 75 g a.i. ha^{-1} was applied respectively with a compressed air, moving nozzle spraying cabinet to deliver 367.5 L ha^{-1} liquid. The mortality of plants was detected 21 days after treatment. If all plants were dead in the pots in all replications, the population was determined not resistant to ACCase inhibitors. If there were some plants surviving the application, the population was confirmed resistant to ACCase inhibitors.The results showed that 27 of 47 populations evolved resistance to ACCase-inhibitors in China, 17 populations located in Jiangsu province, 4 in Anhui province, 4 in Hubei province, 1 in Shandong province and 1 in Sichuan province,while no resistant populations were detected in Hebei and Henan province.The experiment indicated that most populations of American Sloughgrass in wheat have evolved resistance to ACCase-inhibiting herbicides in China, especially in the rice-wheat rotation area such as Jiangsu and Anhui province, located in the Yangtze River region. The resistant level and distribution were very helpful and necessary to the management of resistant weed in China.

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Keywords: American Sloughgrass (*Beckmannia syzigachne*), ACCase-inhibiting herbicides, Resistance, Distribution

Diversity of cross-resistance patterns to ACCase-inhibiting herbicides in wild oat (*Avena ludiviciana*) biotypes (448)

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Wild oat (*Avena ludoviciana*) is a prevalent weed in wheat fields of Iran. Accordingly, ACCase (Acetyl-CoA carboxylase) inhibitors, which include aryloxyphenoxypropionate (APP), cyclohexanedione (CHD) and phenylpyrazolin (PPZ) herbicides, are selectively applied to control wild oat and other weedy grasses. The continued reliance on ACCase inhibitor herbicides during the last two decades is associated with the extensive appearance of resistant wild oat biotypes. Resistance across ten ACCase-inhibiting herbicides was characterized in fifteen *Avena ludoviciana* biotypes from the southern grain belt of Iran (Fars and Khuzestan Provinces). Whole plant bioassays were conducted at the Iranian Research Institute of Plant Protection, Tehran, during 2014-2015 to determine the diversity of cross-resistance patterns to diclofop, fenoxaprop-P, clodinafop, quizalofop-R, haloxyfop, sethoxydim, cycloxydim, clethodim, pinoxaden and clodinafop + pinoxaden among wild oat populations. The different biotypes showed different ranges of resistance to given herbicides. Thus based on results, all biotypes (exception of ES that was susceptible to clodinafop) exhibited cross-resistance to diclofop, fenoxaprop-P and clodinafop. Moreover, nearly 53% of populations were resistant to quizalofop-R, whereas 27% were resistant to haloxyfop. Two biotypes of four sethoxydim-resistant populations showed cross resistance to cycloxydim. However, none of the wild oat biotypes were resistant to clethodim or pinoxaden. Cross-resistance in wild oat within the APP herbicides at 75% was much greater than within CHD herbicides at 13%. It is evident that most wild oat populations from the grain production belt of Iran have evolved resistance to a number of ACCase-inhibiting herbicides. Pinoxaden and clethodim can be suitable alternatives to control ACCase-resistant wild oats biotypes when combined with herbicide rotation and non-chemical weed management.

Keywords: ACCase inhibitor, cross-resistance, herbicide resistance, wild oat, whole-plant assay

The poster in a PDF version is available here.

Determination of ALS and ACCase inhibiting herbicide resistant biotypes of *Lolium* spp. in wheat fields (304)

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Lolium species are the most important grass weeds in Turkey, because of their wide distribution and abundance in winter cereals and other crops. Recently, many growers in various areas of Turkey complained of reduced control of *Lolium* species in winter cereals after use of ALS and ACCase inhibitor herbicides. There is no information in the scientific literature concerning*Lolium* species response to these herbicides and their level of resistance in Turkey. With this aim the seeds of these species were collected from 456 different wheat fields in South Marmara, Middle Anatolia and Black Sea regions. Greenhouse experiments for whole plant bioassays were conducted to confirm herbicides resistance in *Lolium* species (*Lolium perenne* L., *Lolium rigidium* L., *Lolium temulentum* L. and *Lolium multiflorum* L.), and to determine the levels of resistance to available herbicides. These accessions were tested for resistance to Pyroxsulam+Cloquintocet mexyl (Safener), mesosulfuron methyl+iodosulfuron-methyl-sodium, clodinafop-propargyl (cloquintocet mexyl), pinoxaden, pinoxaden+clodinafop propargyl, propoxycarbazone sodium+ mesosulfuron-methyl+(mefenpyr-diethyl) (Safener) at registration doses. If the efficacy of herbicides were less than 80% these populations were included in further dose-response experiments according to this method. Of the 456 accessions tested, 160 accessions were not controlled by ALS and ACCase inhibitors when applied at recommended field rate. Some accessions exhibited the highest survival to treatment with field rates of these herbicides. The Weibull dose-response curve, an asymmetric sigmoid curve, was fitted to data to obtain ED_{10}, ED_{50} and ED_{90} in R program. Thirty-nine of *Lolium* spp. (12 of *L. perenne*, 21 of *L. rigidium*, 3 of *L. temulentum*. and 2 of *L. multiflorum*) accessions tested were not controlled by ALS and ACCase inhibitors and these were accepted as a resistant population.
The authors thank The Scientific and Technological Research Council of Turkey (TUBITAK) and Ondokuz Mayıs University for supporting the Project (Numbers TOVAG 113O417 and PYO.ZRT. 1905.14.009).

Keywords: ALS and ACCase inhibitörs, wheat, *Lolium* spp., herbicide resistance

The poster in a PDF version is available here.

Monitoring herbicide resistance development in *Apera spica-venti* (APESV) in Latvia (736)

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Since 2010 surveys related to the evolution of herbicide resistance in APESV were performed in Latvia to better characterize the situation in fields where ALS herbicides had been used intensively for a long period. This survey focuses particularly on complaint cases of decreased herbicide efficacy received from farmers. Samples of APESV panicles with ripening seeds were harvested and seeds were used to perform bioassay analysis in the glasshouse. Plants grown from the collected seeds were treated with herbicides with different modes of action (MoA). In 2014 - 2015 samples of green plants were also analyzed in the laboratory for target-site-resistance (TSR) and enhanced metabolic resistance (EMR) to herbicides from the ALS and ACCase groups (HRAC, B, A group respectively). In 2010 poor control from ALS inhibitor herbicides was reported in only 1 sample out of 17. In 2015 resistance was confirmed in 6 samples out of 7, and TSR to ALS herbicides was confirmed. In the past two years samples also showed TSR and EMR to ACCase inhibitors. This resistance probably developed when herbicides were commonly applied in spring in winter cereals mostly for *Avena fatua* control, but this application was too late for proper APESV control, likely leading to increased selection of resistant plants. While these results do not reflect the overall situation about herbicide resistance on farms in Latvia, they do allow an evaluation of the situation on farms where intensive ALS herbicide usage was practiced with limited crop rotation and a minimal tillage system. These data stress the use of an Integrated Weed Management approach to limit the evolution of resistance in APESV. This includes combinations of chemical and non-chemical methods. The main APESV control in winter cereals has to be in autumn by using other MoA herbicides, ploughing, and including spring crops in the rotation.

Keywords: Apera spica-venti, monitoring, resistance, ALS inhibitors, ACCase inhibitors

The poster in a PDF version is available here.

Cross resistance to ALS inhibitors of *Ammannia arenaria* and its competition with paddy rice (143)

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Ammannia arenaria has been becoming one of the most harmful weeds in paddy rice field in China in recent years. The objectives were to determine the cross resistance of the weed to different ALS inhibitors and its competition ability. The bioassay was conducted in greenhouse with herbicide postemergence treatment. The dosage causing 50% fresh weight reduction (ED_{50}) of bensulfuron-methyl (BSM) to susceptible biotype HZ001 of *A. arenaria* was 0.18 gai/ha, and the resistance index (RI) of biotype NB143, JX110, JS039 and AH014 to BSM were 44.63, 67.90, 17.59 and 8.37, respectively. The RI of the four BSM resistant biotypes to penoxsulam were 5.43, 4.96, 3.73 and 4.55, respectively; and that to bispyribac-sodium were 4.60, 5.05, 2.17 and 3.63, respectively; and that to imazethapyr were 6.45, 2.60, 4.16 and 1.96, respectively. The seeds of the BSM susceptible biotype (SB, HZ001) and resistant biotype (RB, NB143) were sowed simultaneously with rice in field, respectively, and the seedlings were thinned to 58 plants/m^2. The weed grew really slowly within 15 days after sowing (DAS) but tremendously fast in the following time. Both the two biotypes were lower than rice plant before 45 DAS but much higher than it after 55 DAS. The RB plant was 14.7% lower than SB finally, and the rice yield was decreased by 50.8% under competition with RB and 73.1% for SB.

The results indicated that *A. arenaria* was extensively cross resistant to the mainly used four groups of ALS inhibitor. The interference of the resistant weed to rice was great, even though there is fitness cost in height. (The work was funded by National Natural Science Foundation of China (No.31171863), and Special Fund for Agro-scientific Research in the Public Interest (201303031, 201303022)), and science and technology department of Zhejiang province (2015C32062).

Keywords: *Ammannia arenaria*, cross resistance, ALS inhibitor, competition, Oriza sativa

Increasing weed cover of *Epilobium* sp. and *Conyza* spp. in olive groves from Alentejo, South Portugal (370)

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Glyphosate resistance in Portugal is exclusive to perennial crops (vineyards and olive groves), where *Conyza* and *Lolium* spp. were the most prone species to the onset of resistance. This paper presents the results of a study to confirm if glyphosate resistance was responsible for the lack of control in two weed species from an olivegrove in the south of Portugal: *Epilobium* spp. and *C. canadensis.* Resistance studies were carried out with dose-response bioassays, where fresh weight was assessed 21 days after the application of seven doses of glyphosate (180 -5760 a.e.ha-1) to plants at rosette stage (BBCH 118), in a RBD design with 8 replicates and it was repeated. A non-linear logistic model was fitted to the data and ED_{50} and ED_{90} values were calculated for each species. The results of field trials for the assessment of different herbicides and time of application are also presented. Management strategies with herbicide programs comprising mixture of different MOA: aminotriazol + flazasulfuron (F3+B); flazasulfuron + glyphosate (B+G); flazasulfuron + glyphosate + MCPA (B+G+O); glyphosate + fluoroxipir (G+O); glyphosate +MCPA (G+O) and glufosinate (H) could be effective alternatives (> 95 %) for the control of theses species in olivegroves.

Keywords: Glyphosate, weed resistance, dose-response, mechanism of resistance, field trials

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Multiple herbicide resistance in corn poppy (*Papaver rhoeas*) populations from Spain (188)

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Papaver rhoeas L. (corn poppy) is the most common dicotyledonous weed in winter cereals in southern Europe. It is a competitive species and its presence within the crop results in significant yield reduction. In Spain multiple resistance (2,4-D and tribenuron-methyl) corn poppy populations have been reported in the last decades. As occur in other European regions, a single nucleotide substitution at position Pro197 of the ALS gene is responsible for the resistant response to sulfonylureas (SUs). However, the cross-resistance patterns or the presence of non-target site resistance (NTSR) mechanisms for non-SUs herbicides are not clear. With regard to 2,4-D, the resistance mechanisms remain undiscovered. Recently in Spain, lack of control of corn poppy has been described in fields where post-emergence mixtures containing bromoxynil were applied. This research will bring new data of the cross-resistance patterns to non-SU herbicides (triazolopyrimidines and imidazolinones) and the presence or not of NTSR mechanisms. Moreover, a new study conducted with Spanish 2,4-D resistant corn poppy biotypes, suggested that lack of translocation in those resistant populations could be involving the resistant response of insensitive plants. Experiments under way aim to discover which genes are involved in that translocation pattern. A population already resistant to ALS inhibiting herbicides and synthetic auxins could also be resistant to nitriles, with resistance factor depending on the growth stage at application. Finally, it will be discussed if those resistant mechanisms are related to some extent and the implications for integrated weed management.

Keywords: Synthetic auxins, ALS inhibiting herbicides, nitriles, target site resistance, non-target site resistance

The poster in a PDF version is available here.

Papaver rhoeas (L.) and *Tripleurospermum maritimum* ssp. *inodorum* (L.) resistant to ALS-inhibiting herbicides in Poland (315)

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Common poppy (*Papaver rhoeas* L.) and scentless chamomile (*Tripleurospermum maritima ssp. inodora* L. Dostal) are species often infesting winter crops in Poland; however, there is recorded insufficient control them in some sites of the country. The aim of the investigations was to determine, if scentless chamomile and common poppy exhibit resistance to herbicides. In 2012, several samples of scentless chamomile and common poppy were collected from winter wheat crop where the weed species were very poorly controlled. In the first greenhouse experiments five herbicides at recommended doses were tested in scentless chamomile (tribenuron methyl, chlorosulfuron, isoproturon + diflufenican, metazachlor + chinomerak, isoproturon) and two in common poppy (tribenuron methyl and isoproturon + diflufenican). Herbicide spraying was made with a greenhouse sprayer at the stage of 3-4 leaves. In the second experiment, tribenuron methyl at several doses (2.34; 4.69; 9.38; 18.75; 37.5; 75 and 150 g/ha) was used both for scentless chamomile and common poppy to plot the regression curve and calculate the resistance index. Assessment of herbicide effect was carried out 4 weeks after the treatment with evaluation of fresh mass of the above-ground plant parts. Two out of five examined biotypes, both of scentless chamomile and common poppy, turned out to be resistant to tribenuron methyl. Resistant biotypes were not controlled even after use of tribenuron methyl at a dose 4 times higher than recommended. It is the first such case of resistance of the two weed species to herbicides in Poland. Admittedly, at present it is of no considerable economic importance, yet it is another proof of the growing problem of weed resistance to herbicides in Poland.

Keywords: Scentless chamomile, common poppy, tribenuron methyl, resistance index

The poster in a PDF version is available here.

Investigating the extent of herbicide resistance in problematic grass weeds in the Czech Republic (540)

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In recent years, the importance of grass weeds has increased in the Czech Republic. Intensive use primarily of acetolactate synthase inhibiting herbicides for their control resulted in increase of resistant populations. Whole-plant bioassays and molecular assays for confirmation of resistance in *Apera spica-venti*, *Alopecurus myosuroides*, *Avena fatua* and *Bromus sterilis* populations were conducted in this study. Seed samples were collected in winter cereals fields from survival after herbicide application in different parts of the Czech Republic. Plants were cultivated in the vegetation hall and treated post-emergent by frequently used herbicides using a laboratory chamber sprayer. The efficacy of propoxycarbazone, pyroxsulam, iodosulfuron, chlorsulfuron (ALS inhibitors); pinoxaden, fenoxaprop, fluazifop and propaquizafop (ACCase inhibitors); and isoproturon and chlortoluron (PSII inhibitors) was evaluated. The mechanisms of herbicide resistance of *Apera spica-venti* and *Alopecurus myosuroides* to ALS inhibitors were studied by PCR amplification and sequencing of ALS domains. From tested populations of *Apera spica-venti*, 66% of samples were resistant to ALS inhibitors, 2% to PSII inhibitors and only 2 samples (1% tested samples) to ACCase inhibitors. Target-site resistance to ALS inhibitors in *Apera spica-venti* was confirmed. Four resistance-conferring ALS mutations were identified: Pro-197-Ala, Pro-197-Thr, Trp-574-Leu and Trp-574-Met substitution. Resistance to iodosulfuron and isoproturon was found in *Alopecurus myosuroides* but no substitutions leading to target-site resistance to ALS inhibitors were detected. One population of *Bromus sterilis* was tolerant to propoxycarbazone. The first resistant populations of *Avena fatua* to fluazifop and propaqiuzafop were identified. Results point out the continuing development of resistance in grass weeds and the necessity to urgently adopt anti-resistant strategies. This research was funded by project QJ1310128 of the National Agency for Agricultural Research.

Keywords: ALS inhibitors, grass weeds, target site resistance, target site resistance

The poster in a PDF version is available here.

Distribution and mechanism of resistance to ALS-inhibiting herbicides in shattercane and Johnsongrass populations from the north central great plains of the USA (103)

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Overreliance on acetolactate synthase (ALS)-inhibiting herbicides for weed control during the 1990's resulted in selection of ALS-resistant shattercane [*Sorghum bicolor* (L.) Moench *ssp. drummondii* (Nees ex Steud.) de Wet ex Davidse] biotypes in Nebraska. The objective of this study was to assess the baseline presence of ALS-resistance in 190 shattercane and 59 johnsongrass [*Sorghum halepense* (L.) Pers.] populations collected across northern Kansas, northwestern Missouri, and southern Nebraska in 2013. In 2014, a preliminary field experiment was conducted to evaluate the presence of herbicide resistance in the aforementioned populations. Treatments consisted of four herbicides (clethodim, glyphosate, imazethapyr, and nicosulfuron) applied at labeled rates. Clethodim and glyphosate controlled all shattercane and johnsongrass populations evaluated. Putative imazethapyr and nicosulfuron (ALS-inhibiting herbicides) resistant populations were further exposed to a dose-response study under greenhouse conditions. Five shattercane and five johnsongrass populations were confirmed resistant to imazethapyr. Four shattercane and three johnsongrass populations were confirmed resistant to nicosulfuron. All ALS-resistant shattercane and johnsongrass populations were collected in Nebraska except for one johnsongrass population, resistant to nicosulfuron, that was collected in Kansas. Research investigating the molecular mechanism of herbicide resistance in each population is underway. ALS-resistance persists, even though ALS-inhibitors have not been widely used to control shattercane and johnsongrass for over 15 years, indicating the lack of a strong fitness cost associated with ALS-resistance. Therefore, shattercane and johnsongrass should be properly managed prior to and during the commercialization of ALS-tolerant grain sorghum [*Sorghum bicolor* (L.) Moench *ssp. bicolor*] in the United States (expected in 2017), especially in regions where ALS-resistance has been confirmed.

Keywords: Herbicide resistance management, ALS-resistance persists, Fitness cost

The poster in a PDF version is available here.

Clodinafop resistance in a population of *Avena ludoviciana* in wheat in India (677)

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Wild oat (*Avena ludoviciana*) is the most competitive grassy weed of wheat in several continents and is considered 13th most important weed worldwide. It is the most prevalent weed of wheat in north India in cropping systems other than rice-wheat. Reduced efficacy of isoproturon was dependent on application stage, but its use was significantly reduced due to *Phalaris minor* resistance in the early 1990 which paved for the adoption of ACCase and ALS inhibitors in the late 1990. Recently reduced efficacy of clodinafop was reported from farmer's field where its repeat application even at higher rate failed to control *A. ludoviciana*. Seed of putative resistant populations was collected from two locations from cotton-wheat rotation areas and were compared in the screen house and growth room with known susceptible population from Research Farm of CCS Haryana Agricultural University, Hisar, India. Plants raised in pots were treated with recommended rates of clodinafop, fenoxaprop, pinoxaden, sulfosulfuron, metribuzin and ready mix of fenoxaprop+metribuzin, mesosulfuron+iodosulfuron, pendimethalin+metribuzin 25 DAS and compared with PRE application of pendimethalin, pyroxasulfone, pendimethalin+metribuzin and metribuzin alone. Spraying was done with a backpack sprayer fitted with a floodjet nozzle delivering 500 l/ha water volume. Treatments replicated thrice were arranged in a CRD design along with untreated pots for the three species. Observations were recorded on visual mortality and fresh weight was recorded at harvest. In another experiment graded doses of ACCase inhibitors were used for quantifying resistance level. Germination of three species was compared in Agar media using different concentrations of clodinafop and pinoxaden in the growth room. Data was subjected to ANOVA using SPSS. Screen house and growth room studies confirmed clodinafop resistance in one population from farmer's fields whereas the second one was intermediately resistant, but both were sensitive to pinoxaden and other herbicides, though efficacy of pendimethalin was non-satisfactory.

Keywords: Clodinafop resistance, *Avena ludoviciana*, wheat, Resistance management, Resistance characterization

Distribution and frequency of glyphosate-resistant weeds in Nebraska (487)

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There are currently seven reported herbicide-resistant weed species in Nebraska, five of which are resistant to glyphosate. Overall distribution and frequency of these resistant species is unknown. Collection of weeds were made in Nebraska by traveling the state and arbitrarily selecting from fields that were abundant with weedy escapes. Emphasis was made on locating fields that had weedy escapes that were not just along the edge of the field or road sides but interspersed with the cultivated crop. Plant seed heads were harvested from 20 individual plants and dried at 20 °C for three weeks. Seeds were germinated in a greenhouse and treated using a single nozzle research track sprayer calibrated to deliver 94 L/ha at 414 kPa, with a Teejet AI9502EVS nozzle with glyphosate at the varying rates: 0, 217, 434, 868, 1736, 3472, and 6946 g ae/ha when plants were 10-15 cm tall. Visual estimations of injury were recorded 28 days after treatment (DAT) on a scale of 0-100 (0 being no effect from herbicide and 100 being complete control). Living plants at 28 DAT were severed at the base and dried at 65 °C for 72 hours and dry weights were recorded. Data were fitted to a non-linear regression model using the drc package in R 3.1.2. The I_{50}, I_{90}, GR_{50}, and GR_{90} values were estimated for each population using a four parameter log logistic equation: y=c+(d-c/1+exp(b(logx-loge))). Resistant weed populations were observed in 12 of 78 counties. Results from this survey will assist growers in understanding where resistant populations are located in the state and encourage them to follow proper application techniques, discouraging them from continued use of the same herbicide mode of action, and hopefully impede the further evolution and spread of herbicide-resistant weeds in Nebraska and the Midwest United States.

Keywords: Herbicide-resistance, Nebraska, EPSPS Inhibitor

The poster in a PDF version is available here.

Distribution and frequency of glyphosate-resistant horseweed (*Conyza canadensis* (L.) Cronq.) in Nebraska (488)

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Glyphosate-resistant horseweed (*Conyza canadensis (L.) Cronq.*) was first confirmed in Nebraska in 2006 and since then an increase in populations that have evolved resistance are reported each year. The overall distribution of these glyphosate-resistant horseweed populations in Nebraska is currently unreported and unknown. The objective of this study was to find the current frequency and distribution of glyphosate-resistant horseweed in the state of Nebraska. A total of 130 horseweed populations were collected arbitrarily from 44 counties during the fall of 2014 and 2015. Plants were germinated in a greenhouse in the Pesticide Application Technology Laboratory (PAT Lab) in North Platte, NE from January to December of 2015. Rosettes were treated at 4-5 cm in diameter. Each population was randomized with seven treatments and at least four replications. Plants were treated with the following rates of glyphosate: 0, 217, 434, 868, 1736, 3472, and 6946 g ae/ha using a single nozzle research track sprayer calibrated to deliver 94 L/ha at 414 kPa with a Teejet AI9502EVS nozzle. Visual estimations of injury were recorded based on a 0-100 scale (0 being no effect from herbicide and 100 being complete control) 28 days after treatment, and plants were severed at the base and dried at 65 °C for 72 hours and dry weight of each plant was recorded for dose response analysis. Data were fitted to a non-linear regression model using the drc package in R 3.1.1. The I_{50}, I_{90}, GR_{50}, and GR_{90} values were estimated for each population using a four parameter log logistic equation: y=c+(d-c/1+exp(b(logx-loge))). A majority of the 130 populations screened showed some level of glyphosate-resistance. Because of high frequency of the glyphosate-resistant horseweed biotype in Nebraska, growers are encouraged to adopt control methods and techniques that are recommended for the control of glyphosate-resistant horseweed.

Keywords: Marestail, EPSPS Inhibitor, herbicide-resistance, IPM

The poster in a PDF version is available here.

Giant ragweed resistance to glyphosate in Nebraska (171)

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Extensive use of glyphosate and Roundup Ready crops has changed farming practices over the last 15 years. Repeated use of glyphosate on over 100 million hectares has developed glyphosate resistance in 13 weed species in the United States. The current suspected glyphosate resistant (GR) giant ragweed population was found in a corn and soybean production system with history of glyphosate use for weed management in David City, NE. Therefore, field experiments were initiated in 2012 to determine the level of glyphosate resistance in the suspected GR giant ragweed population in David City, NE. The experiments were conducted twice with four replications. Trial by treatment interactions was not significant therefore; data were combined over experimental runs. Weed control was assessed visually at 7, 14, and 21 DAT, and dry matter data was recorded. Dose response studies were conducted with five glyphosate rates (0, 1X, 4X, 8X, and 16X of label rates) applied postemergence at two application timings (10 and 20 cm). Glyphosate resistance was determined by the ED_{80} and ED_{90} values of the population. The estimated level of glyphosate resistance at 21 DAT for 10 and 20 cm tall giant ragweed was 14X and 36X, respectively. To achieve 90% control of this population, at least 14 times the label use-rate (1060 g ai/ha) was needed, indicating that the suspected giant ragweed population was glyphosate-resistant.

Keywords: Glyphosate, giant ragweed, resistance, maize, soybean

The poster in a PDF version is available here.

Single nucleotide polymorphisms in sulfonylurea herbicide resistant *Alopecurus aequalis* populations in wheat fields, Japan (55)

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Alopecurus aequalis is a grass weed common in wheat and barley fields in Japan, and predominantly self-pollinated. This species developed resistance to sulfonylurea (SU) herbicide, one of the acetolactate synthase (ALS) inhibitors, a widely used herbicide. Resistance to SU herbicide is endowed by point mutations at the ALS genes, ALS1 and/or ALS2. Single nucleotide substitution at the ALS genes was investigated by CAPS and sequencing for each 30 individuals from 19 populations in wheat fields, Kyushu, southern parts of Japan and 3 populations in other parts of Japan. Among them, 18 populations were SU-resistant and 4 populations were SU-susceptible. In SU-resistant populations, substitutions to Ser, Thr, His, Leu, Ala, Arg, Phe and Asn were found at the position of Pro197 of ALS1. At the position of Trp574 of ALS1, substitution to Leu was found. At the position of Pro197 of ALS2, substitutions to Ser, Thr, His and Leu were found. Double mutations at the position of Trp574 of ALS1 and Pro197 of ALS2 were also found. In 16 SU-resistant populations, single nucleotide polymorphisms were found. Five amino acid substitutions were found in a population at the maximum, and also some individuals were hetero at the ALS locus. *A. aequalis* is a predominantly self-pollinated species, but frequent gene flow from individuals of neighboring populations is suggested. Research to clarify the genetic structure of seed banks is undergoing.

Keywords: Sulfonylurea herbicide, *Alopecurus aequalis*, herbicide resistance, single nucleotide polymorphisms, target cite mutation

The poster in a PDF version is available here.

Evidence for co-occurrence of resistance to ALS inhibitors and 2,4-D in corn poppy (*Papaver rhoeas*) (366)

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Corn poppy (*Papaver rhoeas*) has long been associated with target-site and more recently non-target site resistance to ALS inhibitors (HRAC group B). Amounting evidence suggests that this species may also develop resistance to synthetic auxins (HRAC group O). The present study aimed at screening three *P. rhoeas* populations (F3B, F1D and F4C) from central Greece fields with a known history of group B and O herbicides, to identify populations where resistance to both herbicide groups may be present. Plants of these populations and of a reference population (S, 100% sensitive plants) were sprayed with an ALS inhibitor (iodosulfuron+mesosulfuron) or a synthetic auxin (2,4-D ester). Iodosulfuron+mesosulfuron was applied at 0, N and 4N, where N=250g ha-1 (recommended field rate) with 0.2% surfactant (sodium alkyl ether sulphate). S population was treated with iodosulfuron+mesulfuron at 0 and N. 2,4-D was applied at 0, 0.5N, N, 2N and 4N where N=345g ha-1 (recommended field rate). S population was treated with 2,4-D at 0.25N, 0.5N, N, and 2N. The experiment was performed in a glasshouse during April-May 2015 (15-25°C, natural photoperiod). The herbicides were applied with a bench sprayer fitted with one even-distribution flat-spray nozzle delivering 350L ha-1. Visual phenotype rating (dead or alive) was performed four weeks after treatment. At 4N iodosulfuron+mesosulfuron no plant survived in any population, whereas at N all S plants died but 44% F3B, 4% F1D and 13% F4C plants survived. At N 2,4-D all S plants died, whereas 54% F3B, 51% F1D and 48% F4C plants survived. At 2N 2,4-D all S plants died, whereas 32% F3B, 17% F4C and 30% F1D plants survived. The results show that one *P. rhoeas* population (F3B) contains plants with resistance to both ALS inhibitors and synthetic auxins, which has implications for future management of this species.

Keywords: *Papaver rhoeas*, Herbicide resistance, ALS inhibitors, Synthetic auxins

The poster in a PDF version is available here.

Session 2
BIOLOGICAL WEED CHARACTERISTICS

Allelopathic effect of aqueous and methanol extracts of weed species *Asclepias syriaca* on germination and seedling growth of some monocot and dicot plants (287)

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For the purpose of the environmental protection and preservation of human health there is a tendency towards reducing herbicide use: recent studies have focused on non-chemical weed control measures. As allelopathy includes all processes caused by secondary metabolites that are also produced by plants, it could have a multiple effects on plant – plant relations. Allelochemicals present in the vegetative and generative organs of plants, could have impact on the composition of the weed flora, on growth, development, and also on the yield of cultivated crops.
Aqueous and methanol extracts from root of weed species *Asclepias syriaca* L. were bioassayed against plants of the family *Poaceae* (*Sorghum halepense* (L.) Pers. and *Sorghum bicolor* (L.) Moench) and *Asteraceae* (*Ambrosia artemisiifolia* L. and *Erigeron canadensis* L.). Both extracts in concentration from 10 to 40 g dry tissue L^{-1} were applied to filter paper in Petri – dish with 100 seeds, in four replication. The research has proven a significant degree of inhibitory effects of the aqueous extract at all concentrations applied to the length of radix and shoots sprouts, as well as on the overall number of germinated seeds of the tested plant species. The methanol extract has also exhibited an inhibitory effect on all test plants except for the weed plant *A. artemisifolia* in which the stimulating effect is determined.

Keywords: Allelopathy, *Asclepias syriaca* L., methanol extract, water extract

The poster in a PDF version is available here.

The effect of essential oils on germination of some dicotyledonous plants (294)

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The application of essential oils in agriculture has been more intense over the last few years. The negative consequences of continued use of synthetic pesticides led the research towards finding alternative ways of controlling weeds, pests and pathogens. Essential oils are complex mixtures of various chemical compounds with distinct pharmacological and phytopharmacologic performance.
Tests were conducted with the objective of determining the influence of different concentrations of the essential oils of cumin (*Carum carvi* L.), coriander (*Coriandrum sativum* L.), and fennel (*Foeniculum vulgare* Mill.) on seed germination, seedling growth and seed development of grown plants lettuce (*Lactuca sativa* L.), arugula (*Eruca sativa* Mill.), white clover (*Trifolium repens* L.) and phacelia (*Phacelia tanacetifolia* Benth.). The ether oils were applied at concentrations of 2.5 µ/ml, 1.25 µ/ml, 0.625 µ/ml, 0.25 µ/ml, 0.125 µ/ml and 0.06 µ/ml. The fourth day after the setting of the trial, the average seedlings length (mm) was measured.
The highest average seedlings length was recorded after the application of the essential oils of *C. carvi* at a concentration of 2.5 µ/ml for *T. repens*, while the lowest average length of seedlings was established in the application of the essential oils of *C. sativum* at a concentration of 0.06 µ/ml to seed of *Ph. tanacetifolia.* Inhibitory effects of higher oil concentrations were recorded after the application of *F. vulgare* essential oil to the seeds of *Lactuca sativa* plants.

Keywords: Essential oils, seed germination, cumin, coriander, fennel

The poster in a PDF version is available here.

Effect of environmental factors on *Digitaria insularis* seed germination (28)

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Digitaria insularis (sourgrass) is a perennial weed native from tropical and subtropical America that reproduces by seeds and rhizomes. It is an important weed in summer crops from the north agricultural area of Argentina, due to the high seed production and dispersion of small hairy seeds that allows the colonization of new areas and the occurrence of glyphosate resistant biotypes. The objective of this work was to analyze the effect of environmental factors on the stimulation of seed germination in two populations of *D. insularis* from different origins.
In germination chambers, two completely randomized design experiments with 4 replicates of 36 seeds per replicate were performed. Factors were population origin (Córdoba and Santiago del Estero) and germination temperature (constant 25ºC and fluctuating 20/35ºC). Other factors were humidity/desiccation cycles (zero, one and two cycles) and light (visible light and darkness) in the first experiment, and light quality (red light 60 minutes, far red light 60 minutes, red light 60 minutes/darkness 30 minutes/ far red light 30 minutes) in the second experiment.
The highest seed germination percentages were observed at fluctuating temperatures (20/35ºC), regardless of the presence of light. Seeds from Santiago del Estero showed higher germination percentage (97%) than seeds from Córdoba (84%). At fluctuating temperatures, no differences were observed among humidity/desiccation cycles and light quality treatments. But at 25ºC constant temperatures, seed germination increased as the number of humidity/desiccation cycles increased and the exposition of far red light during 60 minutes reduced seed germination.
In summary, regardless the origin of the seeds tested in this work, the best conditions for *Digitaria insularis* seed germination are fluctuating temperatures (20/35ºC) while visible light is not important. At constant temperatures, moisture fluctuations stimulate and far red light reduces seed germination.

Keywords: Sourgrass, Temperature, Humidity/desiccation cycles, Light quality, Seed origin

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Emergence behavior, plant development and control of different *Amaranthus* species in Germany (60)

Hans-Peter Söchting *(Julius Kühn-Institut/Federal Research Centre for Cultivated Plants, Braunschweig, Germany)*

The mainly from North America immigrated *Amaranthus* species are spreading increasingly on arable land in Germany. Besides *A. retroflexus* (redroot pigweed) especially *A. albus* (tumble pigweed) and *A. blitoides* (prostrate pigweed) are spreading at a high rate. These thermophile species are found in nearly all spring crops and exceptionally often in maize and sugar beet.
In a pot experiment the emergence behaviour and plant development of the species *A. albus, A. blitoides, A. chlorostachys* (smooth pigweed), *A. graecizans* (tumbling pigweed) and *A. retroflexus* were examined. Concerning both the emergence behaviour as well as the development time to seed, differences in maturity were immense between the species. For example *A. viridis* and *A. graecizans* emerged later than the other species but for these two species the period from germination to seed maturation was shorter. This will ultimately have an impact on the control of these species in agricultural practice.
Furthermore, the development and the control with herbicides of *A. albus, A. blitoides* and *A. retroflexus* was also investigated under practical conditions in 3 years of experiments on sugar beet fields. In biotests it was possible to control the species with the usual herbicides, but in practice problems of controlling were immense. A high number of *A. albus* plants emerged a long time after the last herbicide application, this made the control of this species impossible. In future, with an increase of these species in Germany, controlling them will become considerably harder.

Keywords: Amaranthus species, emergence behavior, plant development, herbicide control

The poster in a PDF version is available here.

Influence of environmental factors on seed germination and emergence of Asia minor bluegrass (*Polypogon fugax*) (124)

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Polypogon fugax (Asia minor bluegrass) is a major weed impacting rape (*Brassica napus*) production in Dongting Lake District, China. Growth chamber experiments were conducted to determine the influence of environmental factors on germination and emergence of Asia minor bluegrass (AmB).
Seed germination was greatest at a constant temperature of 20 °C or an alternating temperature of 22/15 °C. Seeds could germinate in the dark, but light exposure significantly enhanced the germination percentage. More than 50% of seeds germinated over a pH range between 4 and 10. Seed was highly sensitive to osmotic stress and germination was completely inhibited at an osmotic potential of -0.4 MPa, indicating that it was favored by a moist environment. Increasing salinity reduced germination of AmB seeds from 58% at 0 mM to 13% at 80 mM NaCl. The highest seedling emergence (62%) was observed when seeds were placed on the soil surface, and no seedlings emerged from seeds placed at a depth of 5 cm.
This work shows that the climate and soil conditions in Dongting Lake District are suitable for AmB seed germination and that no-till fields where seeds remain on the soil surface promote the successful establishment of the weed.

Keywords: Temperature, light, pH, osmotic and salt stress, burial depth

Is emergence pattern of *Sonchus oleraceous* affected by soil tillage system? A study conducted on bare soil, maize and soybean (164)

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Soil tillage modifies weed seedling emergence by acting on the vertical seed distribution in the soil profile. Seed burial depth has the potential to change quantitatively and qualitatively weed emergence. *Sonchus oleraceus* is a dominant weed increasing in prevalence in conservation tillage managed fields. It seems that reduced tillage creates optimal conditions for its establishment over the years. To better understand the emergence pattern of this species for management decisions, an experiment was conducted to study the response in terms of emergence magnitude and dynamics to different soil tillage systems in northeast Italy.
The research consisted in comparing weed emergence patterns in tilled and no-tilled systems in bare soil (under simulated conditions), and in field with maize and soybean. In bare soil, two treatments were performed to simulate conditions in arable (seeds buried in the soil and mixed in 5 cm–deep soil) and no-till managements (seeds on soil surface without disturbance). Emerged seedlings were counted and removed weekly from spring till August. Moreover, field experiments were conducted in 2011 in maize and 2013 in soybean. In each year, two fields were monitored, a conventionally tilled field (autumn mouldboard ploughing and spring harrowing) and a conservation tillage field (sod seeding with the previous crop residues on the soil surface). Emergence was sampled weekly by destructive counts in 11 fixed 0.3x0.3 m^2 quadrats per field.
From comparison of the emergence patterns in conventional and conservation system, no difference was observed in dynamics expressed as percentage both in bare soil and in the two crops, even if density was different between tillage systems in particular in maize: 8 plants/m^2 in conventional and 152 plants/m^2 in no-tilled system. These findings are important for a future emergence modelling for this species, the same algorithm can be used both in tilled and no-tilled system.

Keywords: Emergence pattern, emergence magnitude, predictive model, sod seeding

The poster in a PDF version is available here.

Modelling the effects of water stress and temperature on germination and emergence of Jimsonweed (*Datura stramonium*) seeds (416)

Sajad Mijani *(Ferdowsi University of Mashhad, Mashhad, Iran),* ***Ebrahim Kazerooni Monfared*** *(University of Applied Science and Technology, Gilan, Iran),* ***Somayeh Tokasi*** *(PhD Graduated of weed science, Gilan, Iran)*

Knowledge of the environmental factors (moisture and temperature) affecting the germination and emergence is essential to developing a predictive model for this plant. For these purposes, three experiments (GGC=Germination (Growth Chamber), EGC=Emergence (Growth Chamber) and EF=Emergence (Field)) were assessed during 2009-2010. Cumulative germination and emergence of jimsonweed (*Datura Stramonium*) seeds was modelled by the Weibull equation. In the first experiment (GGC), Temperatures of 5 to 45 °C and water stress treatments of 0 to -1 MPa were tested using growth chamber. No germination occurred in 5 and 10 °C and on the other hand, germination occurred in 15 °C just under 0 MPa. As the temperature increases from 15 to 30 °C germination percentage increased and then declined. Maximum tolerance of seed germination to water stress was observed in 30 °C (0 to -1 MPa) and 35 °C (0 to -0.8 MPa). In the second experiment (EGC), emergence of jimsonweed seeds under temperatures (20/10, 30/20 and 40/30 °C, Day/night) and soil moisture treatments (field capacity (-0.045 MPa) and 70 % of field capacity (-0.172 MPa) were tested. No emergence occurred in 20/10 °C and on the other hand, seed emergence under 70 % of field capacity (63.6- 68.1 percent) was increased compared to field capacity (37.7- 44 percent) in two other temperatures (30/20 and 40/30 °C). In the third experiment (EF), evaluation of seed emergence under three planting dates (June, July and August) and three irrigating regimes (every two, three and four days) was investigated. The hydrothermal time required for 50% seed emergence in planting dates of June, July and August with three irrigating regimes (every two, three and four days) 34/7, 26/3, 30/4 and 38/6, 46/6, 30 and 82/3, 43, 13/4 were estimated, respectively. The results of this study can be used to better manage jimsonweed in agro-ecosystems.

Keywords: Hydrothermal time model, ntegrated weed management, soil moisture, Weibull model

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Session 3
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND

Differences in herbicide sensitivity and growth among clonal populations of *Cyperus esculentus* found in Belgian maize fields (333)

Benny De Cauwer *(Ghent University, Ghent, Belgium),* ***Sander De Ryck*** *(Ghent University, Ghent, Belgium),* ***Sofie Claerhout*** *(Ghent University, Ghent, Belgium)*

Cyperus esculentus L. (yellow nutsedge) belongs to the world's most important arable weeds. Despite intensification of control over the last decades, this invasive troublesome neophyte now covers about 8000 ha of arable land in Belgium. Success of control strategies largely varies from field to field. Hence, clonal populations found in Belgium might have a differential genetic background. In this study herbicide sensitivity and growth characteristics of *C. esculentus* var. *leptostachyus* clonal populations were evaluated. Dose-response pot experiments were conducted in the greenhouse to evaluate the effectiveness of two foliar-applied herbicides (bentazon and glyphosate) and two preplant incorporated herbicides (S-metolachlor and dimethenamid-P) for controlling 14 clonal populations of *C. esculentus* collected in Belgian maize fields. In an outdoor container experiment, effectiveness of 20 strategies (no control, manual hoeing, covering by agrotextile and 17 chemical control programs) for controlling 4 clonal populations was evaluated. Chemical control programs comprised 15 combinations of preplant incorporated (S-metolachlor, dimethenamide-P) and/or preemergence (dimethenamide-P) and/or postemergence (pyridate, bentazon, mesotrione, nicosulfuron, thiencarbazone-methyl+foramsulfuron) maize herbicides applied as single or split applications apart from two glyphosate-based fallow programs. Aboveground live biomass and number of newly produced tubers were determined. Finally, 25 clonal populations were screened for their growth characteristics and ability to set viable seeds under outdoor conditions. Large interclonal differences in herbicide sensitivity (up to a factor 5) were observed. Programs with a preplant incorporated herbicide were most effective and provided season long *C. esculentus* control; tuber size and tuber number were significantly lower compared to programs without preplant incorporated herbicides. Clonal populations exhibited huge differences in shoot number (up to factor 6), inflorescence number, tuber size (up to factor 3), tuber number (up to factor 5) and seed production. Future *C. esculentus* management strategies should take into account differential herbicide sensitivity and growth characteristics of *C. esculentus* populations.

Keywords: Tuber number, vegetative growth, reproductive growth, chemical weeding strategies, variability

The poster in a PDF version is available here.

Evaluation of weeding strategies mixing chemical weed control and mechanical weed control on sunflower and rape crops (780)

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In a context of reduced herbicide use, and considering the need to weed properly to preserve good yields, an adequate solution is to combine chemical and mechanical weed control. These weeding strategies were tested in some experiments carried out on sunflower and rape crops. We used harrow comb, rotary hoe, hoeing machine, and pre-emergence herbicides sprayed on the row at sowing, etc. In some strategies, herbicide levels were reduced. Some treatments involved herbicide-tolerant varieties with adapted weed-killers. The efficacy of these strategies was compared. Non-weeded test plots were kept and classical weeding strategies served to evaluate these new strategies. The terms of the trial tested followed the regulatory context of herbicide homologations each year. In sunflower, the results showed that mechanical interventions such as harrow comb used in good conditions allowed herbicide reductions with a satisfactory weed management results whatever the chemical treatment. An infestation level gap was noticeable between plots weeded with harrow comb (more chemical treatment) and plots weeded only with herbicides. In the rape crop, the program using pre-emergence herbicide sprayed on the row followed by inter-row hoeing showed a good complementarity with an efficiency of about 80%. However, when the program only involved a reduced herbicide dose or when it was only hoeing, weed control was not satisfactory. These results are interesting but other experiments will be needed to account for the evolution of homologations and also allow us to enhance our knowledge on these strategies and their impacts on different weed species.

Keywords: Weeding strategies mixing chemical weed control and mechanical weed control, rape and sunflower crops, efficacy

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Weed control with new herbicides saflufenacil and isoxaflutole + thiencarbazone-methyl in no-till maize production (479)

Goran Malidza *(Institute of Field and Vegetable Crops, Novi Sad, Serbia),* ***Milos Rajkovic*** *(Provincial Secretariat for Agriculture, Water Management and Forestry, Novi Sad, Serbia)*

No-till production has many benefits like fuel saving, moisture conservation and other advantages valued through agro-economic and other parameters. Crop residues on the soil surface protect it from water and wind erosion and thus reduce the risk of sealing and nutrient surface run-off. The goal of this research was to evaluate the possibility of weed control with the new herbicide saflufenacil in a no-till production system in maize. Three years of field trials (2011-2013) were performed in Čenej, Serbia, on no-till soil after harvesting soybean. Random block system in 3 or 4 replications and a plot size of 25 m^2 were used. Soil surface was mainly covered with harvest residues and above-ground parts of emerging weeds. After sowing and before crop emergence, 3 to 4 L/ha of glyphosate (360 g/L) was applied with or without combination herbicides terbuthylazine, s-metolachlor, dimethenamid-P, saflufenacil, mesotrione, izoxaflutole or thiencarbazone-methyl. A second treatment was carried out after crop and weeds emergence, and the following herbicides and their combinations were used: nicosulfuron, foramsulfuron, rimsulfuron, prosulfuron, dicamba, tembotrione and mesotrione. After herbicide application, weed number and shoot biomass were evaluated on three occasions. At the end of the growing season, maize grain yield was calculated. Main weed species in first year of trials were: *Erigeron canadensis, Setaria verticillata* and *Sorghum halepense*; in second year: *Ambrosia artemisiifolia, Echinochloa crus-galli* and *Xanthium strumarium* and in third year: *Amaranthus retroflexus, A. artemisiifolia, Lactuca seriolla*, *Papaver rhoeas*, *S. verticillata* and *S. halepense* from rhizome. All treatments showed high efficacy (>95%) in reducing number and weight of dominant weed species. No significant differences in maize grain yield between herbicide treatments were observed. Our results confirmed that with appropriate choice of herbicide and time of application, dominant weeds can be effectively eliminated in a no-till system.

Keywords: No-till, maize, weed control, saflufenacil

The poster in a PDF version is available here.

Weed population and weed density effects of reduced tillage in silage maize (690)

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Silage maize (*Zea mays*) cultivation is associated with negative impacts on soil and water quality as reduced soil organic matter, nitrate leaching, soil-biota decline and soil compaction. Efforts are made to reduce tillage intensity to overcome these negative impacts. Although less intensive tillage reduces cultivation cost directly, in the longer term effects may contrast, e.g. regarding weed pressure and weed flora. In three long-year field experiments, two on sandy soils running from 2012 and one on marine loam soil running from 2009, conventional inversion tillage is compared with reduced tillage systems: non-inversion tillage, direct seeding, and strip tillage with a rotary harrow system, designed for use in terminated grassland without any previous cultivation. Each monoculture experiment started from a grassland situation. The experiments are set up with a randomised complete block design with at least 60 m^2 plots. Weed counts in 1.5 m^2 subplots were made before chemical weed control yearly. The most important weed species initially present were *Poa annua*, *Stellaria media*, and *Chenopodium album*. Over time *Solanum nigrum* increased at the marine loam site whereas at the sandy soil sites mainly *S. media* seems to increase. Weed abundance varied highly among sites between a few to close to 1,000 weeds per sq. meter. For conventional inversion tillage and strip tillage lower weed pressure occurred than for non-inversion tillage and direct seeding. The low weed pressure for strip tillage is explained from the limited soil surface cultivated and grass cover at the remaining surface. During the experiment weed control strategies were sometimes intensified; in case of mechanical control the strategy was adapted to the different circumstances in the reduced tillage systems. These adaptations enabled stabilisation of the weed density after control in a four year period, after an increased weed density particularly after starting with non inversion tillage.

Keywords: Maize, weed control, weed flora, reduced tillage, conservation agriculture

Tolpyralate: a novel corn herbicide (766)

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Tolpyralate (code number: SL-573; trade names: Brucia™, Shieldex™, and Ashitaka™) is a novel herbicide being developed by Ishihara Sangyo Kaisha, Ltd. Tolpyralate is a pyrazole compound, and it is an inhibitor of 4-hydroxyphenylpyruvate dioxygenase (HPPD). Post-emergence herbicide efficacy of tolpyralate was evaluated using barnyard grass (*Echinochloa crus-galli*), large crabgrass (*Digitaria sanguinalis*), giant foxtail (*Setaria faberi*), tall waterhemp (*Amaranthus tuberculatus*), Palmer amaranth (*Amaranthus palmeri*) and common ragweed (*Ambrosia artemisiifolia*) in pot-scale trials. Tolpyralate at the rate of 30 g ai/ha provided 88% control of barnyard grass and 99–100% control of the other weed species by 21 days after treatment (DAT). While tolpyralate showed strong herbicide efficacy on weeds at a low dose rate, it was quite safe for corn (*Zea mays*). The selectivity of tolpyralate between weeds and corn is completely different. We found that 6.25 g ai/ha of tolpyralate provided 90% control of velvetleaf (*Abutilon theophrasti*) and 82% control of goosegrass (*Eleusine indica*), whereas 500 g ai/ha of tolpyralate inhibited only 5% of corn growth (14 DAT). We further examined if sensitivity to tolpyralate was different depending on corn varieties; however, none of the varieties tested showed severe injury following tolpyralate application. Field trials were conducted to evaluate the performance of tolpyralate 100OD (adjuvant built-in formulation). When corn reached the 5–6 leaf-stage, tolpyralate 100OD was applied. 300–500 mL/ha of the formulation (equivalent to tolpyralate 30–50 g ai/ha) provided excellent annual grass and broadleaf weed control without causing significant injury to the corn. These results demonstrated that tolpyralate is a highly corn-selective herbicide that strongly controls a wide range of annual weeds.

Keywords: Weed management, HPPD-inhibiting herbicide, pyrazole herbicide, corn herbicide

Effect of herbicide use and field management on weed density in cereal fields in Latvia (307)

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Herbicide application has been the main weed control method in arable fields in Latvia for several decades. As according to the EU legislation the weed control methods have to comply with the principles of integrated weed management, it is important to investigate the effects of farming practice on weed communities in each region. It is known that intensive management of fields reduces overall weed density as well as the number of weed species. However, continuous cereal monoculture and use of herbicides or management practices that are not effective on *Poaceae* family weeds can contribute to the spread of noxious weed species, such as *Avena fatua* and *Apera spica-venti*. Weed resistance to herbicides is an emerging problem in Latvia, so it is important to understand what other weed control methods can be effective in local conditions. Weed surveys were carried out in three consecutive years in 51 farms in Latvia. Cereals were grown in the majority of arable fields in Latvia and of the surveyed fields. In more than 60% of the surveyed fields herbicides with the same mode of action were used and in 40% of the fields acetolactate synthase inhibitors were used repeatedly in two consecutive years. Mode of action of the herbicide or herbicide combination applied during the crop production cycle, as well as crop sowing time, influenced total weed density in the surveyed fields. Differences in the density of annual monocot weed species were also apparent between the regions, that can be attributed to difference in overall management intensity. Effects of field management factors on total weed density and dominant weed species are discussed.

Keywords: Herbicide use, cereals, weed density, weed survey

The poster in a PDF version is available here.

Mustard compared to legume in a wheat cropping system (457)

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The objective was to determine weed effects of mustard substituted for legume in typical winter wheat (*Triticum aestivum*), spring wheat, spring pea (*Pisum sativum)* rotation in northern Idaho, USA. *Sinapis alba*, *Brassica junce*a, and pea were grown in three separate 3 year rotations with winter and spring wheat. All crops in a rotation were planted every year for a total of nine 7 by 50 m plots replicated four times in a randomized complete block design. Weeds were counted before and after herbicide application, plant biomass was measured at flowering, and yield was determined at maturity. Wheat following pea had a higher weed population than wheat following either mustard in the first year. This may have been due to residual clopyralid applied to the mustard crops and/or secondary plant compounds released from the mustard into the soil. Plots were divided into sprayed or not sprayed the following years to address the effect of residual herbicide. In non-herbicide treated plots, winter wheat following *Sinapis alb*a had less weed biomass (133 g/m^2) than winter wheat following pea (266 g/m^2) after completion of one 3 year rotation. The same trend occurred in spring wheat with weed biomass of 374, 242, and 206 g/m^2 two years after pea, *Brassica juncea* and *Sinapis alb*a, respectively. Also, when weeds were controlled with herbicide, winter wheat grain yield was lower following *Sinapis alba* (8140 kg/ha) compared to *Brassica juncea* and pea (10,150 and 10,014 kg/ha, respectively). This may indicate some *Sinapis alba* residual activity on weed and wheat plant growth. *Sinapis alba* did not suppress weeds in the crop year. At six years, after two complete rotations, *Vulpia myuros* had infested the pea plots, but was not present in either mustard.

Keywords: *Sinapis alba*, *Brassica juncea*, crop rotation

Effect of herbicide treatment and cover crop on weed occurrence in glyphosate-tolerant maize (351)

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Field trial with HT maize variety NK603 tolerant to glyphosate (provided by Monsanto company) was established in 2013 and 2014 in Odrepsy, CZ, in 3 blocks with different herbicide treatments, each of them consisting of following variants in three replicates: conventional ploughing, conservation tillage, mulch tillage (MT) with *Sinapis alba*, MT with *Trifolium incarnatum*, MT *Hordeum vulgare* (winter barley), MT *Phacelia tanacetifolia.* Plot size was 540 m^2 (30 x 18m). Herbicide treatments were as follows: 1. Conventional POST standard iodosulfuron-methyl-Na 1.5 g/ha; foramsulfuron 45 g/ha; isoxadifen-ethyl 45 g/ha; 2. Split dose of glyphosate 1080 g/ha crop BBCH 13 + 1080 g/ha crop BBCH 16-18. 3. POST acetochlor 1170 g/ha; terbuthylazine 556 g/ha + glyphosate 1080 g/ha – crop BBCH 13-14. Weed occurrence was recorded once per month. There were no significant differences in grain yield among all tested treatments, soil tillage systems and cover crops – average yield of all the plots was 8.3 tons per ha in both 2013 and 2014. In total, 63 species of vascular plants were found in 2013 and 85 in 2014. There were no statistically significant differences between numbers of weed species among soil tillage/mulch crop variants within individual herbicide treatments in 2013. In 2014, there were differences between conventional tillage and plots with Phacelia in H1 and Phacelia and conventional tillage, reduced tillage and Yellow mustard in H3. In 2014 H1 was in nearly all the cases shoving statistically significantly higher number of weed species compared to other herbicide treatments. The differences were lower at the beginning and at the end of experimental period. In 2013, in majority of observation terms no statistically significant differences were found in weed species numbers among the treatments, in other cases H1 was showing higher numbers compared to H2 and H3.

Keywords: Genetically modified crops, chemical weed management, mulch tillage

The poster in a PDF version is available here.

Studies on bio-efficacy and phyto-toxicity of pendimethalin 38.7 % CS against weeds in groundnut (Spanish bunch) and its residual effects on succeeding wheat and sorghum crops in groundnut-sorghum/wheat sequence cropping system (94)

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Groundnut is an important oilseed crop of India. Weeds pose a serious problem and weeds alone account for one-third of the total losses due to pests. Pre-emergence herbicides such as Alachlor 50 % EC, Pendimethalin (30 % EC and 38.5 % CS) and Oxyfluorfen (23.5 % EC) are being used for control of weeds in groundnut. Pendimethalin is available in emulsifiable (EC) and capsulated suspension (CS) formulations. It is reported that pre-emergence application of Pendimethalin 38.7 % CS is more effective than Pendimethalin 30 % EC in control of weeds. Therefore, a field trial was carried out during two consecutive years (2012-13 and 2013-14) at MARS, UAS, Dharwad on medium Vertisol to determine the efficacy of CS formulation of Pendimethalin @ 483.75 g, 580.50 g, 677.25 g, 750.00 g and 1354.50 g/ha over EC formulation of Pendimethalin @ 1000 g/ha in controlling weeds in groundnut during kharif and its residual effects on succeeding sorghum and wheat during rabi. Results indicated that pre-emergence application of both formulations of Pendimethalin, in general, were more effective in controlling annual grassy and annual broad leaved weeds. However, pre-emergence application of Pendimethalin 38.7 % CS @ 483.75 g to 1354.50 g/ha was ineffective against congress weed (*Parthenium hysterophorus* L.). Pre-emergence application of Pendimethalin 30 % EC @ 1000 g/ha was very effective against congress weed. Pre-emergence application of Pendimethalin 38.7 % CS resulted in relatively higher weed biomass and lower weed control efficiency than pre-emergence application of Pendimethalin 30 % EC. Both the formulations of Pendimethalin did not cause toxicity on groundnut or succeeding sorghum and wheat. Pre-emergence application of either Oxyfluorfen 23.5 % EC @ 100 g/ha or Alachlor 50 % EC @ 2500 g/ha were effective against congress weed and did not cause any ill effects on succeeding sorghum and wheat.

Keywords: Pendimethalin 38.7 % CS, Pendimethalin 30 % EC, Phyto-toxicity, Broad leaved (Dicot) weeds, Annual grassy (Monocot) weeds

The poster in a PDF version is available here.

Chemical control of the invasive weeds *Ambrosia artemisiifolia* and *Acalypha virginica* in maize fields (627)

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Ambrosia artemisiifolia and *Acalypha virginica* are exotic weeds in Europe that are becoming key weeds in summer annual crops. In this study, different chemical weed control strategies were compared in maize: pre-emergence, pre+post emergence, post-emergence, untreated check. The study was carried out in northern Italy during 2015 at two different sites, Grugliasco and Mesero. *A. virginica* was present only at the Mesero site. A RCBD with 21 m^2 and 25 m^2 plots, and with four and three replicates was used in Grugliasco and Mesero, respectively. The efficacy of each weed control strategy was assessed by measuring plant density (plants/m^2) and ground cover (%). Weed assessments were carried out about one week after the treatment application. At the first assessment, in Mesero the infestations of *A. virginica* and *A. artemisiifolia* in untreated plots were 560 plant/m^2 and 70 plant/m^2, respectively. At the same assessment, at Grugliasco, more than 47 plants of *A. artemisiifolia* were recorded. At both sites, all the compared weed control strategies completely controlled *A. artemisiifolia* infestations. In Mesero site, *A. virginica* infestation was completely controlled by pre and pre+post emergence treatments. At the assessment carried out after the post-emergence application the average plant density of *A. virginica* was 73 plant/m^2 in treated plots, and 362 plants/m^2 in the untreated checks, with an average efficacy about 89%. The reduced efficacy of the post-emergence strategies is probably due to the advanced growing stage of *A.virginica* plants at the time of post-emergence application.

Keywords: Invasive species, *Ambrosia*, *Acalypha*, control strategies, chemical management

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Clearfield® production system in oilseed rape – a new weed management solution (806)

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Winter oilseed rape (OSR) is one of the most important crops in Europe. In recent years the acreage increased to 6,3 Million hectares. To avoid major yield losses, efficient and highly reliable weed management is needed. The majority of herbicides used today are applied pre-emergence or early post-emergence. They contain mainly soil-active substances, strongly dependent on soil moisture. Therefore, treatment success strongly depends on weather conditions after application and in the seedbed. A broad-spectrum post emergence product offering reliable weed efficacy under different weather and soil conditions is a huge advantage. A second threat, driven by increased production of OSR, is the spread of cruciferous weeds and close OSR-related weeds, such as wild radish and charlock. Those weeds are not well-controlled only with available herbicides. The introduction of imidazolinone-tolerant winter OSR in Europe brings genuine improvements in weed control. The Clearfield® system combines imidazolinone-tolerant rape varieties with Clearfield® herbicides, which are registered in all relevant European countries. The Clearfield® herbicide CLERAVIS contains the known active ingredients Metazachlor and Quinmerac and on top the broad-spectrum active ingredient Imazamox. Since 2007, BASF has conducted field trials all over Europe. In randomized, replicated small plot trials the benefit of the Clearfield® system in comparison to conventional weed management systems was tested. Over the years, remarkable weed control reliability is evident under different environmental conditions and cropping systems. Besides the broad-spectrum efficacy, the efficient control of cruciferous weeds and cereal volunteers is demonstrated, which finally resulted in increased yield.

Keywords: Clearfield®, herbicide tolerance, Imazamox, winter oilseed rape, weed control

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Precision weed control based on UAV imaging (289)

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Site specific weed control provides plant protection applications using herbicides with adequate doses at the right place taking into account weed occurrence and density. The detection of the actual weed situation within fields and a subsequent well targeted herbicide application plays an important role for a sustainable and socially well accepted weed control in the future. Ecological and economical benefits are obvious. Site specific weed control can be done according to weed maps. Therefore, information is required about the appearance of weeds species and their specific distribution on fields. For several years, unmanned aerial vehicles (UAV) were used in spatial vegetation detection and analyses. This technology has been applied in agriculture for automatic weed sampling with digital cameras in our trials. The UAV (Hexacopter) was equipped with a commercial camera (Sony alpha NEX-5N, 60 mm focal length). For specific weed detection, a flying altitude of 5 and 10 m above ground was carried out. The total number of single weed species was determined in every image and compared to manual weed counting results (HerbCountGUI Ver. 0.1, Matlab 2010a, The MathWorks, USA). Manual weed sampling was simultaneously done at the same locations in the field. UAV imagery has become a useful tool in weed detection. Our experience indicates that for weed estimation with multicopters high resolution images are needed to separate small structures in the images. The comparison of image data with results from manual weed counting showed a high correlation which indicates low altitude images have sufficient information for an object-based automatic weed recognition. An image based differentiation between crops and weeds only through RGB-color deviation was not feasible. Finally, the spatial information on weed occurrence was used for site specific herbicide application.

Keywords: Image processing, multicopter, site specific weed control, weed distribution, weed species

The poster in a PDF version is available here.

Relationship between weed infestation intensity and grain yield of maize grown in rotations (66)

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The level of grain yield decrease usually depends on weed composition, weed species adaptation to different cropping measures, resources demands, sensitivity to herbicides, etc. Our aim was to evaluate correlatiosn between weed infestation level and grain yield of maize in different systems of rotation. A field experiment was conducted during 2009-2012, as a split-plot trial on the experimental field of the Maize Research Institute, Belgrade, Serbia. The basic treatment was a rotation system: maize continuous cropping (MC), maize-wheat rotation (MW), maize-soybean-wheat (MSW) and maize-wheat-soybean rotation (MWS). Different herbicide rates represented treatments in sub-plots in maize: the combination of isoxaflutole and acetochlor (Merlin 750-WG+Trophy 768-EC) was applied in recommended (105 g a.i. ha^{-1} + 1536 g a.i. ha^{-1}) and half of the recommended rate (52.5 g a.i. ha^{-1} + 768 g a.i. ha^{-1}), while herbicides were not applied in the control. Each treatment had four replications and was done with hand-held sprayer calibrated to deliver 200 L ha^{-1} at 300 kPa (3 bar) with a flat-fan nozzle (Teejet, 1.4 mm E 04-80). Weed infestation level was estimated six to seven weeks after herbicide application. Samples were drawn randomly by the one square meter and average values of weed individuals across all herbicide treatments were calculated. Grain yield of two maize hybrids (ZP 677 and ZP606) was measured at harvest. The regression interdependence between maize grain yield and number of weed individuals in each cropping system was calculated. Weed numbers and maize grain yield were significantly negatively correlated for both hybrids in MC and MW. Weed infestation intensity have influenced maize grain yield also in three crop rotations but coefficients of correlation were the lowest among all. It can be concluded that rotations are better for more effective weed control in maize than maize continuous cropping, especially extended one with legume crops.

Keywords: Crop rotation, maize, weeds, control, corelation

The poster in a PDF version is available here.

Response of twenty different *Hordeum spontaneum* biotypes to two time of application of sulfosulfuron and sulfosulfuron + metsulfuran-methyl (798)

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Wild barley (*Hordeum spontaneum* C. Koch) is a dominant troublesome weed in most wheat fields of Fars province and other parts of Iran, which is hardly controlled by using common graminicides. Based on previous experiences, time of application of sulfosulfuron (75% DF) and sulfosulfuron + metsulfuran-methyl (80% WG) for different biotypes of *Hordeum spontaneum* (hs) was tested in Fars, Khuzestan, Kermanshah, Tehran, Esfahan and Western Azarbahjan provinces during 2012-2014. The trial consisted of two factors, 1- Five treatments of herbicides: sulfosulfuron at 30g/ha and sulfosulfuron + metsulfuran-methyl at 45g/ha sprayed at two different growth stages of hs: 2-4 leaf and second stem knot, and a control plot with no herbicide treatment. 2- Twenty biotypes of hs collected from above mentioned provinces. Evaluation included wet and dry weight of hs and leaf area, 30 days after herbicide application. Also measured after seed ripening were hs density, dry weight, final height of hs, number of spikes, number of seeds per spike and thousand seed weight. Results indicated that differences existed amongst most tested biotypes. In some biotypes, like Shahreza and Golpayegan, 2-4 leaf stage showed better results, compared to second stem knot stage, but with no statistical difference. Altogether, more negative effects were observed on hs at second stem knot than at 2-4 leaf stage. Moreover, efficacy of sulfosulfuron + metsulfuran-methyl was higher than sulfosulfuron for all biotypes. Overall based on the results of this experiment *application of sulfosulfuron* + metsulfuran-methyl at second stem knot can effectively suppress *Hordeum spontaneum.*

Keywords: Hordeum spontaneum, second stem knot, sulfosulfuron, sulfosulfuron + metsulfuran-methyl, wheat

Plant-back Interval for glyphosate- and glufosinate-resistant corn after Group 1 herbicide application (100)

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Studies in 2013 and 2014 examined the tolerance of corn to Group 1 herbicides when they were used to terminate a failed stand of glyphosate- and glufosinate-resistant corn. To simulate this scenario, Group 1 herbicides were applied 1 wk or 1 d preplant (PP) and several parameters were measured. Corn injury 1, 2, 4, or 8 wk after emergence (WAE) was similar to the untreated control, regardless of herbicide treatment, dose, or application timing. Across herbicides and doses, application timing did not affect plant stand or aboveground biomass 2 WAE, plant height 4 WAE, or yield. Across application timings, plant stand and aboveground biomass were similar to the untreated control, regardless of herbicide treatment or dose; however, some herbicides reduced height and/or yield. For example, compared to the untreated control, fluazifop-p-butyl (75 and 150 g a.i. ha^{-1}) and sethoxydim (300 g a.i. ha^{-1}) each reduced height by about 3% while clethodim (30 and 60 g a.i. ha^{-1}), fluazifop-p-butyl (150 g a.i. ha^{-1}), and quizalofop-p-ethyl (72 g a.i. ha^{-1}) each reduced yield by about 2%. Therefore, in the rare situation where a grower may need to terminate a failed corn stand, Group 1 herbicide selection should be based on efficacy rather than plant-back restrictions.

Keywords: Application timing, Height, Biomass, Yield, Plant-back restrictions

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Integrated strategies of black-grass (*Alopecurus myosuroides*) control in winter wheat (697)

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Black-grass (*Alopecurus myosuroides*) is one of the most aggressive grass-weeds in many western European countries, but in recent years it is also quickly spreading in eastern European countries, such as Poland. Herbicides are often considered the primary method of black-grass control, but lack of new modes of action and increasing resistance problems means that integrated and non-chemical methods will become increasingly important. Diversity in weed management strategies using agronomic tools (e.g. crop rotation, ploughing, delayed autumn sowing and competitive crops) is one of the most effectiveness ways to reduce black-grass populations and to improve herbicide activity. The aim of a two-year field experiment was to determine the effectiveness of black-grass control in winter wheat with herbicides applied single or two times in combination with delayed sowing date and mixture of competitive varieties. The four herbicide treatments used were: 1) flufenacet + diflufenican – applied in autumn, (100% dose); 2) flufenacet + diflufenican – applied in autumn (50% dose) and pinoxaden applied in spring (50% dose); 3) flufenacet +diflufenican – applied in autumn (50% dose) and pinoxaden applied in spring (100% dose); and 4) pinoxaden applied in spring (100% dose). The best option for black-grass control was to apply a combination of two separate treatments (3) and single treatment (4) regardless of sowing date or using a competitive mixture of winter wheat varieties. Average reduction of black-grass was 100 and 99%, respectively. The worst scenario was single treatment of herbicide (1) in full dose in autumn (79% control). The best solution according to yielding of winter wheat was to use all three options with autumn treatments (increase yield of 23-28%) and sowing mixture of competitive varieties at normal date or delayed sowing date about two weeks using a single wheat variety (yield increase of 28% and 26%, respectively).

Keywords: Black-grass, herbicide, weed control, mixure of varieties, delayed sowing

The poster in a PDF version is available here.

Temperature effect on the post-herbicide efficacy of Palmer amaranth (*Amaranthus palmeri*) control in sorghum (709)

Seth Menzer *(Kansas State University, Manhattan, United States),* ***Curtis Thompson*** *(Kansas State University, Manhattan, United States),* ***Mithila Jugulam*** *(Kansas State University, Manhattan, United States)*

Grain sorghum yields in the Great Plains of the U.S. are significantly influenced by weeds, especially Palmer amaranth infestations, and POST herbicide application is a major method for Palmer amaranth control in sorghum. POST herbicide efficacy is known to be influenced by environmental factors, including temperature. Many studies have reported decreased POST herbicide efficacy at higher temperatures, but some have reported the opposite trend. Short episodes of high temperature during sorghum production are common in the central Great Plains. The objective of this study was to evaluate the efficacy of POST applied herbicides on Palmer amaranth when exposed to different temperatures. Experiments were conducted under controlled growth chamber and field conditions. In the field, Huskie + Atrazine (1X) was applied at 8:00 am (cooler) or 4:00 pm (warmer) on V3 and V8 stages of sorghum. Visual control of weeds relative to untreated plots was recorded at 1, 2 and 4 weeks after treatment, and dry biomass and yield were collected at physiological maturity. In growth chambers, Palmer amaranth plants were grown under hourly fluctuating temperatures set to reflect the temperature in the field at the time of V3 POST application. When plants reached 10-12 cm tall, they were treated with 0, 1/64, 1/32, 1/16, 1/8, 1/4, 1/2 and 1X rates of atrazine (1X: 560 g ai ha^{-1}) plus Huskie (1X: 35.3 g ai pyrasulfotole and 199 g ai bromoxynil ha^{-1}), or dicamba (1X: 560 g ae ha^{-1}). Half of the plants were treated at 8am and the remaining plants were treated at 4pm. Preliminary results indicate a decline in Palmer amaranth control under high temperatures, suggesting a decrease in POST herbicide efficacy. Understanding temperature effects on herbicide efficacy is important for recommending application times for POST herbicides that improve weed control in grain sorghum.

Keywords: Herbicide efficacy, temperature, Palmer amaranth

Optimisation of chemical weed control in maize undersown with tall fescue (297)

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Under new EU regulations, farmers use 5 percent of their land as Ecological Focus Area (EFA). Using cover crops is one option to meet this EFA requirement. Cover crops can be sown immediately after the harvest of the main crop or undersown in the main crop. Undersowing tall fescue (*Festuca arundinacea* L.) in silage maize is gaining interest in Belgium. It takes away the need of soil tillage after maize harvest and eliminates the risk of not being able to timely install the cover crop. However, this system faces two main challenges: 1/ herbicide treatments should hamper early growth of tall fescue (to reduce crop yield losses) but allow quick recovery after maize harvest and 2/herbicides should provide satisfactory weed control. To address these challenges, a field trial was established comprising silage maize plots with or without undersown tall fescue in a randomized block design. Prior to installation, field plots were uniformly infested with *Echinochloa crus galli* or *Echinochloa muricata* seeds. Six herbicide treatments were evaluated: an untreated control, a grass-friendly treatment with pyridate and four broad-spectrum herbicide mixes comprising a soil acting herbicide (S-metolachlor, dimethenamid-P), one or two HPPD-inhibitors (sulcotrione, tembotrione, topramezone) and/or nicosulfuron at low dose. Herbicides were applied at BBCH14 of maize. Weed density per plot was determined right before and 3 weeks after herbicide application. At maize harvest, maize yield, weed biomass and tall fescue biomass were determined. Undersown tall fescue reduced maize yield up to six tonnes per hectare. Highest yield reductions were found in plots treated with grass–friendly mixes. A good balance between tall fescue growth, maize yield and weed control was found in plots treated with low doses of topramezone + tembotrione in combination with dimethenamid-P or in plots with full dose of tembotrione in combination with S-metolachlor.

Keywords: Undersowing, barnyard grass, tall fescue, field trial, herbicide

The poster in a PDF version is available here.

Application of dicamba + triasulfuron for weed management in oat varieties (407)

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Crops and varieties are characterized by a wide range of competitive abilities in weeds suppression. Enhancing the ability of crops to suppress weeds by using different varieties and their mixtures is an attractive control option for weed management. Competitive potential of crops can be also used together with other methods of plant protection, like reduced doses of herbicides. While it is known that cultivar mixtures usually stabilize crops and reduce yield losses caused by diseases, there are few reports on the possibility of combination of cultivar competitive potential and reduction in the use of herbicides. The aim of the present study was to assess the competitive abilities of oat cultivars and their mixtures taking into account the possibility of application of reduced herbicide doses. Field experiments were carried out in the years 2010-2012 to access the effect of dicamba+triasulfuron on the three oat varieties and their two and three-component mixtures. Herbicide was applied at recommended and reduced dose at the beginning of oat tillering. Analysis of the weed infestation (weeds number and fresh weight), yield and its quantitative and qualitative parameters were described. The weed infestation was compared between sole crop and mixtures and between the herbicide doses. Results from the experiments proved the usefulness of reduced doses of dicamba+triasulfuron and confirmed differences between varieties and their mixtures for weed suppression ability.

Keywords: Oat, dicamba, triasulfuron, variety mixtures, reduced herbicide doses

The poster in a PDF version is available here.

Effect of timing and dosage in herbicide application on *Alopecurus myosuroides* in winter wheat (755)

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Alopecurus myosuroides is a major weed in Europe. It was only found in Taiwan in China years ago, but now, it is a problem weed in many fields in Shandong, Hebei, and Shanxi. No report was found of its chemical control in China. Field experiments were conducted to determine the weed control effect and the response of winter wheat to 8 herbicides at recommended dose at different times during the 2013-2014 growth seasons in Jinan Shandong province. The results showed that pyroxsulam (7.5% WG) had the best control effect with 97.1%~100.0% fresh weight (FW) reduction at all application times. The herbicide combination of mesosulfuron-methyl + iodosulfuron-methyl-sodium (3.6% WG) led to 80.1%~98.6% FW reduction. Pinoxaden (50g/L EC) was effective (99.3%~99.9% FW reduction) when treated before over-wintering, but control was reduced to 74.1%~88.9% when treated during the over-wintering period and to 46.2%~75.8% when treated during the early turning green period. Clodinafop-propargyl (15% WP) and fenoxaprop-p-ethyl (69 g/L EW) led to 81.1%~96.8% FW reduction when treated before over-wintering and the early turning green period, but only led to a 41.4%~76.0% FW reduction when treated during the over-wintering period. Isoproturon (50% WP), tralkoxydim (40% WDG) and flucarbazone-Na (70% WG) were not effective at any application time we studied.

Keywords: *Alopecurus myosuroides*, hebicide, weeds control effect, winter wheat

Benefits of herbicidal control of annual grasses and broadleaf weeds in tef, *Eragrostis tef* (Zucc.) Trotter in Ethiopia (828)

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Both grasses and broadleaf weeds are threats to tef (*Eragrostis tef* (Zucc.) production in Ethiopia, adversely affecting yield and quality. A demonstration of post emergence herbicide pyroxsulam application was conducted during 2014/2015 in four regions (Oromia, Amhara, Tigrai and South) of Ethiopia to familiarize farmers with chemical control of grasses and broad leaf weeds in tef and to reduce grain yield losses incurred by weeds. The most prevalent weeds in fields were *Setaria pumila*, *Phalaris paradoxa*, *Bromus pectinatus*, *Avena fatua*, *Snowdenia polictacha*, *Guzotia scabra*, *Polygonum nepalense*, *Galinsoga parviflora*, *Amaranthus hybridus*. The results showed that application of pyroxsulam at the rate of 0.4 l ha-1 reduced weed population densities (P<0.05). Grain yield was improved by more than three fold over the untreated plots. Therefore, application of pyroxsulam at the rate of 0.4 l ha-1 on tef to control weeds is economically beneficial and could potentially provide tef growers improved yield and sustainable production of the crop.

Keywords: Weed, Herbicide, *Eragrostis tef* (Zucc.), Ethiopia

Weedy rice damage and control strategies in China (199)

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To clarify weedy rice distribution and infestation in China, an intensive survey was conducted in 25 provinces. The survey revealed that more than 3.33 million hectares of rice were infested with weedy rice across China. The most severe infestation was found where interseeding, direct seeding, or no-till systems were employed, while only sporadic infestations were found in transplanted rice (includes machine transplanting, hand transplanting, and seedling throwing). Specific weedy rice biotypes were associated with different regions and planting regimens.

Weedy rice infestation caused 10-50% grain yield reductions. Rice grain contaminated with weedy rice reduced grain quality, resulting in lower market price.

An integrated management strategy is recommended for weedy rice control. Inversion tillage deeply buries weedy rice seeds, making germination and emergence difficult. In heavily infested fields where direct seeding was practiced last year, subsequent direct seeding should be done only after plowing. Use clear water sources, and clean, high quality seed. In heavily infested areas, harvest by hand or thoroughly clean harvesting machinery when moving from field to field. Where fields heavily infested with weedy rice have been interseeded or direct seeded for 2 or more years, recommendations call for planting by the seedling throw method or by hand or machine seedling transplanting, followed by irrigation to establish a water layer. Pretilachlor provides good control of weedy rice in direct-seeded flooded paddies, though it should be applied immediately (same day) after planting of pre-germinated rice seeds.

Keywords: Pretilachlor, weedy rice infestation survey, weedy rice, damage, control strategies

Major weeds and weed management practices in irrigated lowland rice areas of Luzon Island, Philippines (791)

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Weed populations are usually mixed and composed of a number of different species in any given field. Weed management practices (any practice, not just herbicides) will have a slightly different effect on the individual species in the population mixture. Over time, continued use of one practice can lead to the population being dominated by one species or group of species. Weed and weed management practices were gathered in selected rice farmers in irrigated lowland areas of Luzon Island, Philippines during 2015 dry and wet cropping seasons.
Thirty-five percent of the total fields had 1- 10% weed infestations both above and below rice canopies. Grasses were the most dominant followed by broadleaves, sedges, and unidentified small weeds. Species of E. colona and E. crus-galli were the most common dominant grass weeds while F. miliacea, C. difformis, C. iria, and C. rotundus for sedges, and S. zeylanica for broadleaves. Herbicide application was the most common weed management technique used to combat against weeds. Among the herbicides, butachlor was the most commonly used both at seedling and tillering stages of rice crop.

Keywords: Luzon island Philippines, major weeds, weed management, irrigated lowland rice

The poster in a PDF version is available here.

Antagonism occurs when quizalofop is mixed with ALS inhibiting herbicides in ACCase-Resistant Rice (772)

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Non-genetically modified ACCase–resistant rice, currently under development by BASF, allows for the use of quizalofop (QRR) to control grass weed species. In 2015, a study was conducted at LSU AgCenter H. Rouse Caffey Rice Research Station near Crowley, LA to evaluate potential antagonism of quizalofop when mixed with herbicides with ALS activity. Each plot included 4 rows of 'QRR' and 1 row of 'CL 111', 'CLXL 745', 'Mermentau', and red rice. Percent control was recorded for each rice cultivar and barnyardgrass at 14 and 28 days after treatment (DAT). The experimental design was a randomized complete block with a two-factor factorial arrangement of treatments with four replications. Factor A was no quizalofop or quizalofop at 120 g ai ha^{-1}. Factor B consisted of penoxsulam at 40 g ai ha^{-1}, penoxsulam plus triclopyr at 352 g ai ha^{-1}, halosulfuron at 53 g ai ha^{-1}, bispyribac at 34 g ai ha^{-1}, orthosulfamuron plus halosulfuron at 94 g ai ha^{-1}, orthosulfamuron plus quinclorac at 491 g ai ha^{-1}, imazosulfuron at 211 g ai ha^{-1}, and bensulfuron at 43 g ai ha^{-1}. At 14 DAT, a single application of quizalofop controlled barnyardgrass 88% and all rice cultivars 88 to 90%. Quizalofop activity was reduced to 76 to 84% control when mixed with penoxsulam for barnyardgrass and the rice cultivars. The addition of penoxsulam plus triclopyr to quizalofop had similar results to quizalofop mixed penoxsulam. The addition of bispyribac to quizalofop resulted in similar control observed with a mixture of quizalofop plus penoxsulam plus triclopyr. At 28 DAT, similar results were observed with quizalofop plus penoxsulam containing herbicides and bispyribac. In conclusion, caution should be taken when mixing quizalofop with penoxsulam, penoxsulam plus triclopyr, or bispyribac. A second application of quizalofop may be necessary when antagonism occurs for control to reach acceptable levels.

Keywords: ACCase resistant rice, quizalofop, antagonism, herbicide interaction

The poster in a PDF version is available here.

Pre and post herbicidal weed management in rice-rice cropping system in eastern India (213)

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Being the most important cropping system of eastern India, rice-rice system supports the life and livelihood of the billions. Amongst diverse issues causing poor national average productivity of rice weed is the prime one. The peasants of eastern India usually control weeds in rice through hand pulling. High labour wage, paucity of labour etc. at the critical crop weed competition phase makes the farmers bound to think about some alternatives like herbicides etc. With these concepts keeping in views a filed experiments was carried out in a medium land having *inceptisol* soil at a farmer's field (22°57′N, 88°20′E) of Muratipur, West Bengal, India during wet and dry seasons of 2013-14 and 2014-15 in a randomised complete block design replicated thrice. Out of nine treatment combinations, three were specified for pre-emergence (PRE) herbicides (pretilachlor 750 g/ha, pendimethalin 1000 g/ha and pyrazosulfuron-ethyl 30 g/ha), three for pre followed by (*fb*) post (PRE+POST) herbicides (pretilachlor *fb* metsulfuron+chlorimuron 4 g/ha, pendimethalin fb metsulfuron+chlorimuron 4 g/ha and pyrazosulfuron ethyl *fb* metsulfuron+chlorimuron 4 g/ha) in combination and the rest three e.g. the farmers' practice, approximately weed free situation and unweeded control were taken for comparing the efficacy herbicidal practices. By reducing the density and biomass of weeds satisfactorily, pyrazosulfuron ethyl *fb* metsulfuron+chlorimuron exhibited the best impact amongst all the herbicidal treatments irrespective of growing season vis-à-vis crop growth stage. This treatment checked the nutrient removal by weeds and augmented the nutrient uptake by crop to a satisfactory extent and statistically it was as good as the treatment creating approximately weed free situation. Thus, by dint of reducing the overall ill impacts of weeds in rice this treatment produced higher grain yield of rice in both the seasons. The PRE+POST herbicides always performed better than the sole PRE herbicides and the conventional farmers' practice.

Keywords: Weed management, Pyrazosulfuron-ethyl, Chlorimuron+Metsulfuron, Rice-rice cropping system, Eastern India

The poster in a PDF version is available here.

RinskorTM active: A new arylpicolinate herbicide from Dow AgroSciences with utility in rice crops in Europe (611)

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Rinskor™ active (proposed ISO name in review) is a new arylpicolinate herbicide being developed by Dow AgroSciences with utility in rice, either in upland or saturated paddies. Rinskor active's broad-spectrum efficacy on grass, sedge and broadleaf weed species in rice has been confirmed in field trials conducted since 2010. Use rates range from 10 to 30 g ai ha^{-1} depending on use pattern and weed species. Species controlled with foliar application in rice include: *Echinochloa crus-galli; Echinochloa spp.; Cyperus difformis; Heteranthera spp.; Alisma plantago aquatica, Murdannia keisak ; Ammannia cocinea; Lindernia dubia and Bidens tripartita*. Rinskor is an arylpicolinate, which is a novel, unique synthetic auxin chemotype that exhibits unique efficacy spectrum and controls ALS-, ACCase-, propanil-, and quinclorac-resistant grass and ALS-resistant sedge and broadleaf weed species. Favorable environmental fate, toxicology and ecotoxicology properties are anticipated for Rinskor. Rinskor exhibits excellent safety to *Indica* and *Japonica* rice varieties, round-grain, medium-grain and long-grain within conventional and Clearfield® rice systems. In rare cases, transitory rice response has been observed that usually appears as "onion leafing" or minor growth reduction. Rinskor will offer an alternative mode of action herbicide for the control of grass, broadleaf and sedge weeds in rice and provide control of many existing target site-based herbicide resistant weed species. The first registrations of Rinskor in Europe are expected in 2020 or 2021.

Keywords: Rinskor™ active, arylpicolinate herbicide, rice, weed species, resistant species

The poster in a PDF version is available here.

RinskorTM active: new arylpicolinate herbicide from Dow AgroSciences with utility in rice crops in Turkey, Middle East and African Countries (593)

Oleg O Shevchuk *(Dow AgroSciences Export S.A.S., Valbonne, France),* ***Natalino Dalla Valle*** *(Dow AgroSciences Italia S.R.L., Bologna, Italy),* ***Monte R. Weimer*** *(Dow AgroSciences LLC, Indianapolis, United States),* ***Richard K. Mann*** *(Dow AgroSciences LLC, Indianapolis, United States),* ***Arif Arslan*** *(Dow AgroSciences A.S., Istanbul, Turkey),* ***Amr Moussa*** *(Dow AgroSciences, Cairo, Egypt)*

Turkey, Middle East and African countries (MEAFT) represent an important rice-growing region with very diverse cropping systems and intensity of production. The common need across the region is weed control either by manual hand-weeding or use of herbicides. Weeds developing herbicide resistance in rice have increased in frequency, and the effectiveness of some herbicides and some herbicide modes of action has decreased resulting in an inability to effectively control some weeds with many currently available herbicides.
Rinskor™ active (proposed ISO name in review) is a new arylpicolinate herbicide being developed by Dow AgroSciences with utility in various rice cropping systems.
Trials conducted across MEAFT since 2010 demonstrated the broad cross-spectrum weed control activity of Rinskor in rice at rates from 10 to 30 g ai ha^{-1}. Key species controlled include: *Ammannia coccinea*; *Echinochloa* spp; *Cyperus difformis*; *Cyperus rotundus*; *Eclipta alba*; and *Heteranthera* spp. Rinskor is a arylpicolinate synthetic auxin chemotype that has a unique spectrum of activity and the ability to control ALS-, ACCase-, propanil-, and quinclorac-resistant grass and ALS-resistant sedges and broadleaf species. Rinskor exhibits excellent safety to Indica and Japonica rice varieties in direct seeded or transplanted rice. Rinskor will offer an alternative mode of action to control grass, broadleaf and sedge weeds in rice and will provide control of existing target site resistant species. The first registrations of Rinskor across MEAFT are expected in 2018-2019.
™Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow.
™Rinskor is not registered at the time of this presentation. The information presented is intended to provide technical information only and is not an offer for sale.

Keywords: Rinskor™ active, arylpicolinate herbicide, rice, weed control, herbicide resistance

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Response of seven aquatic plants to a new arylpicolinate herbicide (344)

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The herbicide 4-amino-3-chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl)-5-fluoro-pyridine-2-benzyl ester (SX-1552 or XDE-848 BE; proposed ISO common name in review) is a new arylpicolinate herbicide currently under development for weed management in rice production, aquatic weed management, and other uses. Greenhouse research was conducted to evaluate the effect of SX-1552 and SX-1552A (an acid metabolite) on seven aquatic plants: alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.], bacopa [*Bacopa caroliniana* (Walter) B.L. Rob.], fanwort (*Cabomba caroliniana* A. Gray), monoecious hydrilla (*Hydrilla verticillata* L.), parrotfeather [*Myriophyllum aquaticum* (Vell.) Verdc.], variable watermilfoil (*Myriophyllum heterophyllum* Michx.), and waterwillow (*Justicia americana* (L.) Vahl.). SX-1552 and SX-1552A, were applied to these species as an in-water, four week static exposure at rates of 0 to 81 µg/L. *Cabomba caroliniana* was not controlled by SX-1552 at the rates evaluated, in contrast to the other species tested. Dry weight EC_{50} values were 5.0 and 5.1 µg/L, respectively. These six species were less sensitive to SX-1552A with dry weight EC_{50} values of 1.6 to 77.1 µg/L. Plant control ratings also indicated that response of the six sensitive species increased from two to four weeks after treatment.

Keywords: Aquatic plant management, synthetic auxin

Session 4
WEED ECOLOGY

Weeds response to rising atmospheric CO_2 (453)

Joao P Refatti *(Federal University of Pelotas, Pelotas, Brazil),* ***Luis A Avila*** *(Federal University of Pelotas, Pelotas, Brazil),* ***Edinalvo R Camargo*** *(Federal University of Pelotas, Pelota, Brazil),* ***Eduardo A Nogueira*** *(Federal University of Pelotas, Pelotas, Brazil)*

The increasing of carbon dioxide (CO_2) in air can cause considerable changes in vegetation as well as other living organisms. In plants, the increase of atmospheric CO_2 concentration can affect the plant metabolism and growth. The objective of this study was to evaluate the effect on enhanced CO_2 concentration on physiological and morphological parameters in rice and weeds. The experiment was carried out in an Open Top Chambers, in a randomized complete block design, arranged in split-plot with factorial 2x6, with five replicates. Factor A, allocated in the main plots consisted of two concentrations of atmospheric CO_2, 400 ppm (ambient) and 700 ppm (estimated level for 2100). Factor B, in subplots, consisted of different biotypes of cultivated rice (*Oryza sativa* L.), imidazolinone herbicide resistant and susceptible red rice (*Oryza sativa* L.), barnyardgrass (*Echinochloa* spp.) and Alexandergrass (*Urochloa plantaginea*). Different atmospheric CO_2 concentrations were obtained using a system based on sensors, valves and a programmable central controller. The variables evaluated were the photosynthetic rate (A), stomatal conductance (Gs), transpiration (E), water use efficiency (WUE) and plant height. It was used an infrared gas analyzer (IRGA) LI-6400XT model configured with CO_2 concentration of 400 ppm and PAR of 1500 $\mu m^{-2} s^{-1}$. Species/biotypes tested, despite being grown in different concentrations of CO_2, when subjected to the same concentration on the IRGA, show no differences on photosynthesis, stomatal conductance, transpiration and water use efficiency. Plant hight was not affected for Alexandergrass but for the other species (barnyardgrass, alexandergrass, rice and red rice) were affected, with taller plants when grown in 700 ppm of CO_2.

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Keywords: Rice, Open Top Chambers, Carbon dioxide, Alexandergrass, Barnyardgrass

Growth response of rice and dominant weed species under elevated temperature (748)

Kee Woong Park *(Chungnam National University, Daejeon, Korea),* ***Min Yong Eom*** *(Chungnam National University, Daejeon, Korea),* ***Md. Shahidul Haque*** *(Chungnam National University, Daejeon, Korea),* ***Ok Jae Won*** *(Chungnam National University, Daejeon, Korea),* ***Tae Seon Park*** *(RDA, Wanju-gun, Korea)*

It is well known that greenhouse gases in the atmosphere cause an increase of the Earth's global temperatures. In the context of climate change, temperature is one of the most important factors affecting the rate of plant growth and development. The warmer temperatures and the potential for more frequent extreme temperature events expected with climate change will impact plant productivity. Therefore, the present study investigated the growth response of rice (*Oryza sativa*) and dominant paddy weeds under elevated temperatures. Rice and major paddy weeds (*Monochoria vaginalis, Echinochloa crus-galli* and *Ludwigia prostrata*) were grown under different temperature regimes (ambient, ambient+0.8 ˚C, ambient+1.9 ˚C and ambient+3.4 ˚C) in phytotrons. Results revealed that plant height, leaf stage, leaf area and dry weight of rice and three weed species increased with the temperature rise. Plant height and dry weight of rice and weeds were significantly increased with elevated temperatures especially at ambient+1.9 ˚C and ambient+3.4 ˚C. Among the species, *L. prostrata* showed the most increase in every growth parameter under elevated temperatures (ambient+1.9 and +3.4 ˚C). Our findings suggest that climate change in the form of instant rising of temperatures increases growth of weeds and rice in paddy fields and such elevated temperatures could further weeds' competitive advantage with concomitant negative effects on rice production.

Keywords: Climate change, rice, weeds, phytotron

The poster in a PDF version is available here.

Effect of different climatic conditions and nitrogen application on growth of *Bromus tectorum* L. (506)

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Rising atmospheric CO_2-concentration and temperature, and nitrogen pollution in the environment can affect the growth and ecology of plant species. We evaluated the growth of *Bromus tectorum* L. under different CO_2-concentrations, temperature and nitrogen levels. CO_2-concentrations [normal (400 ppm) and elevated (800 ppm)], temperature levels [normal (temperature 20/15 °C day/night) and elevated (temperature 25/20 °C day/night)], and nitrogen levels [low (0 kg/ha), medium (60 kg/ha) and high (120 kg/ha)] were randomized in four close glasshouses with controlled environment. An analysis of variance indicated that different climate conditions (CO_2-concentrations and temperature levels) had a significant effect on plant height, leaf length, leaf area, fresh weight and dry weight of *B. tectorum*. Moreover, nitrogen significantly affected leaf area and fresh weight of *B. tectorum*. The interactive effect of climatic conditions and nitrogen had a significant effect only on leaf area. Elevated CO_2-concentration and elevated CO_2-concentration + elevated temperature had increased the plant height, leaf length, leaf area, fresh weight and dry weight of *B. tectorum* over control and elevated temperature. Nitrogen application had increased the leaf area and fresh weight of *B. tectorum*. In treatments including control, elevated temperature and elevated CO_2-concentration + elevated temperature, the leaf area was significantly increased by the medium rate of applied N (60 kg/ha); however, at elevated CO_2-concentration, the leaf area was increased by both the levels of N (60 and 120 kg/ha). We concluded that increasing CO2-concentrations and temperature in the atmosphere and soaring nitrogen levels in the environment can significantly affect the weeds in terms of their growth.

Keywords: Nitrogen pollution, Climate change, CO2-concentration, *Bromus tectorum* L., Growth

Eco-physiological drivers of *Parthenium* weed invasion: an overview (519)

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Parthenium weed (*Parthenium hysterophorus* L.), a well-known noxious weed species, has invaded diverse climatic and biogeographic regimes in more than 50 countries across the continents. Efforts are under way to minimize the parthenium-induced environmental, agricultural, social, and economic issues. However, meager information regarding its invasion mechanisms and interference with ecosystem stability is available. It is hard to devise effective management strategies without understanding the invasion process. There are certain ecological and physiological cues which play important role in parthenium weed invasiveness. Strong morphological traits like vigorous growth habit, pubescent leaves, luxurious flowering, flexible rosette formation, tap root system, and abundant seed production contribute towards its invasiveness. In the meantime, the C_3/C_4 photosynthesis, thermal and photo insensitivity, enzymatic regulation, and antioxidant feedback are some key physiological interventions making parthenium a problematic weed. The morphological and physiological adaptations to a wide range of abiotic stresses also add up to its invasive power under diverse range of climatic conditions. The allelopathic potential of parthenium weed has also been well explored and declared as a possible mechanism for invasion. The importance of superior morphological and basic physiological traits in parthenium weed invasiveness is certain and well established. However, the comprehensive research is needed to determine the relative contribution of such factors towards overall invasion. The invasiveness of parthenium weed might be due to complex interactions of multiple mechanisms being operated simultaneously. Future research must be oriented to characterize and quantify the ecological, physiological, and biochemical drivers in order to draw a clear picture of parthenium weed invasion.

Keywords: Allelopathy, Biological invasion, Weed ecology

The poster in a PDF version is available here.

Eco-biology of alien invasive weed; *Rottboellia cochinchinensis* in vertisols soils of Tamil Nadu, India (473)

Chinnusamy Chinnagounder *(Tamil Nadu Agricultural University,Directorate of Crop Management, Coimbatore, India),* ***Prabhakaran Nachimuthu Krishnan*** *(Tamil Nadu Agricultural University,Directorate of Crop Management, Coimbatore, India)*

Alien invasive weed; *Rottboellia cochinchinensis* (Lour.) W.D. Clayton is native of Southern Asia and is an annual grass that can grow as tall as 3 m and propagates by seeds, which have a dormancy of 1-4 months. *Itch grass* is the most important grass weeds of rainfed or sorghum in black clay soils of Tamil Nadu. *Rottboellia cochinchinensis* is a rapidly spreading, tufted annual grass, to 3,5 m tall, with vigorous growth supported by stilt roots. Leaf blade broadly linear, up to 45 cm long and 2 cm wide, rough on both sides, sheath wide open, lower part of central nerve inflated, with bristle-like hairs along sheath. Ligule membranous and short, 1 mm long. Culms stout, occasionally branching. Inflorescence a simple raceme, spike-like, contracting at the tip, cylindrical. Raceme seems joined between spikelets. At maturity, breaks into hard cylindrical joints, falling with two attached spikelets. One spikelet sessile, oblong-elliptic, pale; the other spikelet stalked, narrowly ovate, 3-5 mm long, herbaceous, green ; pedicel shorter than internodes. Fruit a cylindrical caryopsis. *R. cochinchinensis*, a C_4 species, is prominent in open well-drained places and common on contour banks and roadsides. *R. cochinchinensis* is one of the primary colonizers of disturbed ground and is of some value for grazing. It is an extremely vigorous competitor in upland crops due to its rapid growth and spreading habit and heavy infestation can cause total crop loss. The plant reproduces entirely by seeds and can continue to flower and seed year-round when moisture conditions are favorable a single plant can bear 2.000 seeds. The weight of 1.000 seeds is 10.6 g and there are 94 seeds g^{-1}. *R. cochinchinensis* is observed to invade black soils of Tamil Nadu. It is a most problematic weed under rainfed conditions in crops like sorghum, pearl millet, pulses and cotton.

Keywords: Alien Invasive weed, Eco-biology, Vertisols soils, *Rottboellia cochinchinensis*, Problematic weed

The poster in a PDF version is available here.

Natural hybridisation between *Solanum nigrum* and invasive species *Solanum physalifolium* (345)

Josef Holec *(Czech University of Life Sciences Prague, Prague 6 – Suchdol, Czech Republic),* ***Kateřina Hamouzová*** *(Czech University of Life Sciences Prague, Prague 6 – Suchdol, Czech Republic),* ***Tereza Dobešová*** *(Czech University of Life Sciences Prague, Prague 6 – Suchdol, Czech Republic),* ***Josef Soukup*** *(Czech University of Life Sciences Prague, Prague 6 – Suchdol, Czech Republic)*

In the area of the Czech Republic *Solanum nigrum* is an important weed species, which occurs mainly on fertile soils in wide row crops such as sugar beet, maize, potatoes, but also in vegetable stands. *S. physalifolium* is a new invasive weed, which can be found in root-crops and vegetable. In the field some plants with inter-medial characteristics were detected, and they were expected to be products of hybridization between *S. physalifolium* and *S. nigrum*. Monitoring and collecting of plants took place on experimental field of CULS, where both these weed species as well as their potential hybrids can be found. Chromosomes counting in cell nucleus of hybrids, PCR – RAPD analysis and statistic evaluation was realized. Levels of agar electrophoresis were evaluated by cluster analysis, using coefficient of similarity. In total, 492 individuals were identified in the field, of which 455 belonged to *S. physalifolium*, 35 to *S. nigrum* and 2 individuals with intermedium characteristics were classified as potential hybrids. Hybrid plants are robust in growth, producing high number of flowers. They are able to produce pollen grains, but the berries are mostly sterile, young fruits do not contain any seeds and shatter soon after flowering. Karyotype analysis of 2 hybrid plants showed 48 chromosomes in cell nucleus. This is in accordance with proposed hybridization between *S. nigrum* (6n = 72) and *S. physalifolium* (2n = 24). Used primers OPB 04 and OPB 13 were able to distinguished between *S. nigrum* (4 individuals analysed) and hybrids (2 individuals) on one side and *S. physalifolium* (5 individuals) on another, while primers OPB 03 and OPB 06 distinguished all three taxa. Our results confirmed previous hypothesis about natural hybridization between *S. nigrum* and *S. physalifolium*. The frequency of this process is relatively low and hybrid plants are showing low fitness.

Keywords: Plant invasions, arable weeds, karyotype, hybrid fitness

The poster in a PDF version is available here.

Morphological response of *Solanum crinitum* in competition with invasive exotic grass in the Carajas National Forest, Brazil (561)

Rafael G Viana *(Federal Rural University of Amazon, Belém, Brazil),* ***Alexandre F Castilho*** *(VALE SA, Parauapebas, Brazil),* ***Cintia H Marega*** *(Federal Rural University of Amazon, Pparauapebas, Brazil),* ***Roberthi A F Teixeira*** *(Federal Rural University of Amazon, Parauapebas, Brazil),* ***Mailson F Oliveira*** *(Federal Rural University of Amazon, Parauapebas, Brazil),* ***Tulio W F Nunes*** *(Federal Rural University of Amazon, Parauapebas, Brazil),* ***Kaléo D Pereira*** *(Federal Rural University of Amazon, Belém, Brazil)*

The Carajás National Forest is a protected area located in the Amazon region in the southeast of Pará, Brazil. Exotic grass of the genus *Urochloa*, have become invasive with potential damage to biodiversity. The objective was to evaluate the morphological responses of *Solanum crinitum* in competition with *Urochloa brizantha*. The experiment was conduct in a greenhouse, in a randomized block design with four replications. Pots with 5 L volume were filled with soil from non-mined waste and properly fertilized. The center of the pot was seeded with *S. crinitum* species and the periphery was seeded with the exotic species *U. brizantha* at densities: 0, 1, 2, 3, 4 and 5 plants per pot. Forty days after seeding was carried out the collect of *S. crinitum* where was quantified: Shoot Dry Weight (SDW), Root Dry Weight (RDW), plant height, number of leaves (NL), stem diameter and leaf area. Mass parameters were performed after drying in a forced air circulation oven at 75 °C and 72 h. The leaf area was measured on a leaf area analyzer. Regression analysis of the data was performed. It was observed a quadratic reduction of SDW and leaf area of *Solanum crinitum* with the increase of plant density from exotic grass. The NL and stem diameter showed linear decrease with increasing plant density of exotic plant. The plant height remained almost unchanged, being possible to maintain the height of the plant in response to competition for light. The RDW showed an increase and after that a subsequent decrease with the increase in plant density of exotic grass. This demonstrates the biomass allocation as a response of the plant in competition, promoting root growth in order to favor water and nutrient absorption, which can also increase the stomatal opening and thus increase gas absorption levels, increasing photosynthetic rate.

Keywords: Native plant, Degraded recovery mining areas, Competitive potential, Invasive plants

The poster in a PDF version is available here.

Morphological response of native plant of Carajas National Forest in competition with invasive exotic grass (560)

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Mimosa acutistipula is a native plant of National Forest of Carajás, Brazil, used in recovery of degraded areas for iron mining. The recovery of mined areas in the National Forest was made with exotic grasses of the genus *Urochloa*, which has become an invasive plant. With the aim of revegetation areas with occurrence exotic grasses it is necessary to study the morphological responses of native species in competition with exotic plants. The objective was to evaluate the morphological responses of *Mimosa acutistipula* in competition with *Urochloa brizantha*. The experiment was conduct in a greenhouse, in a randomized block design with four replications. Pots with 5 L volume were filled with soil from non-mined waste and properly fertilized. In the center of the pot it was seeded *Mimosa acutistipula* species and the periphery of the vessel was seeded with exotic species *Urochloa brizantha* at densities: 0, 1, 2, 3, 4 and 5 plants per pot. Forty days after seeding was carried out the collect of the both plants where was quantified: Shoot Dry Weight (SDW), Root Dry Weight (RDW), plant height, number of leaves (NL), stem diameter, tiller (just for *U. brizabtha*) number and leaf area (cm^2). Mass parameters were performed after drying in a forced air circulation oven at 75 °C and 72 h. The leaf area was measured on a leaf area analyzer. Regression analysis of the data was performed. It was observed reductions in SDW, RDW, plant height, tillers and leaf area and increase in NL for *U. brizantha* with increase in plant density. It was not observed change of SDW, RDW, leaf area and NL in *M. acutistipula* with increase in *Urochloa brizantha* plant density.

Keywords: *Mimosa acutistipula*, Degraded recovery mining areas, Competitive potential, Invasive plants

The poster in a PDF version is available here.

Suppression of weeds with the use of winter cover crops (706)

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Our objective was to evaluate the effect of winter cover crops in the presence of weeds on spring. The crops, *Lolium multiflorum* (Italian ryegrass), *Lotus corniculatus* (birdsfoot trefoil) and *Trifolium repens* (white clover) were seeded in the fallow period of the temperate region of Southern Brazil, as well as species with differential ability on suppressing weeds. The experiment was installed in randomized blocks design with four replications. Previous to the seeding on May 2014, glyphosate was sprayed (1440 g a.e. ha^{1}) using a precision backpack sprayer pressurized by CO_2, connected to application bar equipped with four nozzles 110.015, calibrated to apply 150 L ha^{1}. Ten days later, crop seeds were broadcasted: (1) *L. multiflorum* at 25 kg of seeds ha^{1}, (2) *L. corniculatus* at 8 kg of seeds ha^{1}, (3) *T. repens* at 5 kg of seeds ha^{1} and (4) the mix of three species (25 + 8 + 5 kg of seeds ha^{1}). Seeds were not incorporated into soil. Sixty days later sowing, a phytosociological analysis was accomplished by sampling four points of 0.25 m^2 per plot (16 samples per treatments). We assessed plant density and frequency and areas were intracharacterized by diversity coefficients of Simpson and ShannonWeiner and intercharacterized by the similarity coefficient of Jaccard. The main weeds reported were *Conyza bonariensis* (hairy fleabane), *Richardia brasiliensis* (tropical Mexican clover) and *Soliva pterosperma* (lawn burweed); their occurrences were most pronounced in *L. corniculatus*, and treatments most efficient in suppressing weeds were ryegrass and the mixture of the three species. Diversity coefficients did not vary among treatments being in average 0.75 for Simpson and 2.0 for ShannonWeiner. Areas presented 83% similarity among them; thus, the different winter species did not affect flora composition at significant levels, although *L. multiflorum* showed to be the most efficient species for suppressing weeds.

Keywords: Ryegrass, conyza, herbicide, phytosociological analysis

Population dynamics of endemic and non-endemic grass and sedge species of Guana Island, British Virgin Islands (108)

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Guana Island, British Virgin Islands, is 343 hectares of tropical forest, mountains, hills, and valleys that contain more flora and fauna than any other island similar in size. However, several non-native grass species (*Digitaria* spp., *Setaria* spp., *Sporobolus* spp., etc.) have been documented on Guana Island. The introduction and competitive nature of these non-native species may result in a loss in biodiversity and the extinction of certain endemic grasses. Therefore, we conducted a systematic survey of the grasslands of Guana Island in October of 2013 to determine abundance and distribution of endemic and non-endemic grass and sedge species. A total of 59 line transects measuring 40 to 67 m (3 m apart) were run from the salt pond to White Bay beach. Grass or sedge species were identified and geo-referenced every 3 m along transects for a total of 1,087 data points. Eight grass/sedge species were identified: broadleaf panicum, Indian bluegrass, thin paspalum, goosegrass, common bermudagrass, southern sandbur, crowfootgrass, and tropical fimbry. Data points for each species were counted to determine overall abundance (%). The most abundant species was Indian bluegrass (76%), while all others constituted ≤ 10% of the total area, respectively. Indian bluegrass may have been introduced as livestock forage during the 18th century when the island produced sugar cane. Thin paspalum, although poorly distributed (4% abundance), is endemic to Guana. Coastal sandbur is indigenous to the island; however, our surveys only revealed non-endemic southern sandbur. Land use and anthropogenic activity may have created a goosegrass population (5% abundance) exclusively inhabiting a utility road traversing the area. Tropical fimbry, a sedge native to the Caribbean, had the second highest abundance. This survey may help understand the conservation significance of these species and determine strategies to enhance the survival of endemic plants and the biodiversity of the island flora.

Keywords: Biodiversity, population dynamics, spatial distribution, line transects, indigenous species

The poster in a PDF version is available here.

Changes in paddy field weeds over the last 50 years in Korea (762)

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The Rural Development Administration, Korea conducted investion of the paddy weed distribution from 1971 to 2013 in a 10-year cycle and the results has been used for the efficient management of paddy weeds. In 1971, annual weeds such as *Rotala indica, Eleocharis acicularis* f. *longiseta, Monochoria vaginalis* etc. were dominant. On the other hand, the occurrence of *Echinochloa* species was reduced, but a broadleaf weeds such as *M. vaginalis, Sagittaria pygmaea, S. trifolia* etc. were dominant in 1981. In 1991, perennial weeds such as *Eleocharis kuroguwai*, *S. pygmaea*, *S. trifolia* were dominant rather than annual weeds. In 2000, *M. vaginalis* was the most common, followed by *E. kuroguwai*, *E. crus-galli*, and *S. trifolia*. Herbicide-resistant *E. crus-galli* and *M. vaginalis* were the most dominant, followed by *E. kuroguwai*, *Scirpus juncoides*, and *S. trifolia* in 2013. It has been predicted that the occurrence of *Echinochloa* species will be continuously increasing and perennial weeds will be more common than annual ones in the near future. The occurrence of herbicide-resistant weeds and exotic weeds will be increasing due to global warming and changes in agricultural patterns.

Keywords: *Echinochloa* spp., Herbicide-resistant weeds, Paddy Field Weeds, Perennial weeds

Does the presence or absence of native relatives in the invaded area determine the rate of spread of alien plant species? (658)

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Invasive species can damage ecosystems and the ecological services we derive from them. To explain why some plant species are successful invaders while others are not, we tested a prediction based on Darwin´s naturalization hypothesis, which poses that introduced species with no close native relatives at genus level will spread to a greater number of localities than species with close relatives in the introduced area. We compared the spread rate of introduced species with and without native relatives using herbarium records of 286 exotic weed species. As biological attributes may also determine spread rates, we included them in the analysis after we tested the naturalization hypothesis. We modelled the number of occupied locations as a linear function of residence time. Residuals of this model were used to classify species in two groups, those having more or less locations than expected. These sets were again sub-classified in two subgroups: species with and without relatives at the genus level. We compared the number of relatives between the latter subgroups with a chi squared test. Correlation between residuals and number of relatives was assessed with a Spearman test. We used a decision tree to explain residence time as function of biological attributes. Residence time explains 47.6 % for of the variation in the occupied localities for herbs and subshurbs**.** The spread rates of the introduced species were not associated with the presence/absence or number of close relatives in the invaded area. A decision tree showed that number of localities occupied by the 115 species overdispersed 51.30% was dependent on dispersal syndrome: Dicots, growth form, dispersion syndrome, growth form, life form and type fruit. The 107 species underdispersed 93.46 % showed the syndrome**:** herbs, type fruit, use, dispersion syndrome and growth form. However, these syndroms have not yet diagnostic value for risk analysis.

Keywords: Exotic, native, spread rate, life form attributes, weeds

The poster in a PDF version is available here.

Occurrence of perennial arable weeds in the Czech Republic with respect to the farming systems (684)

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Josef Holec *(Czech University of Life Sciences Prague, Prague, Czech Republic)*

Perennial species with predominantly vegetative form of reproduction are usually difficult to control weeds. Unlike annual species, perennial weeds can occur in the stands of all types of crops. Once established in the field we can expect their occurrence every year. Our three years survey was conducted at conventional and organic farms in 2006-2008. Totally 290 phytocoenological relevés were taken in winter cereals, spring cereals and wide-row spring crops. In each sampled field, one relevé of standard size of 100 m^2 was recorded in the central part. The species coverage was estimated using nine-degree Braun-Blanquet cover-abundance scale.In conventional farming, 121 species were found, of which 15 were perennials, and 162 species in organic farming with 28 perennials. Three species dominated in both types of farming: *Cirsium arvense* occurred in 54 % of all relevés (in 39 % of conventional and 72% of organic), *Elytrigia repens* in 42 % of relevés (33 % resp. 52 %) and *Convolvulus arvensis* in 31 % of relevés (23 % resp. 40 %). *C. arvense* and *E. repens* are not only the most common ones, but also the most competitive and thus noxious perennial weeds in CZ.Other perennials occurring in both farming types were *Mentha arvensis*, *Equisetum arvense*, *Persicaria amphibia*, *Lathyrus tuberosus*, *Sonchus arvensis, Rorippa sylvestris* and some others. *Aegopodium podagraria* occurred only in conventional farming. Among species observed only in organic farming there were found *Agrostis stolonifera*, *Stachys palustris*, *Holcus mollis*, *Tussilago farfara*, *Ranunculus repens*, *Potentila anserina* and some others.Organic farming system showed higher number of perennial weed species and also higher frequency of their occurrence in the fields.

Keywords: Perennial weeds, Czech Republic, conventional farming, organic farming, vegetative reproduction

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Are field edge common ragweed populations higher if they are closer to roadside populations? (227)

Marie-Josée Simard *(Agriculture and Agri-Food Canada, Saint-Jean-sur-Richelieu, Canada)*

Ambrosia artemisiifolia (common ragweed) is abundant along roadsides in southern Québec (Canada). Densities along rural roads are generally higher than along field edges or in fields (after weed control). Field edges are not intensively managed and could be invaded by roadside *Ambrosia a*. populations. We therefore hypothesized that field edges that are adjacent and parallel to roadsides would have more *Ambrosia a*. plants than field edges that are perpendicular to roadsides or edges surrounding more isolated fields. To test our hypothesis, 25 pairs of adjacent (AD) and isolated (IS) fields, located in southern Québec, were selected. Field pairs had to be on the same farm and as similar as possible. AD fields had to be adjacent to a paved public road and IS fields had to be accessible only by farm roads and surrounded by other fields or forested land. For each field pair, the density of *Ambrosia a*. was evaluated in quadrats located every 20 m along 1-the roadside section bordering the adjacent field (RO), 2-the edge of the adjacent field parallel to the roadside (AD-pa), 3-the edge of the adjacent field perpendicular to the roadside (AD-pe), 3-a field edge of the isolated field (IS). Results indicate that *Ambrosia a*. densities were higher along roadsides than along all field edges, as expected. Densities in field edges adjacent to roadsides were not higher than those in perpendicular edges. Although densities were lower in isolated field edges, values were not statistically different from other field edges. *Ambrosia artemisiifolia* densities along field edges are probably modulated more by past and present weed control strategies in fields, or field edge characteristics, than the presence of bordering roadside populations.

Keywords: Weed distribution, weed density, weed survey

The poster in a PDF version is available here.

Long – term changes in the weed communities on arable land caused by herbicide use (356)

Markéta Mayerová *(Crop Research Institute; Czech University of Life Sciences Prague, Prague, Czech Republic),* ***Josef Soukup*** *(Czech University of Life Sciences Prague, Prague, Czech Republic)*

Weed communities on arable land have been partly influenced by ecological site conditions, but mainly by farming practices. The most important factors affecting the weed communities is the herbicides use. The aim of this study was to evaluate the changes in diversity of weed communities in long-term field trial and determine weed population shifts caused by long – term application of herbicides.The field experiments were established in 1972 at two research stations in the Czech Republic – Hnevceves and Pernolec. Two crop rotations with different share of cereals (50 and 75 %) and three herbicide treatments were used: 1. Untreated, 2. Synthetic auxines (MCPA, 2,4-D), 3. Targeted herbicide combinations (sulfonylureas, triazines, ureas, bentazone, MCPA). Continuously, now after more than 40 years, occurrence of weed species and population have been assessed and statistically evaluated by multivariate analysis, and diversity indexes were calculated.The redundancy analysis revealed significant changes of weed composition influenced by time (14.5%), type of crop (12%) and herbicide application (4%). Some weed species receded or became extinct in Pernolec in all variants – e.g. *Myosotis arvensis, Raphanus raphanistrum, Scleranthus annuus* and *Erophila verna;* on the other hand, the abundance of some weed species such as *Tripleuspermum inodorum, Centaurea cyanus, Galeopsis tetrahit, Veronica ssp.* has increased on untreated plots. No significant differences affected by treatment were detected in population of *Apera spica-venti, Chenopodium album, Galium aparine, Arabidopsis thaliana* and *Stellaria media*. The highest species diversity was found in Pernolec on untreated control, the lowest species diversity in Hnevceves on treated plots. In 2014 and 2015 Shannon´s H´ and Shannon´s E´ significantly decreased in Pernolec in treated variants compared with untreated control (average decrease of 40% and 25% respectively). Due to weed management the changes in the weed populations were confirmed over time.

Keywords: Diversity, herbicides, changes, weed communities

The poster in a PDF version is available here.

Weed species composition changes through time: abandoned arable land in a dry region of central Europe (439)

Martina Sojneková *(Mendel University in Brno, Brno, Czech Republic)*

Abandoned fields are a common aspect of contemporary countryside, but it is still unclear, whether the spontaneous succession is a suitable method for restoration of ex-arable land or not.The aim of the study was to describe changes in weed species composition, richness and diversity on abandoned fields in the warm and dry area of the Southern Czech Republic. Vegetation was sampled in 62 phytosociological relevés during the years 2007–2009 for which the time since the abandonment (4–19 years) was determined from historical aerial photographs. These permanent plots were resampled in 2015 after 6–8 years of succession. Characteristics of vegetation and environment were compared. The succession age was supposed to be one of the most important factors influencing plant communities.Annual weeds were replaced by perennial dry grassland in less than four years after abandonment. The number of archaeophytes, including common ruderal species, decreased, while the number of neophytes did not. There was no significant change recorded between the old fields regarding the number of annuals and biennials. The spread of shrubs was limited by drought and also by nature conservation management.

Keywords: Czech Republic, Ex-arable land, Succession

Changes in weed flora in cereal and willow crops established after termination of a short- rotation willow cultivation (300)

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To obtain a better understanding of factors determining floristic diversity in the agricultural landscape, the weed flora in cereal and willow cultivations established on a site formerly grown with willows was monitored. The questions were: (1) Is species richness and composition of the weed flora affected by the cropping system? (2) Are there temporal changes in weed flora species richness and composition within and between cropping systems? The field experiment was established after 25-years of willow cultivation in Central Sweden. Taxonomic floristic inventory by means of Braun-Blanquet approach was used to assess the cover-abundance of a weed flora in both cropping systems. The total weed species richness, richness of weed species shared in and specific for a given cropping system, differences in life-cycle strategies of weed species, Jaccard and Sørensen similarity coefficient was assessed for both cropping systems. Non-metric Multi-Dimensional Scaling and Redundancy Analysis were employed to investigate differences in weed flora species composition and distribution pattern in relation to the cropping system, season and environmental conditions as inferred from Ellenberg values. The results confirmed that the weed species richness and percentage of weeds in different life cycle categories (i.e., annuals, biennials or perennials) varied between crops and seasons. The richness of cereal- or willow-specific weeds increased and decreased respectively during seasons. Compositional changes and differences in distribution pattern of weed flora may be explained by crop, season, and/or environmental conditions inferred from Ellenberg values. Higher species richness and more complex composition of weed assemblages in willow cultivation compared with cereals confirms that short rotation forests with willow increase floristic diversity in agroecosystem thus may contribute to biodiversity preservation on landscape scale. Moreover, understanding how weed flora assemble under different management regimes is essential in compromising floristic diversity preservation with weed control for current and future sustainable agriculture.

Keywords: Biodiversity, short rotation forestry, species richness, weed assemblage, weed-crop interaction

The poster in a PDF version is available here.

Spatial and temporal changes on weed flora and Orobanche cumana abundance in sunflower fields: An impact assessment of environmental, management and site factors (378)

Petros Vahamidis *(Agricultural University of Athens, Athens, Greece),* ***Garifallia Economou*** *(Agricultural Univeristy of Athens, Athens, Greece),* ***Dionyssia Lyra*** *(International Center for Biosaline Agriculture, Dubai, United Arab Emirates),* ***Dionissios Kalivas*** *(Agricultural Univeristy of Athens, Athens, Greece),* ***Elissavet Gavriil*** *(Agricultural Univeristy of Athens, Athens, Greece)*

Weeds and especially Orobanche cumana Wallr. consist a major problem in sunflower (Helianthus annuus L.) production. The developments of herbicide-resistant crops (HRCs) provided additional options for post weed management and hence the HRCs are dominating agricultural production systems of sunflower in Greece. ExpressSun® and especially Clearfield® are the main technologies in sunflower production in recent years. The aims of this study were to identify, a) the changes in weed species composition in sunflower under the repeated use of the aforementioned technologies during the past four growing seasons and b) the environmental and farming factors which determine the weed species composition. During two cultivation periods July 2012 and July 2015 extensive surveys were conducted in 27 and 50 sunflower fields, respectively, across Evros region of north Greece. In each field we sampled 10 quadrats of 1 m^2 following a Z pattern. Weed species in each quadrat were counted and their Abundance Index (AI) was determined using three quantitative measures (frequency, uniformity and mean field density). Canonical Correspondence Analysis (CCA) served to quantify the relative contribution of several variables of climate, site and crop management to weed species composition. Considerable differences in weed species composition of sunflower fields were mainly associated with irrigation, temperature and weed management technology, especially in 2015. Based on AI the most important weed species during 2012 surveys were in decreasing order; Solanum nigrum L., Chenopodium album L. Xanthium strumarium L. and Sorghum halepense L. and during 2015; C. album, Echinochloa crus-galli (L.) Beauv., S. halepense and Xanthium strumarium. O. cumana has been occurred in very low infestation level confined to the margins of the fields during both surveyed periods, showing the efficient control under the application of both systems ExpressSun® and Clearfield®. According to CCA O. cumana was favored by high soil organic content and dry conditions.

Keywords: Weed flora, Orobanche cumana, spatio temporal changes

The poster in a PDF version is available here.

Changes in the community of weeds associated with sugar and current distribution in Cuba (530)

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The weed management is only effective if the predominant species present and associated with the cultivation are known in each field. However, despite studies conducted weed identification, it is necessary to update them regularly; since the use of certain control methods produce variations in emergency and composition of the weed species from one year to another. Considering the above, the aim of present work was developed in order to determine changes in the weed community associated with sugarcane and current distribution in Cuba. For its execution were taken over a period of eight years, data from surveys conducted to identify weeds wide country Integrated Control Weed Service (ICWS); which they were performed by the visual method, scouring the countryside for their diagonals. It was determined for each species distribution in the field through the relative frequency subsequently classified by value, in the categories of: accidental (less than 25%); rare (25-49%); moderately frequent (50 to 75%) and very frequent (more than 75%). The distribution of the most common species was performed with the help of Geographic Information System (GIS) MapInfo. Identified 15 families, 29 genera and 35 species, of which three were grouped into the category of fairly frequent, three in the rare and 29 in accidental. It is concluded that in the period there were changes in the weed community associated with the crop, with the addition of three new species (*Sorghum arundinaceum*) *Leucaena leucocephala* (Lam.) de Wit. and *Phyllanthus niruri* L.; and the significant reduction in two of them (*Kallstroemia maxima* (L.) T. et G and *Argemone mexicana* L.).

Keywords: Community weed, frequency, distribution, sugarcane

Role of herbicides and cropping systems on weed flora shift in wheat in India during the last quarter century (546)

Samunder Singh *(CCS Haryana Agricultural University, Hisar, India)*

Wheat is the most important cereal crop of India grown in 31.19 million hectares producing 95.85 million tons grains with an average productivity of 3.08 t ha^{-1}. North India is the grain bowl of wheat contributing significantly to the central pool with >4 t ha^{-1} yields. Weeds are one of the major constraints in realizing the potential of high yielding varieties with yield penalty ranging from 10-80% depending upon the adopted agronomic practices and weed infestation. During the last quarter century there has been a significant change in the agronomic practices leading to enlarged weed problems in spite of many fold increase in the use of herbicides for the management of problematic weed species and even resulting in the evolution of resistant weed species. Weed surveys were conducted from 1990 to 2015 using qualitative method of weeds scouting, where sampling were made every 10 km on weed infestation and their intensity under different cropping systems *viz*. rice-wheat, cotton-wheat and millet-wheat. Weed dynamism significantly altered weed flora composition under different cropping systems, soil types, fertility status, rainfall amount and underground water quality; though grassy weeds are still a major challenge for efficient weed management. Reduced control of some weed species was observed off late and *Phalaris minor* has become the most ubiquitous weed resistant to herbicides of several sites of action posing a major threat to wheat production. Several weed species that were minor have become troublesome due to unaltered cropping system and repeat application of similar sites of action herbicides, complicating their management. The present paper will discuss shift in weed flora as a result of agronomic practices and herbicide use pattern to meet the challenges for sustainable weed management by adopting a suitable management strategy and to lower the risk of herbicide failures due to evolution of resistant weed species.

Keywords: Weed flora shift, Herbicide resistance, Efficient weed management, Agronomic practices, Climatic factors

Weed communities changes in wheat crops resulting from management improvements in the rolling Pampa, Argentina (559)

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Species diversity and composition of weed communities shift in response to technological transformations in agriculture. In the Pampas of Argentina, agricultural systems have been profoundly transformed since the 1990s, especially due to the rapid adoption of no-tillage and genetically modified soybean varieties. These changes have also promoted modifications in wheat cropping systems, particularly due to double cropping with soybean. The objective of this research was to characterize the changes in the weed communities of wheat crops after recent transformations in cropping systems in the Pampa. Study of changes in species diversity and compositions was based on three sets of weed surveys carried out in 1996-1997, 2003-2004, and 2009-2010. Mean species richness decreased during the study period ($S_{1996-1997}$= 13, Standard Error of mean (SEM)= 0.8, $S2_{003-2004}$= 7, SEM= 0.6 and $S_{2009-2010}$= 4, SEM= 0.4). Numbers of abundant species (exponential Shannon index: $eH'_{1996-1997}$= 9, SEM= 0.7, $eH'_{2003-2004}$= 4, SEM= 0.4, and $eH'_{2009-2010}$= 3, SEM= 0.2) and dominant species (reciprocal Simpson index: $1/D_{1996-1997}$= 7, SEM= 0.6, $1/D_{2003-2004}$= 3, SEM= 0.2, and $1/D_{2009-2010}$= 2, SEM= 0.2) also decreased. Floristic composition tended to be more similar during the study period, particularly due to the loss of rare species. Mean wheat yields increased about 45% during the period (1991-1995: 2973 kg ha-1, SEM= 91.2; 2006-2009: 4291 kg ha-1 SEM= 100.7). While no-tillage was used to sow only 7% of wheat crops in 1996-1997, all crops were sown with this practice in the remaining two surveys. No-tillage allowed the earlier sowing wheat varieties with longer cycles, whose length increased in about four weeks. Weed control was almost exclusively based on a single post-emergent herbicide formulation (Dicamba+Metsulphuron Methil A), while glyphosate applications in fallows began since no-tillage adoption. This research contributes to understand the changes in weed community assembly due to rapid technological transformations in agricultural systems.

Keywords: Agricultural intensification, Community assembly, Crop management, Species diversity, Weed shift

The successional vegetation sites of selected spoil heaps in North Bohemia (Czech Republic, Central Europe) (785)

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The North Bohemia (Czech Republic, Central Europe) is a region affected by surface brown coal mining. The issue of biodiversity in post-mining areas has been gradually attracting the public attention which resulted in the need of biodiversity monitoring. The aim of the study was to compare the diversity of terrestrial plants communities on sites at different stages of succession on selected spoil heaps in North Bohemia: Střimice (early stage, 4–10 years), Radovesice (middle stage, 11–25 years) and Horní Jiřetín (late stage, 26–40 years). The research question was if there is a difference in a species richness and evenness between individual spoil heap successional stages. The vegetation was evaluated by methods of Central European geobotanical school using the Braun-Blanquet scale of abundance and dominance. Statistical analysis was performed by generalized linear model (GLM) with negative binomial distribution. A total number of 68 taxa from 21 families were found on selected spoil heaps. The species composition of individual locations was similar with overlaps in species occurrence. The species from *Asteraceae*, *Fabaceae* and *Poaceae* families occurred predominantly. Mainly biennial and perennial species were found such as an expansive grass *Calamagrostis epigejos* and *Cirsium arvense* which strongly dominated in all communities. The highest species richness was found at the Střimická dump, which corresponds with its early successional stage; other (older) sites were overgrown by self-seeding shrubs and trees. Any significant difference in species richness between middle and latest successional stage has not been confirmed. The results confirm the dependence of species composition on successional age, continuous loss of herbaceous annual species and a need of rational vegetation management on spoil heaps.

Keywords: Plant species composition, post-mining areas, spontaneous succession, biodiversity, successional stages

The poster in a PDF version is available here.

How the weed communities are built under the pressure of a barley cultivation from a field scale perspective (807)

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The way in which weed communities are formed through biotic and abiotic filters, along with their alterations within time and space, greatly affects the sustainable management in agroecosystems. Taking into consideration that barley is a highly competitive crop, we decided to study the occurrence of weeds in a barley field for three consecutive years, 2012-2014. The experiment was carried out in a field (0.1 ha), which was cultivated with brewery barley and located in AUA's experimental station in Spata. The field was divided in 48 sampling units of $1m^2$ and was free of any herbicide applications. The field margin was an uncultivated zone for a long time, occupied by weed populations of varied species in high densities. During each growing period records of the density and frequency of weeds were logged over the course of 15 days, for five months. Moreover meteorological data were taken into account such as total precipitation and mean temperature. The Inverse Distance Weighting spatial interpolation method was applied and weed density maps for each sampling period for the three years were created. The weed population density varied between the three subsequent years, although their spatial-temporal distribution revealed the same pattern. Throughout the three years of the experiment the 5 most important weeds that successfully surpassed the field margins and were occurred within the barley field were Matricaria chamomilla L., *Malva sylvestris* L., *Avena sterilis* L., *Chrysanthemum coronarium* L. and *Sinapis arvensis* L. The quite dissimilar climatic conditions during the three cultivated periods, had as a result a differentiation in the rank of weed abundance. The fact that the weed population showed a permanent increased spatial appearance along the part of the field neighbouring to the uncultivated area, indicates that certain crops could actually act as ecological filters for the weed acclimation and dispersal.

Keywords: Spatio temporal weed appearance, barley, weed mapping

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Session 5
CROP-WEED INTERACTIONS

Morning glory interference in corn (820)

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Zea mays L. (corn) is currently the third cereal in the world in terms of production. Direct and indirect interferences from weeds are an essential yield-reducing factor in corn, and one of the most important weed genera in corn is *Ipomoea* sp.. Species of this weed compete for water, light, nutrients and space. Significant losses in productivity and quality are frequently experienced, as well as difficulties in harvest due to the climbing habit of these plants. The current study aimed to evaluate the effects of direct interference of *Ipomoea hederifolia* L. (morning glory) on corn growth and yield. As experimental units cement boxes with 125 liters capacity (0.25 m^2) were used. The treatments were: (I) *I. hederifolia* monoculture; (II) corn monoculture; (III) corn with *I. hederifolia* intertwined, but in separate boxes; (IV) corn with *I. hederifolia* intertwined in connected boxes; and (V) corn in coexistence with *I. hederifolia* in connected boxes but without allowing the weed to intertwine. A completely randomized design with four replications was used. At the end of the corn cycle, 150 days after emergence, height, stem diameter, and yield were evaluated in corn. Foliar area, stem and leave biomass dry weight were obtained from *I. hederifolia* plants. Two representative plants of each species were evaluated per box. The data were submitted to analysis of variance, followed by F-test and comparison of means using the Tukey test at 5% probability. Significant differences were not found in corn height and diameter. However, the presence of *I. hederifolia* coexisting with corn in separate boxes reduced corn productivity by 52%. For *I. hederifolia* no differences in foliar area or leave and stem biomass dry weights were observed among the treatments. We conclude that the presence of *I. hederifolia* can significantly affect the growth and yield of corn.

Keywords: *Ipomoea hederifolia*, Zea mays, competition, weed

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Above- and below-ground interference of corn with soybean cultivars (373)

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Plants compete for resources below and above the soil surface. However, the intensity of competition varies according to the species in coexistence. In the early vegetative phase, competition for soil resources is reported to be more important than that for solar radiation, thus favoring species with greater root surface area. Later, as the plant canopy closes, taller species with greater total leaf area are favored by light competition. In soybean – corn rotation systems in Brazil, soybean yields suffer from competition by corn plants that spontaneously emerge from seeds left in the field in the previous season. The objective of this study was to investigate the separation of above- and below-ground competition between soybean cultivars and corn. A greenhouse study was conducted at the Federal University of Pelotas, Brazil, in 2014/2015. Pots were arranged in a split-plot design, with four replications. The main plot consisted of two soybean cultivars (TEC 5718IPRO and TEC 6029IPRO) in combination with corn as the main factor (8 plants pot^{-1}) and four competition conditions as sub-factor (below- and above-ground, below-ground only, above-ground only and no competition). Plant height, stem/culm diameter, leaf area, shoot and root dry mass and chlorophyll index were recorded in soybean and corn. Competition for below-ground resources was the most critical aspect of interference among corn and soybean cultivars. Soybean cultivar TEC 5718IPRO, with short plant height and determinate growth habit, invested more in root development, specific leaf area and leaf area ratio in competition with corn. Corn grown with soybeans cultivars (below-and above ground and below-ground only), presents higher shoot and root dry mass, leaf area and chlorophyll index compared to corn grown alone. Soybean cultivars have different plant characteristics that allow them to show different competitive abilities. However, corn is a superior competitor causing soybean yield losses when grown together.

Keywords: Competition, shoot dry mass, genetically modified corn, solar radiation, soil resources

The poster in a PDF version is available here.

Effect of weedy rice with different densities on yield of cultivated rice and relevant physiological mechanisms (190)

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With the extension of labor-saving cultivation modes, weedy rice (*Oryza sativa* f. spontanea) has become one of the major malignant gramineous weeds in rice Weedy rice can inhibit the growth and development of cultivated rice and reduce crop yields. Weedy rice JS-Y1 and rice cultivar Nanjing 44 were used in a field experiment to investigate the effect of different densities (0, 4, 8, 12, 16 plant m^{-2}) of weedy rice on photosynthetic characteristics, chlorophyll fluorescence parameters, light transmission rate, lipids peroxidation and defensive enzyme activities and yield components of cultivated rice. The results showed that the yield of cultivated rice significantly decreased by 17%, 43%, 67% and 83% respectively at 4, 8, 12 and 16 plants m^{-2} weedy rice densities compared with the weed-free control. Weed-induced yield reductions were largely due to the decrease in the number of effective panicles, number of grains per panicle, grain setting rate and 1000-grain weight. From the elongating stage of cultivated rice, the malondiadehyde (MDA) content of cultivated rice leaves increased significantly under the higher weedy rice densities (8,12 and 16 plants m^{-2}). This could imply that the competition from the weedy rice could interfere indirectly with the normal photosynthetic function of cultivated rice. The catalase and peroxidase of cultivated rice leaves decreased markedly in the grain filling stage. These observations indicate that competition caused disorders in the photosynthesis and metabolism of cultivated rice because of shading or/and allelopathy. Light transmission rate, chlorophyll content, photosynthetic rate and PSII actual quantum efficiency all decreased along with increased weedy rice density. The competition-induced decreases in light transmission rate and photosynthetic functions of cultivated rice, can be considered the key reason for rice production decreases by weedy rice. The possibility of inhibition of rice metabolism through allelopathic chemicals from weedy rice cannot be excluded.

Keywords: Weedy rice, cultivated rice, competition, physiological ecology

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Changes in weed species spectrum in sugar beet (302)

Jan Winkler *(Mendel University, Brno, Czech Republic),* ***Svetlana Chovancova*** *(Mendel University, Brno, Czech Republic)*

Studies on the evaluation of weed species spectrum in sugarbeet were conducted in 1997, 2000, and 2014, in Olomouc-Holice and Velky Tynec (Olomouc region), Czech Republic. The altitude of the experimental sites ranges from 205-240 m amsl. The long-term average annual precipitation of the sites is 517 mm and average temperature is 9.1 C. Phytocoenological relevés (12 m^2 in size) were used to evaluate the weed species spectrum recorded during August of each study year. One phytocoenological relevés corresponded to 2.6 hectares on average. A total of 33 phytocoenological relevés were recorded in 1997 (plot size – 86 ha), 15 relevés in 2000 (plot size – 40 ha), and 25 relevés in 2014 (plot size – 65 ha). Phytocoenological relevés were evaluated using Canonical Correspondence Analysis (CCA). A total of 69 weed species was observed in the three study years. Dominant weed species identified include *Cirsium arvense, Elytrigia repens, Chenopodium album, Polygonum aviculare,* and *Tripleurospermum inodorum* in 1997; *Amaranthus retroflexus, Brassica napus subsp. napus, Chenopodium pedunculare,* and *Chenopodium strictum* in 2000; *Abutilon theophrasti, Amaranthus powelli, Atriplex patula, Atriplex sagittata, Beta vulgaris, Panicum miliaceum,* and *Setaria pumila* in 2014. The results show that some species have disappeared while others have increased their abundance within the study period (1997-2014). A significant increase of alien invasive species from late-spring species group was seen in the last year of observation. The differences in species spectrum between years are likely caused by weather conditions, choice of herbicides and their efficacy, crop rotation, and others. These factors continue to influence changes to weed species composition.

Keywords: Phytocoenology relevé, weeds, sugar beet

The poster in a PDF version is available here.

Chemical control effects on maize – weed interactions: competition under different nitrogen sources (61)

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Crop-weed interactions are usually driven by competition for resources. Maize is a strong competitor, but weeds compete stronger, especially when herbicides are not properly applied. The aim of this investigation was to test the effectiveness of pre- and post-emergence chemical weed control options and to compare the growth and development of maize crop in response to a standard and a novel form of N fertilizer. The investigations were conducted during 2014-2015. The experiment was organised as a split-plot design with two factors (nitrogen form and herbicide treatment) and four replications. Maize hybrid ZPSC 388 was sown in the second part of April. Nitrogen fertilizer was applied in two forms: standard urea and slow release urea with urease inhibitor. Both forms were applied at the five-leaf stage of maize. Herbicide mix for grasses and broadleaf weeds were applied pre-emergence (*S*-metolachlor 960 g ha^{-1} + mesotrione 120 g ha^{-1}) and post-emergence (nicosulfuron 40 g ha^{-1} + mesotrione 120 g ha^{-1}) using a hand-held sprayer calibrated to deliver 200 Lha^{-1} at 300 kPa (3 bar) with a flat-fan nozzle (Teejet, 1.4 mm E 04-80). An untreated control was also included. Three weeks after herbicide application, weed dry biomass was estimated from 1 m^2 quadrats and efficacy was calculated. Further, leaf chlorophyll content, dry biomass and grain yield were determined in the maize crop. Results showed that the post-emergence herbicide treatment was more effective in weed control (95% control) than the pre-emergence treatment (84%), especially in 2014. Herbicide application, especially post-emergence, contributes to maize growth with increasing chlorophyll content and dry biomass. Overall, post-emergence application of nicosulfuron at 40 g ha^{-1} + mesotrione at 120 g ha^{-1} along with the slow-release formulation of urea was found to be the best treatment combination for achieving effective weed control and protecting maize grain yields.

Keywords: Weeds, maize, competition, nitrogen sources

The poster in a PDF version is available here.

They stand among equals: competitive ability of new biotype of weedy rice (*Oryza sativa* L.) with cultivated rice var. MR220 in Malaysia (700)

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In 2005, weedy rice in Malaysia was first observed to mimic cultivated rice. In general, weedy rice in Malaysia was taller than any cultivated rice and it was easy to be identified. However, this new biotype of weedy rice (NBWR) stands as tall as any cultivated rice, such as cultivars MR220 and MR219, with various degrees in shattering capability and seed morphological characteristics. This mimicry may evolve from spontaneous hybridization between weedy and cultivated rice, relics of abandoned cultivars, and/or from seed stock contamination. The objective of this study was to evaluate NBWR competitiveness and its potential threat to Malaysia rice agro-ecosystems. A replacement series study was conducted to evaluate the interference interaction between NBWR and cultivated rice *var.* MR220. Both NBWR and MR220 were planted in various monoculture densities (1, 3, 6, 9 and 12 plants/pot) and in mixture ratio of 3:9, 6:6 and 9:3 plants/pot under greenhouse conditions to assess changes in number of reproductive tiller and yield per plant caused by the treatments. Production of tillers for both types was significantly reduced by the increment of densities. However, inter- and intra-specific competition showed no significant effect to MR220 yield within experimental densities. In contrast, NBWR displayed significant yield decrement against higher densities especially in the presence of MR220. This suggested that the current strain of NBWR has a weak competitive capability against MR220 and may cause no direct interference to rice production. Despite a weak infestation status, the existence of NBWR in Malaysia requires extensive monitoring to prevent the development of more competitive NBWR genotypes.

Keywords: Weedy rice, new biotype, competition, evolution

The poster in a PDF version is available here.

Effects of forage crop mixtures on the abundance and functional composition of weed communities (249)

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Data and theory suggest that diverse plant communities can be more competitive with weedy invaders than monocultures. Experiments that test whether diversity can be used to manage weeds in agronomic systems are limited, particularly in annual forage and cover crop systems. We conducted a field experiment in which monocultures and mixtures of annual forage crops, intended to fill three seasonal “gaps” in the northern temperate forage production period, were assessed for their impact on the abundance and functional composition of weeds emerging from the natural soil seed bank. Weed community functional composition (e.g., broadleaf, grass, and legume) and abundance was quantified at peak biomass in spring-, summer-, and fall-available mixtures and component monocultures. Data were analyzed with ANOVA. Results of the analyses indicate that forage crop mixtures are not consistently more weed-suppressive compared to the most competitive crop grown in monoculture; however, patterns of suppression depended to some extent on when the mixture is planted (fall versus spring) and the specific composition of the mixture.

Keywords: Competition, Community assembly, Diversity

Rice and late water grass competition influenced by elevated temperature (266)

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This study was conducted to investigate the effects of elevated air temperature on competition between rice (*Oryza sativa*) and late water grass (*Echinochloa oryzicola*). Rice and late water grass were planted separately and in combination to achieve a plant density of 30 hills m^{-2} for rice, and 80 plants m^{-2} for late water grass. The three treatments (rice only, late water grass only, and rice and late water grass in combination) were arranged in a randomized complete block design with three replicates. Plants were grown in four glasshouses programmed at different temperature schemes; ambient, ambient +1.5 ˚C, ambient +3.0 ˚C, and ambient +5.0 ˚C. Plant height, leaf stage, leaf area, number of tillers, canopy light penetration, chlorophyll content, and photosynthetic rate were assessed throughout the growing season. Results showed that leaf area and number of tillers of rice were significantly reduced due to competition from late water grass, indicating that the interference of late water grass can cause rice yield loss. The rate of leaf area development and tiller production decreased more by the interaction of late water grass interference and intensity of temperature rise compared to ambient temperature. Further research is ongoing to model the competitive effects of late water grass on rice yield under elevated air temperature.

Acknowledgments
This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ01052602)" Rural Development Administration, Republic of Korea.

Keywords: Crop-weed interaction, temperature rise, competition, late water grass, rice

Critical period for weed control in spring-maize (*Zea mays* L.) in Gansu Province (123)

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Spring maize is gaining importance in Northwest China, including Gansu Province. Weeds are a major constraint to maize production. Field studies were conducted in 2013 and 2014 to determine critical period for weed control (CPWC) in spring maize in Jingchuan and Liangzhou, two representative regions of the Gansu province. Two types of weed removal treatments were studied. The first was intended to determine the beginning of the critical period of weed removal, and the second was to determine the end of the critical period. Natural populations of mixed weed species were allowed to interfere with maize. The predominant weed species were common lambsquarters (*chenopodium album* L.), green bristlegrass (*Setaria viridis* (L.) Beauv.), barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), redroot amaranth (*Amaranthus retroflexus* L.), field sowthistle (*Sonchus brachyotus* DC.), ivy glorybind (*Calystegia hederacea* Wall.), common cirsium (*Cirsium segetum* Bge.), and shepherds purse (*Capsella bursa-pastoris* Medic.). The CPWC in maize based on a 5% acceptable yield loss was calculated by fitting logistic and Gompertz equations to relative yield data. The CPWC in spring maize was determined to be from 16 to 24 days after planting (DAP) in Jingchuan region and from 20 to 53 DAP in Liangzhou region. Thus, results suggest that weed control for spring maize in these two regions should include pre-emergence options.

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Keywords: Spring-maize, weed control, critical period

The poster in a PDF version is available here.

The critical period for weed control (CPWC) in potato (77)

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Potato (*Solanum tuberosum* L.) is grown over a vast area spanning from latitudes 65° in the Northern Hemisphere to 50° in the Southern Hemisphere. Globally, it is the fourth largest consumed plant after corn, rice and wheat. Potatoes have long been playing an important role in the fight against malnutrition and starvation. Therefore, securing potato production and yields are essential internationally. Weeds are a major constraint in potato production. Understanding the critical period for weed control (CPWC) can be a tool for effective weed control and reducing the impacts of weeds. Field experiments were conducted during 2012 and 2013 field seasons in Kayseri, Turkey to assess the CPWC for potato. A four parameter log-logistic model was used to analyse two sets of relative crop yield. Data were obtained during periods of increased weed interference and also during weed-free periods for comparison. In both years, the relative yield of potato decreased with a longer period of weed interference and increased with a longer weed-free period. In 2012, the CPWC changed from 112 to 1014 GDD (Growing Degree Days), which corresponded to 8 to 66 days after crop emergence [DAE]). In 2013, the CPWC was found to be between 135 and 958 GDD (10 to 63 DAE), based on a 5% acceptable yield loss. Weed-free conditions need to be achieved as early as the first week after crop emergence and maintained for ten weeks thereafter to avoid more than 5% yield loss in potato.

Acknowledgements: The authors thank the Research Fund of the Erciyes University for supporting this project (Number FBA-12-3870) and participation at the 7th International Weed Science Congress, June 19 to 25, 2016 in Prague, Czech Republic.

Keywords: Critical Period for Weed Control, Critical Weed-Free Period, Crop competition, Potato

The poster in a PDF version is available here.

Effect of different crops and stubbles on the field emergence of *Raphanus sativus* and *Conyza sumatrensis* (214)

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Unless integrated weed management (IWM) strategies are adopted by Argentinian farmers, weed problems will escalate in the most important local crops (soybean, maize and wheat). Grain crop and stubble management could be successful strategies in IWM but little is known about the effectiveness. The objective of this work was to analyze the effect of different crops and stubbles on the emergence of *Raphanus sativus* and *Conyza sumatrensis*. A factorial field experiment in a CRBD with five replicates was done. Factors were (1) crop species (wheat, canola and without crop), (2) stubble type (maize, soybean and without stubble) and (3) weed species (*R. sativus* and *C. sumatrensis*). Crops were sown in June in plots of 1.05 m x 1 m, with 0,175 m of row spacing, at a density of 200 plants m^{-2} for wheat and 60 plants m^{-2} for canola. Weeds were sown in plastic trays (17 x 13 x 4.5 cm) filled with sterilized soil, at a density of 86 and 250 seeds per tray for *R. sativus* and *C. sumatrensis, respectively*. Trays without bottoms (allowing weed roots into the soil) were introduced in plots and covered with a net to avoid predators. Stubble equivalent to 2600 kg ha^{-1} for soybean and 5400 kg ha^{-1} for maize covering 90 % of the soil were used. Regardless of crop presence, seedling emergence of *R. sativus* was higher with stubble. For *C. sumatrensis* emergence was higher without stubble than with stubble and higher under a crop canopy than without a crop. There were no differences between stubble types on emergence for any of the species. Different weeds may require different stubble or crop management, since emergence may be promoted (*R. sativus*) or reduced (*C. sumatrensis*) with stubble and may be unaffected (*R. sativus*) or promoted under crop canopy (*C. sumatrensis*).

Keywords: Seedling emergence, Crop canopy, Soybean stubble, Maize stubble

The poster in a PDF version is available here.

Weed communities respond to changes in crop sequence composition and land use intensification (422)

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While land use intensification and crop diversification increase land productivity, they may also affect weed community composition. Experiments were set up at three locations in the Rolling Pampa, Argentina to assess weed community shifts due to the implementation of cropping systems differing in the composition and number of crops in a single season. We also studied if weed communities converge when the same sequence is cropped the following two years. Treatments included five cropping systems during the first year: (1) winter cereal/soybean double crop, (2) field pea/soybean double crop, (3) field pea/maize double crop, (4) maize single crop and (5) soybean single crop. All treatments were cropped by the same sequence in the following two years (wheat/soybean double crop and maize). Weed species frequency was surveyed three times, once during each summer crop. Composition shifts between sites, treatments, cropped species, and seasons were evaluated with a multivariate analysis of variance (NMDS) based on dissimilarities (Adonis). Changes in weed community structure were analyzed through the frequency-ranking relationship. Weed communities differed among sites (P<0.0001). Weed shifts at each site were mainly associated with the season and the cropped species (P<0.0001), and with treatment in third place (P<0.001). Treatments presented stronger effects in the first year, mostly due to crop type identity rather than to the number of crops. Differences were reduced thereafter, as the same sequence was cultivated during two consecutive seasons. Frequency of the most common species was the highest in plots cultivated with maize, and lowest in plots that open the sequence with cereal/soybean (P<0.05). This variable was negatively associated with the number of days with high crop cover (crop cover>75%; P<0.01) in the first season, and presented residual effects in the following seasons. These insights can help to design crop production systems aimed at reducing specific weed problems.

Keywords: Cropping system, Double cropping, Ecological intensification

The influence of plant density and sowing delay on weed germination in winter wheat stands (400)

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The need to alleviate negative impacts from farming on the environment, and the development of herbicide resistant weed ecotypes urge for a rational and environment-friendly weed control strategy, preferably based on biological characteristics of crops and weeds.

Aiming at the development of an integrated weed management strategy for wheat a field experiment was conducted at Akademija, Kedainiai district, Lithuania in a conventional soil tillage system. The field experiment was designed to investigate how winter wheat plant density and sowing delay determine weed germination in autumn. Winter wheat var. 'Ada' was drill-seeded at three different seed rates (2, 4 and 8 million germinal seeds per hectare) at recommended time, three weeks later, and six weeks later. Main weeds in winter wheat crops were the common annual dicotyledonous weeds *Thlaspi arvense*, *Viola arvensis*, *Galium aparine*, *Lamium purpureum*, volunteer oilseed rape and the annual monocotyledonous weed *Apera spica-venti*.

Crop density had insignificant influence on weed germination. Only in the stand with the highest density the weed number was 10 – 30% lower compared to the lowest density. No weeds appeared until spring in winter wheat plots with six weeks sowing delay. In plots with sowing delay of three weeks an ambiguous influence on weed numbers was recorded: (1) a 80-100% decrease in the number of *T. arvense* and volunteer oilseed rape, while (2) a 60 – 80% decrease of *V. arvensis, L. purpureum* and (3) a 20-30% decrease of *G. aparine*. *Apera spica-venti* responded conversely; in plots with delayed sowing of winter wheat the number of this weed slightly increased. Admittedly, at late autumn no crop – weed competition proceeded.

For reducing crop – weed competition three weeks sowing delay of winter wheat could be effective. Major delaying of sowing time could lead to significant decrease in grain yield of winter wheat.

Keywords: Weeds, winter wheat, germination, seed rate, sowing delay

The poster in a PDF version is available here.

Development of weed populations under site-specific weed management in winter crops (476)

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Josef Holec *(Czech University of Life Sciences Prague, Prague, Czech Republic)*

Site-specific weed management (SSWM) could decrease environmental impacts of herbicides, but effects on weed population dynamics is yet unknown. Therefore, a SSWM experiment was realized on a 3 ha experimental field in central Bohemia from 2011 to 2014, with winter wheat and winter rape. The experimental area was split into cells of 6 × 10 m. A total of 512 cells were arranged into 16 blocks, which allowed the randomization of four treatments in four replications. Treatment 1 represented blanket spraying regardless of weed infestation whereas treatments 2 to 4 consisted of SSWM with increasing treatment thresholds used for individual weed groups. Each year, weed infestation was evaluated in spring prior to post-emergence herbicide application. The density of each weed species was evaluated manually by counting individual weeds in four sample areas in the central part of each cell. Treatment maps were created for each weed group based on weed abundance data and treatment thresholds. Herbicide application against individual weed groups was performed separately using a sprayer equipped with GPS and boom section control. Differences in yield and population density among treatments were analysed by ANOVA. The yields of winter wheat and winter rape in SSWM treatments varied between 95 % and 103 % of the blanket treatment and differences were statistically insignificant in all years. SSWM led to significantly increased densities of *Galium aparine* and *Tripleurospermum inodorum* populations in the third and fourth experimental years. The effect of SSWM was insignificant for other dicotyledonous weeds. Annual monocotyledonous weeds were represented mostly by *Apera spica-venti*. Plant densities of this species were also higher under SSWM, compared to the blanket spraying regime, but the herbicide savings reached 64 to 81% depending on the actual threshold. *Compared to economic thresholds,* lower SSWM thresholds are recommended for *G. aparine* and *T. inodorum.*

Keywords: Site-specifific weed management, weed thresholds, winter wheat, winter rape, population dynamics

The poster in a PDF version is available here.

Weeds as alternative hosts for plant-parasitic nematodes and their ability to maintain nematode populations larger than the tolerance limit for the main crop (751)

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Plant-parasitic nematodes are obligatory parasites causing significant damages to a wide range of agricultural crops. In the Mediterranean agriculture, several weeds occurring in fruit tree orchards and in small-scale vegetable farming systems act as important reservoirs for these parasites. Thus, weeds can favour an increase in the inoculum/population density of parasitic nematodes for the next growing season, in addition to competing with the crops for light, water and nutrients. This study reports the host suitability of *Solanum nigrum, Sonchus asper and Malva sylvestris* to the nematode species *Meloidogyne javanica, Heterodera goettingiana* and *Pratylenchus neglectus*, respectively. The study was carried out during spring and winter periods, according to the life cycle of the parasites. In order to determine the *good host* status, two variables have been measured, nematode population density and feeding site development. Data on final nematode egg densities in *S. nigrum* and *S. asper* were 2,800 and 2,450, respectively. Results showed that the final nematode populations recovered from the roots of infected weeds were always greater than the carrying capacity known from the literature for some important vegetable hosts for the three nematode species. The specific anatomic-pathology, based on histopathological studies consisting of giant cell formation, syncytia and root lesions induced during nematode feeding is also illustrated and discussed. Results of this study, with three examples of plant parasitic nematodes and crop–weed interactions, showed that weeds when serving as good alternate hosts for pathogenic nematode species can decrease the rate of mortality typically expected among nematode populations in the absence of the primary host crop. Results further indicate the need for managing off-season weeds to limit nematode population growth in the absence of the main host crop.

Keywords: Histopathology, root-knot nematodes, cyst nematodes, root-lesion nematoeds

The poster in a PDF version is available here.

Integrated management of parasitic weed *Orobanche cernua* infesting transplanted tobacco in red sandy loamy soils (258)

Chinnusamy Chinnagounder *(Tamil Nadu Agricultural University, Directorate of Crop Management, Coimbatore, India)*

Management of broomrape is often difficult due to its prolific seed production, longevity of seeds, and close association with the host plants. Several means for managing broomrape have been tried over the years, albeit with limited effectiveness. Trap and catch crops have been used in crop rotations to reduce the broomrape seed bank in the soil. However, the tobacco farmers in Tamil Nadu grow only one crop in a year (*rabi* season) since irrigation sources are limited during *kharif* season and no pre-tobacco trap crop can be grown. Chemical control of Orobanche in tobacco was therefore studied in five on-farm trials in the hot-spot areas with the objective to evaluate an efficient and economic method of *Orobanche* management in tobacco. Treatments were (1) Pre-plant incorporation (PPI) of fluchloralin 1.0 kg/ha, (2) Pre-emergence (PE) of oxyfluorfen 0.1kg/ ha, (3) Pendimethalin 1.0 kg/ha on 3 days after transplanting (DAT), (4) Soil drenching with $CuSO_4$ 0.5% on 55 DAT, (5) Direct contact application (DCA) of paraquat 0.6 g/L, (6) Glyphosate application at 2 g/L of water, (7) Metribuzin application at 0.5 kg/ha, (8) Imazethapyr application at 30 g/HA at 55 DAT, and (9) Plant hole application (PHA) of neem cake 200 kg/ha at 30 DAT. The trial was laid out in a randomized block design with three replicates. Application of imazethapyr at a rate of 30 g/ha at 55 DAT reduced *Orobanche* shoot density and increased tobacco leaf yield and economic benefits better than any other herbicide. Plant hole application of neem cake also showed effective for the control of *Orobanche* and resulted in higher tobacco leaf yield than the pendimethalin application of 1.0 kg/ha at 3 DAT. Integrated management of broomrape in tobacco, using pre-emergence herbicide and plant hole application of neem cake can be recommended.

Keywords: Parasitic weed, Broom rape, Integrated management, Tobacco, Red sandy loam soils

The poster in a PDF version is available here.

Management of *Striga asiatica* in early planted sugarcane in red gravel soil fields of Southern India (236)

Chinnusamy Chinnagounder *(Tamil Nadu Agricultural University, Directorate of Crop Management, Coimbatore, India)*

More than 50% of India's sugarcane (*Saccharum officinarum* L) is cultivated in red gravel soils that are often infested by *Striga asiatica*. To manage *S. asiatica*, an on-farm experiment was conducted in farmer's field to evaluate an efficient herbicidal and integrated management technique for *Striga asiatica* control in sugarcane. The field experiment was laid out in a randomized block design with three replications. There were ten treatments which include (A) Pre-emergence (PE) atrazine 1.0 kg/ ha, (B) 2,4-D Na salt 1.0 kg/ ha+ urea 1% + soap solution 1% as post-emergence (POE) on 75 DAP, (C) PE atrazine 1.0 kg/ha + POE urea spray 20% on 75 DAP, (D) PE atrazine 1.0 kg/ha + POE paraquat at 1.25 kg/ha on 75 DAP, (E) PE atrazine 1.0 kg/ha + POE glyphosate 2.0 kg/ha on 75 DAP, (F) PE atrazine 1.0 kg/ha + Trash mulching at 5 tonnes/ha on 75 DAP, (G) PE atrazine 1.0 kg/ha + 2,4-D Na salt 1.0 kg/ ha + urea 1% + soap solution 1% as POE at 75 DAP followed by mulching with cane trash after final inter-row cultivation at 120 DAP, (H) Hand weeding on 30, 60 & 90 DAP, (I) Hand weeding on 30, 60 & 90 DAP except *Striga asiatica* and (J) unweeded check. Treatment 'G' recorded a higher control efficiency of *Striga* and ordinary weeds than other treatments. Therefore, PE atrazine 1.0 kg/ha +2,4-D Na salt 1.0 kg/ ha + urea 1% + soap solution 1% as POE at 75 DAP followed fb trash mulching at 120 DAP is recommended for effective control of *Striga asiatica* in sugarcane and for higher productivity and profitability. *Striga asiatica* in early planted sugarcane could be effectively controlled with integrated herbicidal and trash mulching**.**

Keywords: Parasitic weed, *Striga asiatica*, Herbicidal control, Sugarcane, Cane yield

The poster in a PDF version is available here.

Genetic characterization of resistance of sunflower (*Helianthus annuus* L.) to sunflower broomrape (*Orobanche cumana* W.) (675)

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Orobanche spp. (broomrapes) are chlorophyll-lacking obligate root parasites, drawing all required water and nutrition from the host through the haustorium, a unique plant organ that connects the parasites with their hosts. Sunflower broomrape (*Orobanche cumana* Wallr.) is regarded as one of the most important production constraints of sunflower in many countries in Europe and the Mediterranean region.
We intend to elucidate the broomrape resistance mechanism of the sunflower variety EMEK 3. Based on previous literature we hypothesize that the resistance mechanism encompasses the production of phenolic compounds and phytoalexins, at the root level. This in turn involves the phenylpropanoid metabolic pathway. We further hypothesize that the resistance mechanism engages transcriptional changes that are induced by inoculation of *O. cumana*. Thus a comparative RNA-sequencing approach of resistant and susceptible host roots at the right stage will identify differentially expressed genes associated with the resistance mechanism.
Observations of host-parasite interactions and *O. cumana* attachment and development on EMEK 3 roots in PEB (polyethylene bags) which enables us to observe the host roots and monitor the development of the various stages of *O. cumana* parasitism germination, shows that the parasite intrusive cells are stopped during the penetration attempt, indicating a "post-attachment" mechanism of resistance. We are now sequencing RNA samples extracted around this inoculation stage from the roots of various sunflower lines.
Breeding for resistance is the most effective and beneficial method of controlling sunflower broomrape, but the resistance of many new cultivars is rapidly overcome. Therefore, a better knowledge of the mechanisms responsible for resistance to parasitic plants is necessary to improve the production of crops with long-lasting resistance.

Keywords: Parasitic plant, Host resistance

The poster in a PDF version is available here.

Distribution and impact of the genus *Cuscuta* L. in Russia (411)

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The genus *Cuscuta* L. is a taxonomically difficult cosmopolitan genus of the family Cuscutaceae Dumort., that counts 150 to 200 species, all of which are parasitic. All species of the genus are included in the quarantine list in Russia but some of them are narrowly specific or native and not harmful to crops. Parasitism by one of the species of *Cuscuta* lead to depression of host plants, reducing the quantity and quality of the harvest and contamination of the fields and pasture, and sometimes intoxication of animals feeding on it.
Identification of fruits and seeds of the weed is difficult because of the lack of clear morphological features. The main aim of the current work is the identification of the weed species in Russia, in order to evaluate their spread.
We analyzed all the major floristic reports in scientific journals and herbarium materials of the genus *Cuscuta* stored in the Herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences, the Herbarium of the Tsytsin Botanical Garden of Academy of Sciences, the Syreyschikov Herbarium of the Moscow State University. Ecological, geographical and morphological methods were chosen as approach to the analysis of taxa.
So far we identified 17 species of *Cuscuta* to be present in Russia: *C. suaveolens* Ser., *C. australis* R. Br., *C. gronovii* Willd. Ex Schult., *C. campestris* Yunck., *C. tinei* Insenga, *C. cesatiana* Bertol., *C. chinensis* Lam., *C. europaea* L., *C. epilinum* Weiche, *C. epithymum* (L.) Nathh., *C. planiflora* Ten., *C. approximata* Babingt., *C. pedicellata* Ledeb., *C. lupuliformis* Krock., *C. lehmanniana* Bunge, *C. monogyna* Vahl., *C. japonica* Choisy. The genus can be divided by 3 subgenera: *Grammica* (Lour.) Engelm., *Monogyna* (Engelm.) Yunck. and *Cuscuta*. The data can be used for the assessment of the impact of certain types of taxa on agricultural crops.

Keywords: *Cuscuta*, parasitic, quarantine, diversity, distribution

Determination of phylogenetic relations of species belonging to the genus dodder (*Cuscuta* spp.) that problem in agricultural and non-agricultural lands in eastern Anatolia (Turkey) (556)

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Dodder species (*Cuscuta* spp.) are parasitic plants that are very difficult to control and therefore impose a serious threat to agricultural production world-wide. There are 16 species belonging to the genus *Cuscuta* in agricultural and non-agricultural lands in Turkey. The seeds of dodder can be spread through contaminated crop seed lots and they remain viable in soil for at least 15 years. The aim of this study was to identify the *Cuscuta* species that are posing a problem in agricultural and non-agricultural lands in Eastern Anatolia Region of Turkey. Herbarium specimens of each sample have been deposited and identified. In order to determine the phylogenetic relations of species belonging to the genus *Cuscuta,* DNA isolation has been made from the body tissue of each sample. Conserved regions on ribosomal DNA (rDNA) have been amplified by universal primers via PCR method and have been cloned in a proper cloning vector. The cloned DNA fragments were sequenced and analyzed using the Vector NTI Advance™ and CLC Main Workbench Software to trim vector sequences. The identity of cloned fragments was determined by comparison to published sequence information in NCBI database using the basic local alignment search tool programs. The present study identified 8 taxa belonging to the *Cuscuta* genus to be present in Eastern Anatolia. The results of the genetic analysis supported the results of morphological detections.

Keywords: Dodder, *Cuscuta* spp., Molecular Phylogeny, Eastern Anatolia

Rhamphicarpa fistulosa, an emerging parasitic weed problem in rain-fed lowland rice production systems in sub-Saharan Africa (545)

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Rhamphicarpa fistulosa (Hochst.) Benth (Rice Vampireweed) is an emerging parasitic weed species in rain-fed, lowland rice fields of sub-Saharan Africa. This species developed into a serious problem upon the expansion of rice cultivation into marginal wetlands, the natural habitat of the parasite. In the past five years, a research program on *R. fistulosa,* named PARASITE (www.parasite-project.org), was carried out. One of the aspects the research program focused on was the facultative nature of the parasitic weed and the implications of this feature for the management of this weed. Experiments confirmed that the species is a facultative root parasite, able to complete its life cycle in the absence of a host. Root exudates, often a prerequisite for seed germination of obligate root parasites, such as *Striga* spp., were not required for germination of *R. fistulosa* seeds, nor did they enhance seed germination rate. Biomass and seed production of individual *R. fistulosa* plants attached to a host plant were found to be four times higher than that of non-attached individuals. These observations were used as a base for developing a life-cycle population model. Simulations with this model confirmed that, depending on life-cycle traits and external circumstances, the opportunistic germination strategy of the parasite is indeed superior over a host plant-induced-germination strategy. Seed longevity and host range were identified as determining factors. Strategies that target these two dependencies therefore bear high potential. The ability for seed germination independent of the presence of host root exudates eliminates the use of trap crops as a control strategy, whereas using the stale seedbed technique bears promise. Other control strategies that were found effective are delayed sowing and the use of organic and inorganic fertilizers. Additionally, a number of lowland NERICA-varieties that combined resistance with good yielding ability were identified.

Keywords: *Rhamphicarpa fistulosa*, parasitic weed, rice, facultative, sub-Saharan Africa

The poster in a PDF version is available here.

In vitro screening of Malagasy rain fed mutant rice lines F154 and B22, tolerant to *Striga asiatica* (296)

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The witchweed *Striga asiatica* causes important losses to rain-fed cereals crops in Africa. In Madagascar, *S. asiatica* inflicted yield losses range between 15% and 100% depending on the soil fertility, the degree of infestation and the sensitivity of the cultivated lines. Two malagasy rice lines were irradiated at different doses of gamma-ray: F154 irradiated at 100Gy and 200Gy, and B22 irradiated at 100Gy, 200Gy and 300Gy. The surviving putative mutants grown on the infested soils were obtained from field screenings during M2 and M3 generations. Here we present results of an *in vitro* screening of the M4 generation. Nine rice seeds per mutant were grown on a growth medium with 500 seeds of *S. asiatica*. Three different growth media were tested: Agar-agar 8%, KNOP solution and MS 5519/2. The experiments were replicated three times and were incubated during eight weeks at 28°C, and a light intensity of 3500klux and daylight period of 16 hours. The *S. asiatica* seed germination, tested with the synthetic stimulant GR24, was 43%. The MS 5519/2 medium was found the best for *in vitro* cultivation of rice. Following *in vitro* screening, 50% of cultivated mutants survived, mainly including the tolerant mutant B22 100Gy. The sensitive mutants were characterized by a high level of leaf tips burning, early senescence and death. All mutants able to survive up to 1 month with minor symptoms were considered as moderately tolerant and those without any symptoms up to 2 months were considered as tolerant to *S. asiatica*. The biochemical and molecular characterization of the selected mutant lines will be carried out later. These will then be tested in the field for performance demonstration. Finally, the tolerant mutant rice lines will be promoted to rice farmers for dealing with witchweed problems.

Keywords: *Striga asiatica*, Oryza sativa, Mutant, In vitro screening, Tolerance

The effect of field dodder (*Cuscuta campestris* Yunk.) on chlorophyll fluorescence and chlorophyll content parameters of alfalfa and sugar beet plants (46)

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The presence of parasitic plants in food crops, and the associated damage, has become a growing problem. Obligate parasites are unable to develop without assimilates received from their host plants because they are either incapable of any photosynthetic activity or their photosynthetic potential is very low. The aim of this study was to investigate the effect of Field Dodder (*Cuscuta campestris* Yunk.) on the chlorophyll fluorescence and chlorophyll content of important host plants.
The impact of Field Dodder on chlorophyll fluorescence and chlorophyll content of infested alfalfa and sugar beet plants was examined under controlled conditions. Several parameters of chlorophyll fluorescence (Fo, Fv/Fm, ΦPSII, Fv and IF) were measured in infested (I) and non-infested (N) alfalfa and sugar beet plants over a period of twenty days, beginning with the day of infestation. Chlorophyll contents, both total (TCC) and relative (RCC), were determined at 1, 7, 14 and 20 days after infestation (DAI).
Field Dodder was found to affect both TCC and RCC in infested alfalfa and sugar beet plants, causing significant reductions in chlorophyll content in both species. Our data show that such reductions in TCC and RCC were greater in infested alfalfa (TCC= 6 – 38%; RCC= 11 – 57%) than infested sugar beet plants (TCC= 10 – 34%; RCC= 6 – 19%). The parasite also reduced several parameters of chlorophyll fluorescence (Fv/Fm, ΦPSII, Fv and IF) in infested alfalfa and sugar beet plants. Contrarily, Field Dodder was found to increase Fo values in both host plant species.
Field dodder affects chlorophyll fluorescence parameters and chlorophyll content in infested alfalfa and sugar beet plants, showing that these parameters may be considered as sensitive indicators of the impact that this parasitic plant has on its hosts.

Keywords: Cuscuta campestris, alfalfa, sugar beet, chlorophyll fluorescence, chlorophyll content

The poster in a PDF version is available here.

Branched broomrape (*Orobanche ramosa*): A serious threat to Texas vegetable industry (835)

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Invasive weeds continue to threaten the productivity and sustainability of pasture and crop production systems in Texas. A most recent and critical weed problem is the re-infestation of broomrape in Karnes County and surrounding areas, the original place where it was first found in 1984. With routine monitoring and spraying, this parasitic, invasive, noxious weed was initially kept under control from spreading to the Winter Garden region, which is an important vegetable production area in Texas adjacent to Karnes County. However, efforts were discontinued since 2008 as government funding was no longer available. In spring 2015, a local grower noticed the re-occurrence of broomrape in local cemeteries and pasture lands and alerted the authorities. A task-force consisting of multi-disciplinary and multi-agency members was soon formed and it quickly responded to the situation. The task-force members visited the site and assessed the situation to devise further actions. Follow-up surveys conducted in spring 2016 revealed additional infestation sites. While seed germination requires presence of a host plant, research indicates that it also requires a temperature cycle for germination. Soil temperature must drop below 9C for preconditioning, with germination occurring when temperatures rise above 15C in the presence of a nearby host. Seedlings take about 45 days from germination to emergence. Multiple cohorts of emergence are noticed following every rise in temperature above 15C during spring. In 2016, the first emergence of broomrape was documented on February 15, suggesting that seed germination occurred at around the last week of December 2015. The current priority of the task force is to monitor and contain existing infestations. High emphasis has been placed on creating awareness on the re-occurrence of this weed and educating the clientele on how to prevent further spread. More research and extension efforts will be implemented in the near future.

Keywords: Parasitic weed, Orobanche, Invasive noxious weed, Haustoria, Quarantine

The poster in a PDF version is available here.

Investigating broomrape (*Phelipanche aegyptiaca*) populations genetic diversity, host preferring and response to herbicides and benzotiadiazole (636)

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In order to investigate genetic diversity of Iranian broomrape populations, their host preferences and responses to herbicides and benzothiadiazole (BTH), 3 separate experiments were carried out during 2010-2012. Twelve broomrape populations were collected from different regions of Iran during the summer of 2009. The genetic diversity of these broomrape populations was investigated with 5 ISSR markers. A factorial experiment was also conducted with a randomized complete block design with 3 replications under natural conditions to investigate herbicides and benzothiadiazole efficacies on each population. The main factor was 12 broomrape populations and the second was (1) glyphosate at 21 and 41 ml a.i ha^{-1}, (2) sulfosulfuron at 27 and 50 g a.i ha^{-1} and (3) benzothiadiazole at 15, 20 and 30 ppm, all sprayed at 30, 40 and 50 days after transplanting (DAT). In the 3rd experiment the host preferences of these 12 broomrape populations were investigated with cucumber, tomato, eggplant, celery and sunflower as potential host plants. The results indicated that the polymorph alleles were 7-10 for each primer. The mean of alleles was 9.2. Of total variance of molecular data, 19 and 10% corresponded to the differences of within and among broomrape populations. Broomrape populations responded different to potential hosts and herbicides. Against all populations, except Orumiyeh, 50 g a.i ha^{-1} sulfosulfuron was the best treatment (80% control). None of the treatments with BTH could control broomrape populations. Mean tomato yield loss for all broomrape populations was 33%. The result of the 3rd experiment showed that cucumber more than the any other hosts were parasitized by Orobanche. We conclude that Iranian broomrape populations were genetically different and these differences can be depicted by their response to the host and herbicides treatments.

Keywords: Egyptian broomrape population, yield loss, sulfosulfuron, glyphosate

The poster in a PDF version is available here.

Modelling cropping system effects on branched broomrape dynamics in interaction with weeds (585)

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Branched broomrape, *Phelipanche ramosa* (L.) Pomel, is a parasitic weed that infects many crop and weed species. As a holoparasite, it entirely relies on host-plant resources to survive and reproduce. It is a major pest of winter oilseed rape in France. In order to design efficient pest management strategies, we modelled the effects of cropping systems on *P. ramosa* dynamics in interaction with weeds and crops in a model called PheraSys.
PheraSys functions and parameters were based on literature and on our own experiments. It simulates processes that determine the multi-annual parasite dynamics, i.e. *in situ* seed mortality, dormancy and germination, and subsequent parasite fixation and survival on the host plant until seed production and release. *In situ* seed mortality is very low (6-8% per year) and seeds display seasonal dormancy from mid-November to March (during French winter). We characterized interactions between *P. ramosa* and crops and weeds by listing host, non-host and false-host species reported in literature, and their ability to stimulate *P. ramosa* germination. We also showed that parasite survival until reproduction depends on host-plant biomass. The model will be evaluated and improved by adding functions quantifying the effects of parasitism on hosts.
PheraSys is an innovative approach as it models the complete life-cycle of *P. ramosa* within a cropping system for the first time. Once the software programming is finished, it will be used to test impacts of current and prospective cropping systems on parasitic weed dynamics. It already points to a few potential management improvements. For instance, burying seeds by tillage is not efficient to deplete the parasite seed bank, because the *in situ* seed mortality is low, but delaying crop sowing would be a promising means to reduce crop infestation due to the parasite seed dormancy characteristics.

Keywords: *Phelipanche ramosa* (L.) Pomel, parasitic plant, model, cropping system, weed management

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Session 6
HERBICIDES AND APPLICATION TECHNOLOGY

Spray deposition and weed control using a conventional boom sprayer and an auxiliary boom sprayer, with reduced spray volumes (182)

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Application technology directly influences the success of a *desiccation*, supporting the effectiveness of weed control. This work evaluated the herbicide deposition on weeds, the spray loss to the soil and the efficacy of weed control produced by two application technologies (conventional boom sprayer and auxiliary boom sprayer, varying spray volumes between them: 100 and 150 L ha^{-1} in the conventional system and 30 and 50 L ha^{-1} with auxiliary boom). The experiment was conducted in a randomized block design with five replications. A tracer was added to the solution containing the herbicide glyphosate in order to detected the spray by spectrophotometry. The spray deposition on the weeds did not differ depending on the presence or absence of the auxiliary boom, nor either spray volume, demonstrating the feasibility of using spray volumes between 30 and 50 L ha^{-1} with the auxiliary boom. The losses to soil were higher when it was sprayed with a conventional spray boom. The weed control was very good regardless of the treatment used.

Keywords: Application technology, Sprayer, Desiccation

The poster in a PDF version is available here.

Automated thinner and weed control machine in lettuce production (357)

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Thinning crops is a labor intensive activity and researchers have sought ways of mechanizing this production practice. Computer processing of digital images of crops now makes it possible to make precise decisions on which plants to remove and leave. Automated thinners that used a spray kill mechanism to remove unwanted lettuce plants and associated weeds offer advantages over mechanical mechanisms (e.g. less inertia, greater speed), and there are now four commercially available machines for thinning lettuce. These machines remove unwanted lettuce plants and associated weeds in a 10 cm wide strip around the seedline and within 9 to 12 mm to either side of the desired 'keeper' plants. Materials used to remove the unwanted lettuce/weeds include salt and acid based fertilizers and the herbicide carfentrazone. In evaluations conducted in 7 commercial lettuce production fields, automated thinners took 2.25 hours/ha and hand thinning 16.21 hours/ha to thin lettuce. Hand thinning removed more weeds than the automated system (73 vs. 68%, respectively). The follow-up double removal/weeding operation 7-14 days following thinning took 16.23 hours/ha in the automated thinner treatment and 13.12 hours/ha in the hand thinned treatment; the increase in time for double removal and weeding in the automated thinner area was primarily due to the greater number of doubles in the automated thinner treatment (2,530 double/ha) than hand thinning (368 doubles/ha). The total time for thinning and double removal/weeding operations was 18.48 hours/ha in the automated thinner treatment and 29.33 hours/ha in the hand thinned treatment. The mean plant spacing in the automated thinner treatment was 26.1 cm and 26.6 cm in the hand thinned treatment. Automated thinner designs continue to improve and refining this technology to improve weed removal is the subject of on-going research.

Keywords: Automated, thinner, weeder, lettuce

The poster in a PDF version is available here.

New method for detection and quantification of imazapic in soil solution following herbigation (832)

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A new herbicide application method (herbigation = herbicide + irrigation) is proposed, delivering the herbicide via drip irrigation system. The advantages of herbigation are: explicit site-specific, high efficiency, and restricted herbicide localization in the soil profile. Imazapic is labeled in Israel for *Phelipanche aegyptiaca* control in processing tomato applied via drip irrigation system. Our objective was to understand the factors involved in the efficacy of herbicide applied using herbigation. We hypothesized that soil and herbicide properties as well as drip irrigation flow rate and spacing play a major role in the herbicide mobility in soil. Our specific objectives were (i) develop a robust bio-assay for detection and measurement of very low imazapic concentrations; (ii) build a non-destructive platform for analyzing the availability of imazapic in the soil solution. Arabidopsis (*Arabidopsis thaliana*) seeds (5) were seeded in an autoclaved agar containing various imazapic concentrations in petri dishes. The seeded dishes were incubated at 24 C (16 h light) for 10 d before roots length was recorded. Arabidopsis root elongation was sensitive to the herbicide and highly correlated with imazapic concentration in the soil solution with ED^{50} value of 1.2 ppb. „MacroRhizon" (Rhizosphere Research Products, Wageningen, The Netherland) soil solution samplers, were placed in various depths under the dripper in heavy soil and utilized to collect soil solution samples. The samples were collected following herbigation of 5 ppm imazapic solution through a 2 Lh^{-1} dripper, filtered (0.4 µ) and taken to the Arabidopsis bio-assay. Imazapic was detected in all soil solution samples collected from more than 20 cm depth. Lethal concentration was detected at 0 to 16 cm depth, with a decline in deeper layers. We concluded that the bioassay combined with „MacroRhizons" samplers can serve as a powerful and robust method for understanding herbicide behavior in soil following herbigation.

Keywords: Herbigation, Imazapic, Soil

Verticutting prior to herbicide application enhances dallisgrass control (120)

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Dallisgrass control is limited by herbicide absorption and translocation to vegetative reproductive structures. Field experiments were conducted in a common bermudagrass rough (5.1 cm) in Winder, GA to investigate the impact of verticutting on postemergence dallisgrass control. Plots (1.5 x 1.5 m) were arranged in a 2 x 5 factorial with four replications. The main factor was cultivation (verticutting or no cultivation) and sub-factor was herbicide treatment. Half the site was verticut to a depth of 2.5 cm. Herbicide treatments were initiated the same day with sequentials 6 weeks later. Treatments consisted of no herbicide, Tribute Total (thiencarbazone + foramsulfuron + halosulfuron) at 0.136 kg ai ha^{-1}, Celsius (thiencarbazone + iodosulfuron + dicamba) at 0.171 kg ai ha^{-1} + Revolver (foramsulfuron) at 0.073 kg ai ha^{-1}, MSMA at 2.5 kg ai ha^{-1}, and Certainty (sulfosulfuron) at 0.066 kg ai ha^{-1} + MSMA at 2.5 kg ai ha^{-1}. Treatments were applied with methylated seed oil at 0.5% v/v. Visual ratings of % bermudagrass phytotoxicity (1 and 2 weeks after treatment) and % dallisgrass cover [8 and 16 weeks after initial treatment (WAIT)] were recorded. Percent cover was converted to % control. Bermudagrass phytotoxicity (≤ 10%) was observed with initial MSMA applications. However, plots recovered 3 WAIT. Verticutting increased dallisgrass control with Tribute Total and Celsius + Revolver from 60% (no cultivation) to 86 and 88% (verticutting) 8 WAIT, respectively. In contrary, verticutting decreased control with MSMA and Certainty + MSMA from 28 and 59% (no cultivation), respectively to 4% (verticutting) 8 WAIT. Verticutting did not improve dallisgrass control in response to herbicides 16 WAIT. Dallisgrass control with Tribute Total and Celsius + Revolver without cultivation was 96 and 98% 16 WAIT, respectively. Certainty + MSMA without cultivation resulted in 89% dallisgrass control, while control with MSMA alone was 63% 16 WAIT.

Keywords: Verticutting, dallisgrass, bermudagrass, thiencarbazone

The poster in a PDF version is available here.

Problems of chemical weeding of crops in Ivory Coast (467)

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Herbicides are increasingly used for weeding crops in Ivory Coast. Formerly practiced by agribusiness corporations and big agricultural producers, chemical weed control is currently the common method of weeds control in Ivory Coast. Several products are found on the market with the risks (environmental, economic, human and animal health, etc.) related to their uncontrolled use. After a few years of practice of this method, it is timely to assess the current situation and propose solutions to problems posed by the use of herbicides.
From an analysis of the proceedings of any meeting of the Pesticide registration committee last 15 years (2000-2015) we gathered for each crop the various authorized active substances. For each of these active ingredients, we identified the number of commercial products allowed on the market. In a first survey, we enjoyed on the ground, the administrative situation of the herbicide exposure in different markets. Another survey of producers and agricultural technicians of agribusiness companies consuming herbicides has allowed to answer some questions related to difficulties in the use of these products in the Ivory Coast. The analysis results show that more active ingredients are currently allowed in Ivory Coast under various trade names. Other results indicate that the difficulties associated with the use of these herbicides are still numerous. The legislation is inadequate or poorly applied. Several unlicensed products are found on the walk. The products are often misused by producers. This causes inefficiencies related to these products.
In relation to the above, a reorganization of the herbicide market is expected

Keywords: Problems, Herbicides, Weeds control, Ivory Coast

Development and evaluation of a controlled system release of tebuthiuron herbicide using microparticles of alginate (429)

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The development of controlled delivery system formulations has received increasing interest in the agriculture area. The tebuthiuron (TBH) is the most commonly used herbicide for the weed control in sugar cane and cotton cultivations in the state of Goiás (Brazil). The TBH and some of its metabolites are detected in surface water by leaching process, evidencing contamination and the need for an efficient process to decrease pesticide residues. The development of a controlled system release appears as a good solution. The present investigation aimed to study the development and evaluation of alginate as a delivery system for the TBH. Alginates are polysaccharides obtained from brown seaweeds. They are composed of b-D-mannuronic acid (M) and a-L-guluronic acid. The microparticles of alginate were obtained using the ionotropic jellification process. An aqueous solution of sodium alginate (1 % m/v) containing the TBH was prepared. The alginate microparticles were synthesized by dropping an aqueous sodium alginate solution (1% m/v) containing the desired amount of TBH into a freshly prepared $CaCl_2$ solution (0.1, 0.3 and 0.5 $mol.L^{-1}$) under magnetic stirring. The particle size and morphological analysis of microparticles was determined by optical microscopy (OM), by field emission gun scanning electron microscopy (FEG-SEM), and by atomic force microscope (AFM). The presence of TBH was confirmed by attenuated total reflectance Fourier transform infrared ATR-FTIR analysis. The encapsulation efficiency was accessed by UV-vis spectroscopy by monitoring the band relative to TBH in aqueous solution. The results show that alginate microparticles presented high encapsulation efficiency of TBH herbicide and are potential candidates for controlled release platforms in agricultural applications.

Acknowledgements
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Keywords: Biodegradable Polymer, Weed control, Microencapsulation, Controlled release

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Site-specific pre-harvest application of glyphosate in oil-seed rape (471)

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Roundup herbicide (glyphosate) is the mostly used herbicide in the world, used very frequently also as a pre-harvest desiccant in oil seed rape. Because the crop maturity is usually not homogenous within the field, different doses of desiccant could be applied in individual parts depending on the crop biomass moisture. Main objective of the research was to find tools for reliable detection of different crop biomass moisture in pre-harvest desiccation of oil seed rape using Yara N-sensor ALS and spectral RGB camera and develop algorithms for site-specific application of glyphosate. During the ripening of the crop, plant samples were taken in the field and the moisture was measured exactly in laboratory. For remote estimation of moisture, images were taken at the same time by RGB and multispectral cameras located on the Falcon 8 drone, NDVI was calculated and the moisture estimated. Yara N-sensor operating in wavelengths 660 nm and 740 nm was mounted on the cabin of the sprayer measuring the reflectance of its own light. Output data were used for on-line calculation of thresholds and on-line identification of places where the machine should spray the herbicide. Treatment maps for variable spraying were derived from both RGB images and N-sensor data. Untreated and fully treated plots were included as a check. Based on treatment maps variable site-specific application of the desiccant was realised according to the crop maturity level. The results show high cost savings potential of variable herbicide spraying before crop harvest. More algorithms for the estimation of the plant moisture using low altitude remote sensing are developed and tested.

Keywords: Glyphosate, site-specific application, N-sensor, remote sensing, NDVI

Investigations on inhibiting the phytotoxicity problem due to the application of non-recommended 2,4 D-amine (578)

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Regardless of knowing their effects on cultural plants, environment and human health, herbicides are being used unconsciously in recent years. Improper use of these chemicals causes phytotoxic injuries on cultural plants followed by yield loss. Farmers are facing problems with phytotoxicity on cotton, maize, wheat and vineyards. Phytotoxicity symptoms are associated with misapplications, off-target drift, and spray tank-contamination. Hormone herbicides like 2,4-D amine are used to control broadleaf weeds in cereals. They are highly volatile herbicides that may cause injury in various proportions on a broadleaf crops like cotton because of misapplications. In order to avoid the negative effects of these herbicides or to overcome the existing phytotoxicity on cultural plants, farmers use some activators as safeners as well as irrigation practices given by suggestion, being unaware of their utility. There is no information on whether these suggestions are correct or not. In order to study this situation, pot experiments conducted with cotton plants for two years containing two irrigation treatments (with and without irrigation after application). Cotton plants were treated with one of five doses of 2,4-D amine based on the recommended dose of 1.6 L ha^{-1}: 12.5%, 25%, 50%, 100% and 200%. Eight hr after treatment we applied different activators in various combinations. Phytotoxicity symptoms on plants were observed visually and the percentage injury was recorded every other week. Additionally, chlorophyll concentration index, vegetation index and stomatal conductance values were measured to evaluate the range of phytotoxicity on plants. The results show that neither activators nor irrigation have any positive effects on plant recovery. Hence, we conclude that activators cannot be used as safeners.

Keywords: 2,4-D amine, phytotoxicity, activator, safener, cotton

Determination of metsulfuron-methyl residues in elephant grass by using (LC/ESI)-Q-ToF-MS/MS (813)

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Elephant grass has been used as animal feed and also in different applications, such as, to protect arid land from soil erosion, to improve the fertility of soil, to use as firebreaks and windbreaks, and to produce bio-oil, alcohol and charcoal. However, one of the its limitation in field implantation in large scale is the interference of weeds. In order to control the infestation of weeds the application of herbicides has been showed to be an effective method, but due to the toxicity of these substances for the environment and animals, the presence of the herbicides residues in plants must be evaluated. Thus, this work presents an analytical method, which was developed to determine the residues of metsulfuron-methyl in elephant grass by using Liquid chromatography coupled to a quadruplole time-of-flight tandem mass spectrometry (LC/ESI)- Q-ToF-MS/MS. The extraction of the analyte was made by using the QuEChERS method (quick, easy, cheap, effective, rugged and safe). In the clean-up step, besides PSA and $MgSO_4$, florisil was also used to remove the interferents. The separation was carried out on an Acquity UPLC® BEH C18 column (1.7 µm, 2.1mm ID, 100mm) using a gradient elution profile and mobile phase consisting of 0.1 % formic acid in water and methanol (positive-ion mode). The method showed good linearity in the concentration range of 0.001–0.2 µg/mL, ($r^2 \geq 0.99$); the limit of quantification (LOQ) was 20 µg/kg^{-1}; the recoveries were in the range of 93–120% and the precision (RSD%) was 12.7 %. The method was applied to analyze samples collected after 45 d after treatment with metsulfuron-methyl (7.8 and 15.6 g ha^{-1}) and an untreated check. None of the sample showed the presence of the herbicide residues above of the limit of quantification (LOD). Acknowledgements: Financial support of CNPq and FAPEMIG is highly acknowledged.

Keywords: Pennisetum purpureum, forages, herbicides

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Droplet spectra and drift potential generated by a ready mix herbicide formulation (803)

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Drift is a movement of the droplets to areas outside the field by one or more of several factors, including the wind. Different types of formulations may be selected by users according to the effect of its components on drift. The objective of this work was to analyze the effect of a pre-mixture herbicide formulation of 2,4-D choline salt and glyphosate dimethylammonium salt engineered for drift reduction on the drift potential compared to a tank-mixture of standard formulations of 2,4-D amine salt and glyphosate dimethylammonium salt. Label rates of the herbicides were diluted to 80 L ha^{-1} and sprayed with flat fan nozzles at 2.8 bar (Teejet XR11002 and AIXR11002). The volume median diameter (VMD) and the percentage of droplets less than 105 µm (V105) were obtained using an online particle size analysis system (VisiSizer/Oxford Lasers Ltd/UK). The drift index (DI) was calculated based on data collected on wind tunnel at 2.5 m s^{-1} wind speed. The amount of drift deposited on nylon strings 2 m downwind from the nozzle were converted to a percentage of the total volume of spray solution sprayed on each replication. The solutions were prepared included a food color dye (Blue FDC 1) for spectrophotometry analysis of drift deposits on the collectors. The results showed that the premix formulation engineered for drift reduction provided lower drift potention based on both the droplet spectra and the wind tunnel data. When spraying with the ready formulation, VMD increased by 17% and 98% for the XR and the AIXR, respectively, while smaller amounts of V105 (49% and 76% less) and lower values of DI (reduction of 57% and 52%) were found for this new technology. It was concluded that the ready mix formulation reduced drift compared to the tank mix of standard formulations of the herbicides.

Keywords: 2,4-D choline, glyphosate, tank mix, wind tunnel, nozzles

The poster in a PDF version is available here.

Availability and activity of glyphosate residues in different types of soil (325)

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The dynamics of herbicides in the environment and in the soil may be affected by agricultural production systems, soil texture, application rate, and the rainfall after application. In the soil, herbicides may be sorbed, leach and /or degraded by physical, chemical or biological processes. These processes play an important role as they influence the amount of herbicide residue available in the soil solution promoting weed control and causing crop injury or selectivity. The objectives of this study were to evaluate availability and activity of glyphosate in soil when applied to different soil textures. Therefore, we conducted laboratory experiments to evaluate how much of the applied glyphosate was sorbed and how much was available in the soil solution after rainfall simulation. Results indicate that 99.6% of the total applied glyphosate adsorbed on the soil and 0.25 to 0.40% of applied glyphosate was available in the soil solution. This small amount does not adversely affect the weeds or crop plants, but can act as a stimulant of growth. Six different soils from the Amazon region were evaluated in bioassays to assess the availability and activity of glyphosate and AMPA on initial growth of sorghum plants. Glyphosate was strongly sorbed to these soils and had no negative effect on sorghum growth.
Acknowledgements: The Vale Co. through the DIOC, by financial resources and facilities along the Igarape Bahia mine, Carajas – PA.Brazil.

Keywords: Dynamics of herbicides, glyphosate, leach, sorbed, Amazon soill

Leaching of hexazinone, sulfometuron and diuron applied alone and in a formulated mixture in a soil with clayey texture (712)

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When interactions among herbicides in a mixture occur, they may be additive, synergistic or antagonist upon weed control. However, those interactions could potentially promote changes in herbicide behavior in the soil. This study evaluated leaching of diuron, hexazinone, and sulfometuron-methyl each applied alone and in the formulated mixture of diuron + hexazinone + sulfometuron-methyl, in six layers of a clay soil. Total leaching was also determined for the same herbicides applied alone and in the mixture. The soil used in the experiment was collected at 0–10 cm depth. Radiolabeled herbicide solutions were prepared and applied to each column. Rain was simulated for 48 hr after which the soil was taken out of each column and segmented in 5 cm-layers. Samples from each layer were oxidized and radioactivity was quantified for each herbicide in each application (alone or in mixture). Results were expressed in amount of radioactivity relative to the total herbicide present in the leached solution. At 0–5 cm, 40% of radioactivity was detected when hexazinone was applied alone, compared to 27% when this herbicide was applied in the mixture. For the deeper soil layers, radioactivity did not differ whether hexazinone was applied alone or in the mixture. Radioactivity was greater at 0–5 cm when sulfometuron was applied alone (86%), compared to the application of the mixture (70%). Deeper in the soil, radioactivity detection was not different between sulfometuron alone and in the mixture. Radioactivity detected for diuron applied alone and in the mixture was the same across soil layers. Radioactivity remained mostly in the 0–5 cm soil layer for diuron (94% and 99% for application alone and in mixture, respectively), indicating that most of this herbicide is sorbed at the first soil layer. Although herbicide leaching varied among herbicides across soil layers, no difference in total leaching was detected for any combination of herbicide and application.

Keywords: Herbicide leaching, herbicide behavior, herbicide mixture

Effect of diethолate on rice germination as affected by temperature (704)

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The use of diethолate for seed treatment in rice acts as a safener to enhance clomazone selectivity. However, the use of diethолate (an inhibitor of P_{450}) in rice may affect seed germination. The objective of this study was to evaluate the effect of seed treatments with diethолate on rice seed germination. The experiment was conducted at Embrapa Temperate Agriculture, Pelotas (RS), Brazil, in a growth chamber with two temperature conditions (20/15 and 25/20 C), with a 12 hr photoperiod. The experiment was a randomized block design in a factorial arrangement. Factor A included two rice varieties; IRGA 424RI and GURI Inta CL. Factor B included the seed treatment: [1] untreated control, [2] diethолate (5 g kg^{-1} seeds), [3] fipronil (0.25 g kg^{-1} seeds) + fludioxonil (0.025 g kg^{-1} seeds), [4] diethолate (5 g kg^{-1} seeds), fipronil (0.25 g kg^{-1} seeds) + fludioxonil (0.025 g kg^{-1} seeds). The germination test (vigor of seeds) was collected with four replications of 100 seeds, performed on filter paper rolls. The counting was performed at 7, 14 and 21 d after initiation of the test, analyzing for normal seedlings. In the first evaluation, in temperature 25/20 C, the seed vigor of IRGA 424RI variety was reduced 25% with use of diethолate compared to untreated control. For the second and third evaluation there was no difference in seed germination. The temperature of 20/15 C there was no influence of the treatments. For the GURI Inta CL variety in temperature 25/20 C, the treatment with diethолate showed a 30% reduction in seed vigor compared to untreated control, but in the final evaluation no difference it was observed in seed germination. At 20/15 C temperature, common in spring times in southern Brazil, rice seeds treated with diethолate had lower germination values.

Keywords: Herbicide, weed control, safener, diethолate

Efficacy of herbicides for *Paspalum plicatum* control at different application times (809)

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Weeds, such as *Paspalum plicatulum* Michx, can interfere with crop development and cause loss of productivity. Among various techniques of weed management, the use of herbicides stands out. The objective of this study was to evaluate the efficiency of herbicides controlling *P. plicatulum* plants. The experiment was carried out in plastic cups, filled with soil and sand (1: 1) containing 60 and 240 d old *P. plicatulum* plants. The herbicides used were: glyphosate – 720 g ae/ha^{-1} (T1), glyphosate – 1440 g ae/ha^{-1} (T2), nicosulfuron – 60 g ae/ha^{-1} (T3), nicosulfuron – 120 g ae/ha^{-1} (T4), ammonium -glufosinato – 400 g ae/ha^{-1} (T5), paraquat – 300 g ae/ha^{-1} (T6), clethodin – 96 g ae/ha^{-1} (T7), haloxyfop – 62 g ae/ha^{-1}(T8), tembotrione – 84 g ae/ha^{-1} (T9) plus a control without herbicide spraying (T10), totaling ten treatments with six replications each. There were five visual injury evaluations recorded once every seven d after application (DAA) and the level of control was given by scores from 0 to 100, where 0 represented plants without toxicity and 100 was accumulation measurements of dead plants, when compared to the control (T1) and dry matter at the end of the experiment. Greater control of plants was observed at 60 d, regardless of herbicide tested. Glyphosate (T1 and T2) and paraquat (T6) were the most effective in controlling *P. plicatulum* in every visual assessment. Haloxyfop (T8), at 14 DAA and clethodin (T7), at 28 DAA had control equivalent to that obtained by glyphosate and paraquat. Aside from tembotrione (T9), all the herbicides reduced the dry matter of *P. plicatulum*.

Keywords: Graminicide, Poaceae, Phytotoxicity, dry matter

The poster in a PDF version is available here.

Response of tomato to simulated soil residues of imazamox (47)

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Imazamox is a selective imidazolinone herbicide applied post-emergence. As imidazolinone herbicides are characterized by extended persistance in various media, there are numerous evidences of their effects on the next susceptible crops in crop rotation schemes.
A laboratory bioassay was conducted to investigate the sensitivity of tomato to the residual activity of imazamox in a sand soil (pH 7.63, humus 0.91%, sand 91.44%, silt 1.32% and clay 7.24%). The effect of three different levels of soil moisture (20, 50 and 70% field water capacity – FWC) was also examined. Imazamox was applied at different rates from 6.25 to 800 µg a.i./kg soil. The parameters measured 21 days after treatment were shoots and roots fresh weight and root length as well as the content of water soluble proteins. The content of soluble proteins was determined by Bradford's method (1976).
Imazamox caused a growth delay and lower protein content at all levels of soil moisture, and the degree of change depended on the application rate. In plants grown in soil with 20% FWC, root fresh weight showed the highest inhibition, root length showed less sensitivity and there was no statistically significant reduction in shoot fresh weight. In soil containing 50% FWC, concentrations ≥100 µg a.i./kg soil caused a significant reduction in root fresh weight and root lenght, while only the two highest concentrations caused a significant reduction in shoot fresh weight. Root lenght was the most sensitive parameter in soil of 70% FWC, while shoot fresh weight was the least sensitive parameter. Soluble protein contents were lower in all trial variants, but the changes did not depend on herbicide concentration.
Acknowledgement: This work was funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia, projects No. TR31043 and III46008.

Keywords: Imazamox, tomato, bioassay, sand soil

The poster in a PDF version is available here.

Increase on atmosphere CO_2 concentration on herbicide selectivity in rice plants (452)

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The consumption of fossil fuels, the burning of forests and industrial activities have contributed to the CO_2 concentration increase in the atmosphere. High level of this gas can directly affects physiological processes and plant growth of both cultivated plants and weeds. The changes vary among species and may affect the selectivity of herbicides. The objective of this study was to evaluate the effect of atmospheric CO_2 concentration increase on herbicide selectivity in rice.
The experiment was conducted in a growth chamber with CO_2 concentration, light, humidity and temperature controlled automatically, in 2015. The experiment design was completely randomized in blocks with four replications in a factorial arrangement. The treatments where: factor A included the herbicides metsulfuron-methyl (2.4 g a.i ha^{-1}), saflufenacil (147 g a.i ha^{-1}), quinclorac (375 g a.i ha^{-1}), bispyribac-sodium (50 g a.i ha^{-1}) and penoxsulan (60 g a.i ha^{-1}) and a control without herbicide application; Factor B were two atmosphere CO_2 concentrations, 400 ppm (current concentration) and the other 700 ppm (estimated level for 2100). The parameters evaluated were phytotoxicity, photosynthetic rate and plant stature. The increase in atmospheric CO_2 concentration does not affect the selectivity of the herbicides tested and do not affect photosynthetic rate in rice plants. Rice plants are taller in an environment with high CO_2.
The authors would like to thank the CNPq and FAPERGS, Brazilian Research Agency (Grants 400897/2014-08 and 0432.2551/14-8), and the University of Pelotas by fund.

Keywords: Carbon dioxide, Environmental, Oryza sativa L., Greenhouse gas

Leaching of commercial mixture with hexazinone + diuron + sulfometuron-methyl in soils by high performance liquid chromatography (511)

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Leaching is the transport phenomenon of substances to depths in the soil profile. Application of two or more herbicides (e.g. hexazinone + diuron + sulfometuron-methyl) is a widely used technique in weed control. Advantages of herbicide application include increased control spectrum, reduced cost and prevention of herbicide-resistant weed species. The objective of this study was to evaluate the leaching potential of the mixture of hexazinone + sulfometuron-methyl + diuron applied to the Brazilian soils [Alfisol – Paleudult, sandy clay texture (sand: 46.6%, clay: 37.6% and silt: 15.8%) and Ultisol – Typic Hapludalf, sandy loam texture (sand: 81.6%, clay: 15.1% and silt: 3.3%)], using chromatographic analysis. Methodology was established based on OECD Guidelines „Leaching in Soil Columns". Three glass columns of 30 cm for each soil type were utilized in this experiment. 200 µL of solution containing the herbicide was applied directly to moist soil at the top of each column. The dose utilized was the highest recommended dose for sugarcane and was equivalent to 391 + 33 + 1,387 g a.i. ha^{-1} of hexazinone + sulfometuron-methyl + diuron, respectively. A flow of approximately 8 mL h^{-1} for 48 h was simulated using a 0.01 mol L^{-1} $CaCl_2$ solution resulting in a rain simulation of 200 mm. At 6, 12, 24, 36 and 48 h after application, leached solutions were collected and the analysis performed. Chromatographic determination of herbicide concentration was performed using HPLC. A total of 52, 69 and 0.2% of the total applied rate of hexazinone, sulfometuron-methyl and diuron, respectively, were found in solution leached through sandy loam texture soil. In sandy clay texture soil, no herbicide was found in leached solutions at any collection time. Soil texture directly influences the leaching of herbicides examined in this study.
Support: Fundação de Amparo à Pesquisa do Estado de Mato Grosso (FAPEMAT).

Keywords: Environmental behavior, leached, pre-emergent, sugarcane

The poster in a PDF version is available here.

Sensitivity of hybrid PR63E82 to tribenuron and propaquizafop in different weather conditions (685)

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The objective of this study was to describe the tolerance of hybrid PR63E82 (ExpressSun technology) to tribenuron (Express 50 SX + Trend 90), propaquizafop (Garland Forte) and their tank-mixture (TM) combination in the base (1X) and double (2X) doses in different weather conditions and growth stages. Herbicides were applied at two times. The first tested treatment (sunflower had two true leaves) followed low temperature (night ground minimum -1 C). A week later, the second treatment was applied (sunflower had four true leaves, night grand minimum after the application was 5.1 C). Ten mm of rainfall were recorded two d before second application. Slight phytotoxicity (8%) was recorded after first application of tribenuron. A higher number of fertile lateral branch occurred only at the 2X dose. Yield of sunflower was not affected. Damage of sunflower was higher on plots treated at the second application time, which was probably caused by rainfall before application. Yield of sunflower were lower compared to untreated check at the second timing. At the 2X dose, a higher number of flower heads (branching stems) were recorded. Sunflower plants treated with propaquizafop showed minimal damage in both tested application timings. Yield or number of flower heads were not affected even at the 2X dose. TM combinations of Express 50 SX + Garland Forte had the highest damaged. The highest phytotoxicity (45%) was observed at the second tested application timing. In both 1X and 2X doses, yield and number of lateral branch were affected compared to untreated check.
The hybrid PR63E82 showed less tolerance to tribenuron, especially in the case of the TM combination with leaf graminicide. Effect of temperature on the sensitivity to tribenuron has not been confirmed. Sensitivity of tested hybrid to the herbicide was influenced more by rainfall before application than by growth stage of sunflower.

Keywords: Helianthus annus, ExpressSun technology, tribenuron, propaquizafop, sensitivity

The poster in a PDF version is available here.

The effect of dose and oxadiargyl application time on weed control in potato (*Solanum tuberosum* L.) (72)

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In order to study the effect oxadiargyl on weed control in potato, a field experimental design was conducted at Alaroog Research Station in Ardabil during 2013. A factorial experiment was arranged in Complete Randomized Design with three replications and potato cultivar was Agria (a common cultivar in Ardabil). Oxadiargyl was used in seven dosages. Zero, 0.16, 0.33, 0.66, 1.33, 2.00 and 2.66 l ha^{-1}. Spraying was done in three stages: potato emergence, stoloning and tuber bulking. The analysis of experimental data by the sigmoidal equations showed that the oxadiargyl application 2.66 l ha^{-1} had maximum effect on weed density and biomass reduction. Oxadiargyl at 1.21 and 0.81 l ha^{-1} reduced 50% of weed density and biomass. In addition, results showed no difference between 2.66 and 2.00 l ha^{-1} for weed density and biomass reduction. Statistical analysis showed that oxadiargyl application at potato emergence had maximum control of weed density and biomass without any difference in stolon development. Oxadiargyl at 2.66 l ha^{-1} at potato emergence increased main tuber weight per plant and total tuber yield.

Keywords: Dose-response, chemical control, Potato growth stage

The poster in a PDF version is available here.

Factors affecting metamitron activity (436)

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A series of pot experiments were conducted to study the impact of growth stage on metamitron efficacy. Eight weed species were grown outdoors and metamitron was applied at the cotyledon stage, cotyledon with emerging true leaves, 2-leaf and 4-leaf stage. In two experiments, the soil versus foliar activity was compared; soil activity was obtained by applying the herbicide solutions directly to the soil surface and foliar activity by covering the soil with vermiculite before an overall spray. One experiment compared the efficacy of metamitron at high and low soil moisture and another experiment examined whether metamitron treatment affected weed sensitivity to subsequent herbicide treatments. Experiments included five doses of metamitron. Data were analysed using a nonlinear dose response model. High responses to growth stages were obtained on *Erodium cicutarium, Polygonum convolvulus, Tripleurospermum inodorum, Geranium molle, Chenopodium album* and *Brassica napus* while less impact of growth stage was observed on *Galium aparine* and *Aethusa cynapium*. Soil activity exceeded foliar activity on *Poa annua* but foliar activity contributed most to the total effect on *C. album* and *Solanum nigrum*. Low soil moisture reduced the soil efficacy on *Stellaria media*. Weeds affected by low metamitron doses tended to be more sensitive to later herbicide treatments.

Keywords: Soil activity, foliar activity, soil moisture, growth stage

Soybean selectivity to pre-emergence herbicides in different soils (441)

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Red rice (*Oryza sativa*) is one of the worst weeds in rice paddy because of morpho-physiological similarity with cultivated rice difficultying the chemical control. A possible alternative to manage this problem is the crop rotation with soybean that allows the use of pre-emergent herbicides and different chemical groups. However, the specific characteristics of lowland soils can affect the activity of candidate herbicides causing losses in soybean and/or insufficient control of the weeds. The aim of this work was to observe the selectivity of sulfentrazone and *S*-metolachlor in different soils cultivated with soybean. In order to conduct the study three lowland soils (Alfisol, Albaqualf 1 and 2) and three upland soils (Ultisol, Oxisoil 1 and Oxisoil 1) with distinct physical-chemical proprieties were collected and used to cultivate soybean. After sowing the herbicides were applied at 0x; 0.25x, 0.5x; 1x; 2x; 4x; 8x and 16x of the label dose of sulfentrazone and *S*-metolachlor. Curves of dose-response were adjusted to the collected data (dry matter) using the log-logistic model ($y=d/1+(x/e)^b$) utilizing the program R with drc package. After the determination of the dose response curves, C_{10} and C_{50} was obtained for each soil. *S*-metolachlor at the recommended dose (1680 g.a.i./ha), did not cause 10% of reduction dry matter (C_{10}), in all soils tested. However, the recommended dose for sulfentrazone (600 g.a.i./ha) caused reduction larger than 50% in dry matter (C_{50}) in Oxisoil 1 (sandy texture). Furthermore, in Albaqualf 1 and 2 the sulfentrazone recommended dose can cause reduction in dry matter, large than 10% considering that C_{10} was 520 and 540 g.a.i./ha. These findings suggests that it is necessary to reduce sulfentrazone dose in soils with high sand, to avoid damage in soybean.

Keywords: Sulfentrazone, s-metolachlor, crop rotation, red rice, dose-response

Session 7
NON-CHEMICAL WEED CONTROL TOOLS

Diversity of weed in a polyculture of tropical species (686)

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To identify weed species and to elucidate their habits of growth and development, diversity of weeds in a polyculture system of tropical species was studied during the dry season in the Soconusco, Mexico region; thus, seven sites formed by ecological neighborhoods were studied: a) papaya Carica papaya L. cv red Maradol, b) banana Musa sp. Colla cv Dominico c) cocoa Theobroma cacao L., as focal trees, and four neighborhoods of cocoa accompanied with shade trees: cassava Manihot esculenta Crantz, chipilín Crotalaria longirostrata L., castor Ricinus communis L. and pigeon pea Cajanus cajan L. Millsp.; those seven ecological neighborhoods, associated with six pineapple plants Ananas comosus L. Merr. Smooth Cayenne cv. Each site was repeated three times and two ecological neighborhoods functioned as experimental unit. The variables studied were: richness and abundance of species, species coverage, weirder species, dry matter production per experimental unit, resistance to glyphosate. We conclude that in a polyculture system of tropical species, the most abundant weeds were Panicum maximum Jacq., Leptochloa filiformis L. Lam Beauv. (Grass), Tridax procumbens L. and Melampodium divaracatum (LC Rich.) DC. (Asteraceae = Compositae), which are positively correlated with the greatest amount of dry matter produced and coverage by species and ecological neighborhood; the weirdest specimens were the ones of the genus Ludwigia sp. (Onagraceae), while the most resistant specimen to glyphosate was Tridax procumbens L. The ecological neighborhood with the most weed dry matter was formed by the cocoa Theobroma cacao L. and chipilín Crotalaria longirostrata L. and the lowest was banana Musa sp. Colla cv Dominico. The ecological neighborhood with the most number of species was cocoa with its neighbor chipilín Crotalaria longirostrata L.

Keywords: Ecological neighborhood, weed richness and abundance, dry matter production of weeds, glyphosate resistance

Weed pressure in response to mulching media during turf establishment (109)

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Turfgrass establishment is often compromised by enhanced desiccation from wind, high temperatures, and reduced water inputs. Application of mulch (ex. cotton gin trash, wheat straw, and hydro-mulch) at time of seeding may increase germination through buffering and insulation. However, mulch may increase weed competition due to the presence of crop or weed seed. Field experiments were conducted in 2008 and 2009 to evaluate the effectiveness of Texas cotton stripper trash and industry standards (hydro-mulch and wheat straw) as mulching media for the establishment of common bermudagrass and buffalograss. The site was tilled to a depth of 10 cm and graded before seeding. Plots (1.2 x 1.8 m) were arranged in a randomized complete block with four replications. A starter fertilizer at a rate of 48.5 kg N ha^{-1} was applied at seeding. 'Sahara' common bermudagrass and 'Topgun' buffalograss were examined at 97.5 and 195 kg ha^{-1}, respectively. Treatments were applied immediately after seeding and consisted of no mulch, unrefined (non-ground) stripper trash (6,515 kg ha^{-1}), wheat straw (4,600 kg ha^{-1}), or hydro-mulch (2,244 kg ha^{-1}). Plots were maintained at 5.0 cm throughout the study. Grid counts were conducted to assess common bermudagrass, buffalograss, and weed cover 4 and 12 weeks after planting (WAP). Common bermudagrass establishment was greatest with no mulch (89%) and hydro-mulch (85%) followed by (fb) wheat straw (70%) and gin trash (60%) 12 WAP. Weed pressure was highest in common bermudagrass plots mulched with gin trash (33%) fb wheat straw (24%) fb no mulch (12%) and hydro-mulch (10%) 12 WAP. Buffalograss establishment was greatest with hydro-mulch (55%) fb gin trash (20%) fb wheat straw (15%) and no mulch (15%) 12 WAP. Weed pressure was highest in buffalograss plots mulched with wheat straw (72%) fb gin trash (52%) fb no mulch (36%) fb hydro-mulch (22%) 12 WAP.

Keywords: Mulch, turfgrass, establishment, buffalograss, bermudagrass

The poster in a PDF version is available here.

Grafting attempts for broomrape management (695)

Ilhan Uremis *(Mustafa Kemal University, Hatay, Turkey),* ***Halit Yetisir*** *(Erciyes University, Kayseri, Turkey),* ***Fatih Karaca*** *(Mustafa Kemal University, Hatay, Turkey),* ***Mehmet Arslan*** *(Erciyes University, Kayseri, Turkey),* ***Ahmet Uludag*** *(Duzce University, Duzce, Turkey)*

Broomrape (*Pheliphanche ramosa* L.) is a foremost problem in most tomato areas, which is an important farming and economic activity in Turkey. A control method itself is not enough to manage broomrape problem. Grafting is a method to control plant pathogens in vegetables. Some commercial tomato varieties Newton, Beril, Selin, Deniz, Logure, King Kong, Yedi, Kemerit and SC 2121 and a wild eggplant species, *Solanum integrifolium*, compared with grafted tomato varieties using splice/tube method in a pot experiment. Scion/rootstock combinations were Newton/ King Kong, Beril/Yedi, Selin/Kemerit. Grafting significantly reduced the number of orobanche (including tubercles) in pots and infested plant (pot) although no resistance was observed. More grafting combinations and field tests should be done.

Keywords: Grafting, *Pheliphance ramosa*, tomato, eggplant, IWM

Mixtures of varieties of spring cereals for weed suppression in organic crop production (321)

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The suppression of weeds exerted by the crop plays a significant role for weed management in organic crop production. Crop species have different competitive abilities against weeds but also crop varieties vary in their suppression of weeds. Previous studies with varieties of spring cereals have demonstrated marked differences in the suppression of weeds caused by different attributes, such as stem height and leaf area index. However, little is known when different varieties of the same cereal species are mixed in different compositions both in terms of the number of varieties included and the seed rates at which they are established. Some studies have focused on yield and disease aspects but this study aimed to identify and select blends of cultivars of spring cereals having a potential for effective weed suppression. The study is part of the PRODIVA project (http://coreorganicplus.org/research-projects/prodiva) which looks at crop diversification as a measure to manage weeds in organic farming.

Here, we present results from field experiments to produce 'ready-to-use' information on variety traits and optimal variety blends providing weed suppression conducted in Latvia and Poland.

Ten barley and six oat varieties, were selected and sown as a sole crop and in mixtures in strict field trials. The selection was mainly based on the earliness, prostrate habit and height of varieties, but also their popularity and suitability for cultivation in a given region of the country and the yield potential were taken into account. The potential of variety mixtures for weed suppression was considered together with other parameters, such as grain yield, grain quality, LAI and tillering ability.

Results show that variety mixtures can improve the competitive ability of both barley and oat as compared to growing a single variety. Some of the tested varieties (barley 'Abava', 'Maali', oat 'Kalle') were particular suppressive when combined in blends.

Keywords: Spring cereals, mixtures, weed suppression, organic production

The poster in a PDF version is available here.

The cover crop kill date: key for the weed control (622)

María Alonso-Ayuso *(Technical University of Madrid (UPM), Madrid, Spain),* ***José Luis Gabriel*** *(Technical University of Madrid (UPM), Madrid, Spain),* ***François Tizon*** *(Université de Rennes, Rennes, France),* ***Juan P DelMonte*** *(Technical University of Madrid (UPM), Madrid, Spain),* ***Miguel Quemada*** *(Technical University of Madrid (UPM), Madrid, Spain)*

Cover cropping is considered a strategy of integrated weed management in agricultural systems. However, the weed suppression effect can vary depending on the species used and the management performed. A field experiment was conducted in Central Spain to study the effect of grass and legume mulches coming from winter cover crops (CC) killed in different dates on weed community (density, richness and diversity of species, and flora composition). Treatments were fallow and two CC species, barley (*Hordeum vulgare* L.) and vetch (*Vicia sativa* L.), sown in October and killed in two different dates in spring with a contact herbicide. Cover crop biomass and chemical composition were determined at the killing date. Soil inorganic Nitrogen was measured before cash crop planting in late April and humidity below the mulch was measured throughout the season. Weed community was studied in different dates. Cover crop species and the kill date affected the weed community in spring. When the commercial plot was sown in late April, the barley and vetch mulches reduced the weed density compared to the fallow in a 68% and 26%, respectively. Richness and diversity of species were reduced for CC treatments as well. The kill date affected the mulch properties and consequently physicochemical parameters in the soil surface were different. A later-killed CC had a better weed control in the early growth stages of the cash crop compared to an early kill date; but it might enhance pre-emptive competition with the cash crop for water and nutrients. The weed flora composition was greatly affected by the CC and the kill date. Therefore, the CC species and the kill date must be considered in order to plan proper and specific weed management strategies, without being in competition with the cash crop.

Keywords: Cover crop mulch, *Hordeum vulgare* L., *Vicia sativa* L., weed suppression, pre-emptive competition

The poster in a PDF version is available here.

Effect of crop rotation on weed seed bank (432)

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Knowledge of weed soil seed bank is of great importance for forecasting weediness for next years. Crop rotation and tillage are two primary practices that have an impact on soil seed bank. In our study, soil samples were taken in order to evaluate the size and species composition of the soil weed seed bank on plots under different growing systems: monoculture of corn of about 40 years, rotation of corn, wheat and soybeans with different fertilization treatments. Samples were collected during October, using probe (diameter 5 cm) to 15 cm depth. Four soil samples collected from 10 sampling points were taken from each of 7 plots. Seeds were extracted from the soil by washing and were determined and counted. Next year (during August) weediness (abundance and species composition) was evaluated in the same plots. The weed seed bank was dominated by *Chenopodium album, Amaranthus retroflexus, Datura stramonium, Sorghum halepense* in all treatments. In the plots which were under wheat in the previous year, besides the listed species, seeds of species characteristic for grain crops were also dominant. The higher number of seeds was observed in treatments where manure was applied. In the unfertilized treatments the seed bank was higher and represented by a higher number of weed species than in other plots. Composition of weed species emerged in the next year were in accordance with results of seed bank analysis and the fact that the investigated plots were seeded to maize. In fact, the dominant species were those typical of row crops.

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Keywords: Crop rotation, seed bank, weed

The poster in a PDF version is available here.

Regulation of perennial weeds considering yield and environmental impact (836)

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Lars Olav Brandsaeter *(Norwegian Institute of Bioeconomy Research, Ås, Norway),*
Kjell Mangerud *(Hedmark College University, Hamar, Norway),* ***Hugh Riley*** *(Norwegian Institute of Bioeconomy Research, Kapp, Norway)*

In organic farming systems weed control is in general performed using mechanical implements especially mouldboard ploughing. However, mouldboard ploughing is directly related to CO_2 losses from the soil, increased use of fuel and repeated soil tillage may cause erosion and loss of nutrients, more so with autumn tillage than with spring tillage. The challenge is to reach an acceptable level of weed regulation and yield in combination with minimum environmental impact. In the present work we have found that, based on the knowledge into weed biology, mechanical and management measures it is possible to plan control of perennial weeds with respect to yield as well as reduced environmental impact.
Root fragments of *Cirsium arvense* present in the upper 5-15 cm of the soil, following spring ploughing, may be strongly hampered by a highly competitive green manure cover-crop (cc) established in the spring (Thomsen et al. 2011). Root fragments may however, be less significant for regeneration and total shoot biomass than the established rootsystem present below ploughing depth (Thomsen et al 2013). In order to reduce the risk of erosion, autumn tillage operations should be avoided. Fallow operations or deep ploughing in spring has been found as affective against weed biomass production as autumn ploughing (Brandsæter and Berge 2012; Thomsen et al. 2015) and no difference in cereal yield (Tørresen et al. 2003; Thomsen et al 2015). The number of fallow operations in spring may be kept to a minimum especially when combined with a green manure cc. Shallow tillage operations in autumn after harvest followed by tine harrowing in autumn should also be further studied. A prolonged period with fallow may have a negative influence on cereal yield and the number of operations for optimization of cereal yield can be lower than that required for maximum weed control.

Keywords: Perennial weed biology, Tillage depth, Timing, Yield

The poster in a PDF version is available here.

Temperature and moisture requirements to reduce seed viability of three prominent weed species in the Pacific Northwest, USA (831)

Pete A. Berry *(Oregon State University, Corvallis, United States),* ***Nami Wada*** *(Oregon State University, Corvallis, United States),* ***Jennifer Parke*** *(Oregon State University, Corvallis, United States),* ***Carol Mallory-Smith*** *(Oregon State University, Corvallis, United States)*

In 2014, nursery and greenhouse products added $830 million to Oregon's economy. Weed control is often rated as the most expensive production costs in nurseries because of the diverse species grown in close proximity; limited number of herbicides can be sprayed without causing injury. Hand weeding is, therefore, the primary weed management with an estimated cost of $2,250 to $8,450 per hectare per year. Soil solarization is a technique where clear plastic is applied to the soil in order to use radiation to heat the soil to a temperature that kills weeds and weed seeds. Little is known about the effectiveness of solarization in the Pacific Northwest where environmental conditions more variable. Preliminary data demonstrated new solarization plastics have resulted in a reduction of weed density from 244 plants/m² to < 4 plants/m². This study determined temperatures required to reduce seed vitality in the specific weed species; *Portulaca oleracea, Chenopodium album,* and *Amaranthus retroflexus* under different moisture treatments. There was a reduction in all three species under moistened conditions with temperatures of 50°C and 55°C after 14 days. Seed viability was reduced between 65 – 95% when weed seeds were in moist conditions of temperatures at 50 C and 55 C. There was no effect on seed viability under any temperature treatment without moisture. In order to reduce seed viability of *Portulaca oleracea, Chenopodium album, Amaranthus retroflexus*, both a temperature of 50°C and moisture are required for solarization to be effective in the Pacific Northwest.

Keywords: Solarization, *Portulaca oleracea*, *Chenopodium album*, *Amaranthus retroflexus*

3D image-based plant modelling for weed detection in row crops (833)

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Image-based models that characterize plant's canopy shape enable evaluating their spatial parameters and can provide autonomous weed-crop classification. Therefore, such models are of great interest for precision agriculture practices. Rapid increase in computing power has made stereovision models an attractive alternative to common single-image-based 2D plant modeling methods. Such models allow complete reconstruction of plant shape and estimation of their growth parameters regardless of imaging conditions. Existing 3D models are limited in handling multiple species and growth stages, and their accuracy is affected by outdoor illumination. This study proposes a novel approach for 3D plant modeling and weed detection. The reconstruction phase of the model integrates local and global optimization criteria, which enables handling the challenging low textures inherent to plant scenes. In addition, it uses a hue-invariant transformation, which has been proven robust for field illuminations, for plant extraction. The model provides a detailed 3D reconstruction of plants' shapes and estimation of their growth parameters, including biomass. The generalized nature of its performance has been demonstrated by reconstructing the geometric shape of different plant species at different growth stages. While general it requires no particular setups or adaptations, and provides accurate estimations of plant height, leaf cover area, and biomass. Furthermore, the detailed reconstructions of the plant's canopy shape along with the accurate parameters estimation proved effective in autonomous weed detection. As the proposed 3D modeling approach requires inexpensive means, is accessible, and efficient computationally, it can be implemented on agricultural vehicles for real-time applications.

Keywords: Structure from motion (sfm), segmentation, weed detection, 3D

The poster in a PDF version is available here.

Weed suppression effect of various cover crops (743)

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Cover crops are receiving an increasing interest due to their multiple role in the agroecosystem. Besides positive environmental effects, cover crops are also important component of Integrated weed and pest management systems. Fast growing and well established cover crops provide strong suppression of weeds during fall and winter period, which can help to reduce soil tillage and herbicide use in the succeeding crops. In years 2011-2013, series of field trials were conducted at the Agricultural institute of Slovenia to study the effect of cover crops on weed control. The cover crops included in the trials and planted in wheat stubbles were: buckwheat, sunflower, oats, ryegrass, niger seed, camelina, radish, rape, crimson clover and lacy phacelia. Compared to fallow plots which were solely cultivated, cover crops significantly reduced weed density and cover in the fall (***P<0.001) and in the early spring of the following year (***P<0.001). Cover crops were terminated and incorporated in the spring of the following year with moldboard plough before planting of spring wheat, spring barley or maize. Contrary to fall and early spring sampling period, 10 weeks after termination and incorporation of cover crops, no significant difference in weed density and weed biomass was observed in the cash crops included in the trial. Cover crops yields in the fall differed significantly between years (***P<0.001). The greatest average fresh and dry matter yield was found in radish and oats. Moreover, these two species also exhibited the strongest suppressive effect in terms of weed density and weed cover reduction. Based on our results, cover crops strongly reduced weed infestation in the late fall and in the following spring, while 10 weeks after tillage and incorporation of cover crops, no effect on weed density and biomass was observed in the cash crops spring wheat, spring barley and maize.

Keywords: Cover crops, integrated weed management, weed suppression, cash crops

The poster in a PDF version is available here.

The influence of crop rotation on weed infestation in maize (229)

Svetlana Chovancova *(Mendel University, Brno, Czech Republic),* ***Vladimir Smutny*** *(Mendel University, Brno, Czech Republic),* ***Jan Winkler*** *(Mendel University, Brno, Czech Republic)*

Crop rotation plays an important role in maintaining productivity of crops. A crop rotation trial was established at the experimental station of Mendel University in cadastral municipality Zabcice, located at less than 25 km south from Brno city (South Moravia, Czech Republic). The altitude is 179 m above sea level, the long-term average annual temperature is 9.2 °C and annual aggregate precipitation is 483.3 mm. The influence of crop rotation on weed infestation in maize was observed in three treatments. The first one was monoculture of maize. Norfolk crop rotation was the second (clover (*Trifolium pratense*), winter wheat, maize, spring barley). The third treatment was a seven-year rotation (gourd alfalfa (*Medicago sativa*) – the first year, alfalfa wheat – the second year, winter wheat (*Triticum aestivum*), forage maize (*Zea mays*), winter wheat, sugar beet (*Beta vulgaris*), spring barley (*Hordeum vulgare*)). Weed infestation were evaluated by counting weeds during maize growing cycle in 2013, 2014 and 2015. Data were statistically analysed by redundancy analysis. A total of 36 weed species was found in maize crop within the three-year monitored period. Results of statistical analysis showed significance at α = 0.002. Based on RDA analysis, the weed species found can be divided into several groups. The first group includes weed species that could be found mainly in maize monoculture: *Datura stramonium*, *Fallopia convolvulus*, etc. The second group of weeds mainly occurred on Norfolk crop rotation: *Chenopodium hybridum*, *Lolium perenne*, etc. The third group of weeds was identified primarily in the seven-year crop rotation: *Cirsium arvense*, *Convolvulus arvensis*, etc. Occurrence of other species were influenced by different factors. Results show that crop rotation significantly influenced the species composition of weeds in maize.

Keywords: Crop rotation, weeds, maize

The poster in a PDF version is available here.

Origin of shoot regrowth of *Cirsium arvense* after simulated soil cultivation (630)

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A commonly used control strategy against the deep-rooted, creeping species *Cirsium arvense* L. is to fragmentise the roots by repetitive soil cultivations, to initiate shoot regrowth that gradually empties the below-ground storage of nutrients. Much effort has been put on studying the capacity of regrowth from root fragments within the top soil. There is, however, evidence that the intact root system beneath ploughing depth play a significant role for regrowth capacity. Two experiments, starting in May (Exp. 1) and August (Exp. 2), respectively, were conducted on a heavy clay soil, severely infested by *C. arvensis.* The aim was to evaluate the actual spatial origin of shoots following soil tillage at 20 cm depth. In both experiments the clay soil from 16 plots (1 m^2 each) was removed to 20 cm depth and replaced by a sandy soil. In half of the plots, all roots of *C. arvense* were separated from the clay soil and thereafter the fragments were replaced at 10 cm depth in the sandy soil layer. No roots were returned back to the remaining eight plots. The origins of all above-ground *C. arvense* shoots were determined in July (Exp. 1) and in June the following year (Exp. 2). In plots with replaced roots, 58% of the emerged shoots originated from below 20 cm (B20), 27% from roots placed at 10 cm depth (F10) and 15% from roots growing in from outside the plot (FS) as means over the two experiments. In plots without returned roots, the corresponding figures were 81% from B20, 2% from F10 and 17% from FS, demonstrating the high capacity of regrowth from the intact root system. No difference was found between treatments in total number of above-ground shoots, implying that returned roots to some extent hampered the growth of shoots from below 20 cm.

Keywords: Cirsium arvense, root fragment, depth

Effect of different tillage methods to the seed productivity of the most common weeds in corn (680)

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Weed seed production is a key factor that affects re-filling of seed bank. Therefore, the study of seed production of all common weed species is required in developing an effective system of weed management. This issue is of particular relevance with the introduction of alternative tillage methods, especially no-till.
During 2010-2014 in research farm „Bohonytske" of the Institute for feed research and agriculture of Podillya in Ukraine we conducted a study on influence of three different tillage methods on reproductive potential of the most common monocot and dicot weeds. Tillage methods were: plowing to a depth of 20-22 cm, disking to a depth of 10-12 cm and no-till. To determine weed seed production we selected 10 plants of each species at 10 points per plot. Data showed that *Chenopodium album L*. under plowing conditions produced 2784 seeds per plant. Using of no-till and disking led to deteriorating growing conditions of *Chenopodium album*, which decreased seed production to 2359 and 2411 seeds per plant. Seed production of *Amaranthus retroflexus L*. in different tillage conditions was 1524-1908 seeds per plant; the lowest seed production was observed under no-till.
Seed production of monocot species was lower than dicots. For example, seed production of *Setaria glauca* L., was 398-500 seeds per plant, and that of *Echinochloa crus-galli (L.)* P. Beauv. was 390-458 seeds per plant. Maximum seed production of both monocot species was observed under plowing.
In our study we found a reduction in seed production of all common species when using disking or no-till. In contrast, application of plowing can provide the best soil conditions to ensure maximum reproductive potential of the weed species.

Keywords: Weed, seed productivity, corn, tillage, no-till

Mulch and PRE herbicide interactions for proactive management of multiple herbicide resistant Phalaris minor in India (640)

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Sole reliance on POST herbicides has resulted in the evolution of multiple resistance in *Phalaris minor* (Littleseed canarygrass), the most ubiquitous weed of wheat in North India. Another sustainability issue in Rice-Wheat cropping system is the production of huge amount of rice residue which is mostly burnt *in situ* leading to soil health and environmental concerns. Utilization of rice residues as mulch can play a vital role in suppressing weeds in wheat but exigent tactics are obligatory for the design of PRE herbicides-mulch combinations for better herbicide performance. With these objectives, field experiments were conducted at CCS, Haryana Agricultural University, Regional Research Station, Karnal, Haryana (India) during winter season of 2014-15 using different mulch levels, PRE herbicides and mixtures, herbicide placement, carrier water volumes, application rates and timings. The results revealed that tank mixture of pendimethalin 1.5 kg/ha+metribuzin 0.140 kg/ha PRE provided significantly better control (84 %) of *P. minor* with high mulch level (12 t/ha) when applied on top as compared to low mulch level (6 t/ha). Emergence of *P. minor* successively reduced, conversely the fresh biomass per plant increased with the increase in mulch levels. In zero till (ZT) sown wheat+rice residue mulch, application of pendimethalin/pyroxasulfone+metribuzin with high carrier volume (1000 L/ha) either as PRE or immediately before the irrigation (20 DAS) significantly improved *P. minor* control than alone application of POST herbicides without causing any crop injury. Increase in herbicide rates didn't improve weed control however, if herbicides were applied under mulch, even reduced rates with lower mulch level provided satisfactory results. Application of pendimethalin 1.0 or metribuzin 0.140 kg/ha PRE alone under 12 t/ha mulch provided 100 % control of *P. minor*. Conclusively, the integration of ZT+ mulch + PRE mixtures is a newfangled alternate strategy to manage resistant *P. minor* and reduce dependence on POST herbicides.

Keywords: Phalaris minor, Mulch, Pendimethalin, Pyroxasulfone, Wheat

Effect of different soil tillage on soil seed bank in long-term trial in the Czech Republic (815)

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Long-term field trial was established on the experimental field station in Žabčice (South Moravia, Czech Republic) in 2003, which is as a model concept for farming with animal husbandry. The principle of this experiment is a 7-year crop rotation (alfalfa, alfalfa, winter wheat, silage maize, winter wheat, sugar beet, sprig barley). This paper evaluates the impacts of different soil tillage (conventional, minimum and no-tillage) with the livestock production management at the most important species of soil seed bank in this area. The evaluation was conducted in the years 2004, 2007 and 2015. Herbicide application was done on occurred weeds every year during whole period of investigation. Our attention was focused on the most frequent weed species in trial, the genus of Amaranth (*Amaranthus* spp.) and fat-hen (*Chenopodium album* L.). Soil samples were taken from all variants of tillage in horizon 0 – 0.3 m by probe. Samples of dry soil weighing 200 g were elutriated with the vibratory sieve shaker ANALYSETTE 3 on a metal sieve with 0.25 mm openings with a mild flow of running water. Only mechanically undamaged seeds (entire) were counted. Kruskal-Wallis non-parametric test was used for evaluation of results. No any statistically differences were found out among variants of soil tillage in different years in amount of seeds of *Amaranthus* spp. and *Chenopodium album* in different soil depth (0 – 0.1; 0.1 – 0.2 and 0.2 – 0.3 m). The highest number seeds of *Amaranthus* spp. were in 2007 and the lowest in final observation in 2015, when the highest seed reduction was in no-tillage variant. In case of *Chenopodium album*, number of seeds decreased gradually in time. In 2015 number of *Chenopodium* seeds were comparable among all variants of soil tillage. This paper was prepared with financial support of the projects no. QJ1530373 and QJ1210008.

Keywords: Soil tillage, weed seed bank, long-term trial

The poster in a PDF version is available here.

Session 8
JOINT IWSS/INTERNATIONAL BIOHERBICIDE GROUP SESSION

Efficacy of *Phoma macrostoma* and *thaxtomin* a on perennial broadleaf weeds in turf (396)

Joseph C Neal *(North Carolina State University, Raleigh, United States),* ***Christopher D Harlow*** *(North Carolina State University, Raleigh, United States),* ***Rocco Schiavone*** *(North Carolina State University, Raleigh, United States)*

Experiments evaluated efficacy of post-emergence applications of bioherbicides on perennial broadleaf weeds in turf. Tests were conducted at North Carolina State University, USA, in established low-maintenance *Cynodon dactylon* turf infested with perennial broadleaf weeds including *Trifolium repens*, *Taraxacum officinale, and Dicondra carolinensis*. Treatments included *Phoma macrostoma* at 6500 and 13000 macrocidin units (mu)/m^2, the phytotoxin thaxtomin A (MBI-005) at 190 and 380 g ai/ha and FeHEDTA at 29.6 and 59.1 kg ai/ha. Experiments included an industry standard synthetic auxin herbicide (2, 4-D + MCPP [mecoprop] + dicamba). *Phoma macrostoma* treatments were made using hand-held shaker jars. Thaxtomin A and FeHEDTA were applied with a CO_2 pressurized backpack sprayer calibrated to deliver 280 or 930 L/ha, respectively. For each bioherbicide, weed control was improved by multiple applications. *P. macrostoma* reduced *T. repens* and *D. carolinensis* ground cover by over 89%, equivalent to the industry standard herbicide. Thaxtomin A caused temporary discoloration of *D. carolinensis* but did not reduce percent cover. Percent cover of *T. repens* increased in areas treated with Thaxtomin A, possibly due to “release” from competition with other weeds. *T. officinale* was controlled 74% by a single application of *P. macrostoma* at 13000 mu/m^2. The high dose of thaxtomin A provided about 50% control of seedling *T. officinale* in pot trials, but less than 20% control of established plants. Combining *P. macrostoma* and thaxtomin A improved control of seedling *T. officinale* in potted-plant tests, but did not enhance control of established weeds in the field. FeHEDTA applications caused rapid foliar necrosis of the three weed species. *T. officinale* exhibited high levels of mortality from FeHEDTA treatments, but *T. repens* and *D. carolinensis* recovered in the spring following autumn treatments. These data are consistent with prior reports that have documented selective control of certain dicot species with these bioherbicides.

Keywords: Biocontrol, turfgrass, Phoma macrostoma, Thaxtomin, FeHEDTA

The poster in a PDF version is available here.

Foliar spray applications with *Phoma macrostoma* for control of *Taraxacum officinale* (22)

Karen L. Bailey *(Agriculture & Agri-Food Canada, Saskatoon, Canada),* ***Russell K. Hynes*** *(Agriculture & Agri-Food Canada, Saskatoon, Canada),* ***Jo-Anne Derby*** *(Agriculture & Agri-Food Canada, Saskatoon, Canada),* ***Dan Hupka*** *(Agriculture & Agri-Food Canada, Saskatoon, Canada)*

Phoma macrostoma 94-44B is registered as a granular-applied bioherbicide that is made using a solid state fermentation process and used for pre- and post-emergent control of broadleaved weeds in turfgrass in Canada and the USA. This study hypothesized that submerged liquid fermentation produces an active ingredient that provides an equivalent reduction of weeds as the *Phoma* granule. The experiment compared a one-time post-emergent application of the *Phoma* granule, *Phoma* liquid, *Phoma* liquid + 1% Silwet, 1% Silwet alone, and Killex® (a standard herbicide for broadleaved weeds) to naturally established *Taraxacum officinale* (dandelion) in turf. The concentration of the *Phoma* active was the same for granule and liquid, but was applied once instead of twice as per the label rate for a post-emergent granule application. Killex was applied once as per label rate. The plots were rated at 0, 2, 4 and 8 wk after application for photobleaching in the weeds and turf caused by the *Phoma* and for % weed cover. Weed reduction was calculated relative to the Silwet control. Turfgrass vigor was also monitored. Dandelion was reduced by 80% with Killex, 75% with *Phoma* liquid + 1% Silwet, 60% with *Phoma* granule, and 50% with *Phoma* liquid. Silwet alone did not reduce dandelion and weed cover increased with time under this treatment. Photobleaching only occurred in dandelion treated with *Phoma*. Turfgrass was reduced in vigor by Killex but recovered by the end of the test. Phoma and Silwet did not reduce turfgrass vigor. A single application of *Phoma* + 1% Silwet provided similar reduction in weeds as Killex and outperformed a single application (1/2X label rate) of the *Phoma* granule. The results provide support for our hypothesis and indicate that a liquid-fermented foliar spray formulation of *P. macrostoma* product would be a suitable alternative to the existing granule.

Keywords: Bioherbicide, mycoherbicide, formulation, dandelion, turfgrass

The poster in a PDF version is available here.

Classical weed biological control: the notable track record of pathogen agents in Australia (754)

Louise Morin *(Commonwealth Science and Industrial Research Organisation, Canberra, Australia)*

Classical biological control (CBC) offers exciting opportunities for weed management and has been extensively used in North America, South Africa, Australia, and New Zealand for several decades. It involves the deliberate introduction of one or more host-specific natural enemies of a target weed from its native range into the region where the plant has become a problem. Once established in the field, biocontrol agents cause recurrent damage to the weed, are self-sustaining and self-disseminating, and thus become a long-term weed management solution without the need to be reapplied year after year. Plant-feeding insects have traditionally been used as biocontrol agents, but since the 70s interest and use of plant pathogens in weed CBC programs have steadily increased. Successful suppression of weed populations by pathogens has been attributed to their ability to adapt readily to the new environment into which they are introduced, their compatibility with the genotype(s) of the weed and their ability to cause severe epidemics. The impact of three pathogens introduced into Australia since 2000 will be discussed: (i) the rust fungus *Puccinia myrsiphylli* on bridal creeper, *Asparagus asparagoides* (Asparagaceae); (ii) the white-smut fungus *Entyloma ageratinae* on mistflower, *Ageratina riparia*; and (iii) the rust fungus *Baeodromus eupatorii* on Crofton weed, *Ageratina adenophora* (Asteraceae). For example, percentage cover and biomass of the weed mistflower at experimental sites were each reduced by more than 50% within 12-18 months of establishment of the introduced pathogen. No non-target impacts have ever been reported following introduction of pathogens for weed CBC in Australia. In most programs, a close partnership with land managers has been crucial to streamline delivery of introduced pathogens across the target weed's range. With such a notable track record in Australia, there is no doubt that pathogens should be more widely explored as potential agents for weed CBC globally.

Keywords: Classical biological control, plant pathogens, environmental weeds, impact, community engagement

The poster in a PDF version is available here.

Raj R. Prasad: Bio-herbicides for integrated management of invasive weeds in forestry (774)

Raj R. Prasad *(Retired scientist, Pacific Forestry Centre, Victoria, B.C., Canada)*

Exotic invasive weeds pose a serious threat to forested and other landscapes in southern British Columbia. Of importance are scotch broom (*Cytisus scoparius*), gorse (*Ulex europaeus*), Himalayan blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*) and daphne surge (*Daphne laureola*). They were introduced as ornamentals in the last century or later and since then have invaded forests, thousands of hectares of urban lands, parks, right-of-ways, roadsides and are displacing/damaging the native species. Gorse is also associated with forest fires because its dried biomass with volatile oils, high fuel-load is highly combustible. Field experiments were carried out to control it by a chemical herbicide (triclopyr), a new formulation of a bio-herbicide (*Chondrostereum purpureum*), a manual cutting method and uses of a mulch. The herbicide (480 gm/L) and the bio-herbicide formulation (with active mycelia and adjuvants to prolong shelf-life) were applied by a squeeze bottle (3 ml/cut stem). The black mulch was a commercial plastic sheet, fitted to cover the entire cut stem surfaces devoid of light and small animal nests. Efficacy was measured by the degree of re-sprouting of the cut stems by which gorse propagates. Details are described in the poster. Results showed that the integrated approach with application of the herbicide, a new formulation of the bio-herbicide and mulching offered a significant control in re-sprouting behavior of the gorse. The new formulation of the bio-herbicide was patented in Canada and U.S.A. and now an improved formulation (Chontrol) is widely used for vegetation management by hydro, utility lines in Canada and U.S.A. Similarly two other bio-herbicides based on *Fusarium tumidum* and *Phomopsis* species have been found to control scotch broom and Daphne surge respectively.

Keywords: *Chondrostereum purpureum*

The poster in a PDF version is available here.

Biological control – a potential solution for some of Europe's most intractable weeds (472)

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The introduction of the EU Water Framework Directive (WFD) requires European waterways to reach a 'good ecological status', a goal that is compromised by the presence of invasive weeds. Conventional methods of control can face major challenges for several reasons, including the restrictions of chemical use in or near water bodies, and the prolific vegetative growth of these plants that can be exacerbated by manual control. In order to achieve the aims of the WFD, the UK government has been funding CABI to investigate an alternative method of control; classical biological control. Research has been undertaken to investigate the potential for biological control of three non-native invasive riparian and aquatic weeds; *Impatiens glandulifera*, *Hydrocotyle ranunculoides* and *Crassula helmsii.* The research for the control of the riparian species, *I. glandulifera* is the most advanced of the three. In 2014, after four years of safety testing, the rust fungus *Puccinia komarovii* var. *glanduliferae* became the first fungal classical biological control agent to be released against a weed in Europe. Updates on the research that has taken place since the initial release will be presented. For *H. ranunculoides*, research is focussed on an Argentinian stem mining weevil, *Listronotus elongatus* and for the control of *Crassula helmsii*, an Australian gall forming mite, *Aculus* sp., is under investigation. The objectives in 2016 are to have drafted Pest Risk Analyses for these two biocontrol agents, to present the results of rigorous specificity screening and to allow the UK government to assess theirsuitability for release into the environment to control these pernicious weeds. A summary of the research on these agents and future scope of the projects will be presented.

Keywords: Weed Biocontrol, *Impatiens glandulifera*, *Crassula helmsii*, *Hydrocotyle ranunculoides*

The poster in a PDF version is available here.

Effect of globe artichoke (*Cynara cardunculus* L.) aqueous extracts on hormone homeostasis and α-amylase activity of Johnsongrass (*Sorghum halepense*) rhizomes (781)

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The allelopathic effects of globe artichoke (*Cynara cardunculus* L.) on growth, lipid peroxidation, and hormonal content of Johnson grass (*Sorghum halepense*) rhizomes were assessed. Treatments consisted of globe artichoke aqueous extracts used as irrigating water. The results showed decreased seedling fresh biomass, shoot height, α-amylase activity, indole acetic acid concentration, and gibberellin concentration of Johnson grass rhizomes with increasing globe artichoke extract concentrations. The lowest α-amylase activity (1.33 nmol g rhizome min^{-1}) and concentration of indole acetic acid (74.2 μg g^{-1}), and gibberellin (108.2 μg g^{-1}) in Johnson grass rhizomes was obtained when 100% aqueous extract of globe artichoke was applied. Malondialdehyde and abscisic acid concentrations (0.77 μmol g^{-1} FW and 151.3 μg g^{-1}, respectively) in the rhizome were the highest when seedlings were treated with 100% aqueous extract of globe artichoke. There were significant negative correlations between globe artichoke total phenolic content with indole acetic acid content (r = – 0.83), gibberellin content (r = – 0.75), α-amylase activity (r = – 0.84) and seedling weight (r =-0.79) in Johnson grass rhizomes. Thus, globe artichoke extract inhibited Johnson grass rhizome growth via increased lipid peroxidation and decreased plant hormonal activities such as indole acetic acid and gibberellin.

Keywords: *Cynara cardunculus*, Abscisic acid, Antioxidant

Practical use of brassicas in weed control (718)

Ahmet Uludag *(Duzce University, Duzce, Turkey),* ***Ilhan Uremis*** *(Mustafa Kemal University, Hatay, Turkey)*

Brassica species are well known for their alleopathic affects. The weed control potential of the garden radish (*Raphanus sativus*) has been studied in Turkey since the1990s and in earlier times it had been used in cotton fields to control johnsongrass. Our studies show that several weed species can be controlled with garden radish in several crops. Field studies showed that the radish can be useful for weed control when grown as a crop within a rotation plan of different crops and when grown as a companion crop. We have shown that other brassica species may also control johnsongrass and some other weed species. Our results suggest that garden radish and other brassicas have a potential role to play in an integrated weed management programme in many cropping systems.

Keywords: Garden radish, brassicas, johnsongrass, extension, IWM

Probing a fungal phytotoxin, phaeosphaeride A, as a biorational herbicide (438)

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Phaeosphaeride A (PhA) was identified to be a major compound from a solid state culture of *Paraphoma* sp. VIZR 1.46 isolated from leaves of Canada thistle (*Cirsium arvense*). This compound is structurally related to a known phytotoxin triticone A and demonstrated non-host specific phytotoxic activity by a leaf disc-puncture bioassay at the concentration 1-3 mM. We evaluated herbicidal potential of phaeosphaeride A (phA) by examining production and application of this fungal phytotoxin and its safety aspects. A simple HPLC technique for detection of PhA in solid substrates (pearl barley, rice and millet) was developed. It allowed the detection of PhA at a level about 1 mg/kg of the substrate with >85% recovery. Maximal yield of the phytotoxin (> 1.5 g/kg) was found in one-month cultures of *Paraphoma* sp. on pearl barley. The high yield of PhA allowed the synthesis of a number of its derivatives to confirm the structure and locatereaction centers. The addition of some commercial adjuvants (Biopower, Trend-90 and Hasten) at the final concentration of 0.1% into 0.1% solution of PhA dramatically increased the phytotoxic activity of the compound on intact leaf segments of *C. arvense* and *Elytrigia repens*. At the concentration of 0.5%, crude fungal extract containing about 50% of PhA caused fast, full mortality of Canada thistle plants at the rosette stage. Finally, PhA was shown to be an ecologically safe substance. The culture of the infusorium, *Colpoda steinii* was slightly sensitive to PhA at the concentration of 0.1 mg/mL. PhA was non-toxic to 10 bacterial and fungal species at the concentration of 100 mkg/disc. In conclusion, it is important that the application technique of PhA be further optimized to decrease its effective concentration. In the case of success, PhA can be a promising active ingredient for the development of a novel biorational herbicide.

Keywords: Biorationals, natural herbicide, phaeosphaeride A

Phytotoxic activity of leaf extracts of *Bidens sulphurea* on germination and seedling growth and composition (659)

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Bidens sulphurea (Cav.) Sch. Bip. is a species that was introduced in Brazil as an ornamental and became a problematic weed. This plant grows rapidly and is a dominant plant, probably due to its allelopathic activity. This feature of *B. sulphurea* makes it a potential source of natural herbicides. When isolated and characterized they can be used directly or synthesized to new related compounds. This study was designed to evaluate the phytotoxic activity of *B. sulphurea* extracts. We employed a reversed-phase column chromatography to fractionate the dichloromethane leaf extract (previously evaluated as the most active), using water / methanol: Fraction A (100% water), B (20, 40 and 60 % methanol), C (80% methanol) and D (100% methanol). When wheat coleoptile bioassay was carried out, it was observed that extracts B, C and D were more active. These extracts were tested on germination and growth of seedlings of Standard Target Species (STS) (*Lepidium sativum* – cress, *Lactuca sativa* – lettuce, *Allium cepa* – onion and *Lycopersicum esculentum* – tomato), as well as the weeds *Amaranthus viridis, Brachiaria decumbens*, *Echinochloa crus-galli* and *Panicum maximum*, at concentrations of 0.1, 0.2, 0.4 and 0.8 mg mL^{-1}. We concluded that these fractions provoked a significant reduction in all parameters evaluated in the STS and in the weeds; fractions with B and C showing greatest activity. We highlight the inhibitory activity of fraction C on germination and growth of root/shoot of *A. viridis*, with reductions over 90% at 0.8 mg mL^{-1}, remaining 65% at 0.2 mg mL^{-1}. Fraction C also showed selectivity to lettuce. From these extracts, reynosin, costunolide and santamarin have been isolated as major components. We can conclude that the high phytotoxic activity of this extract may be due to the presence of these compounds, ensuring the establishment of *B. sulphurea* in the environment.

Keywords: Cosmos sulphureus, Allelopathy, Allelochemicals, Natural herbicides

The poster in a PDF version is available here.

Potential biocontrol agents from the mycobiota of *Schinus terebinthifolius* collected in its native range in Brazil: an overview (251)

Davi M Macedo *(Universidade Federal de Viçosa, Viçosa, Brazil),* ***Gregory S Wheeler*** *(USDA, Fort Lauderdale, United States),* ***Robert W Barreto*** *(Universidade Federal de Viçosa, Viçosa, Brazil)*

Brazilian peppertree (*Schinus terebinthifolius* – Anacardiaceae) is a major ecosystem invader in the United States (Florida, California and Hawaii), Australia, Mauritius and other oceanic islands. It has been a target for biological control for half a century. Although a range of arthropods have been investigated there has been few introductions and no example of significant success after their release. The evaluation of microbial natural enemies, mostly fungal pathogens, is relatively recent and also unraveled a long list of species. Several were found to be new to science, demonstrating the lack of information on this diverse mycobiota. Two have been selected and evaluated as potential biocontrol agents, namely the foliage pathogens: *Septoria* sp. and *Corynespora cassiicola* f. sp. *schini.* A recent finding is that of a new species of *Claviradulomyces*. This cryptic fungal species may be behind an ubiquitous and highly debilitating die-back found in Brazil that may be the main factor that keeps this species in control in the field in Brazil. Although challenging to manipulate it deserves the attention of biocontrol scientists in the future. These and other fungal species and the diseases they cause will be discussed. The study of the mycobiota of *S. terebinthifolius* is a good example of the combination of the pratical search for biocontrol agents and the expansion of the frontier of the knowledge about the world mycobiota.

Keywords: Fungi, biological control, plant diseases, tree invaders, biological invasions

Kordyana brasiliensis: the new biocontrol promise against the invasive weed *Tradescantia fluminensis* (375)

Davi M Macedo *(Universidade Federal de Viçosa, Viçosa – Minas Gerais, Brazil),* ***Louise Morin*** *(CSIRO, Canberra, Australia),* ***Robert W Barreto*** *(Universidade Federal de Viçosa, Viçosa – Minas Gerais, Brazil)*

Wandering Jew or trad (*Tradescantia fluminensis* – Commelinaceae) is a major ecosystem invader in New Zealand, Australia, Portugal and the United States. It forms dense mats under the forest canopy interfering with nutrient cycling, establishment of seedlings of native plants and ecosystem biodiversity. It is broadly acknowledged that biological control is the only viable method of control capable of mitigating such invasions. The search for arthropod and fungal natural enemies in the native range of *T. fluminensis* in Brazil started in 2003 and yielded numerous insects and fungi of interest for biological control. Three insect species have already been released in New Zealand after detailed screening and safety evaluation. Among fungal pathogens, the newly-described species *Kordyana brasiliensis*, the agent behind a white smut-like disease of trad was selected for further evaluation. Its safety in terms of host-specificity was demonstrated through a shade-house test involving members of the Commelinaceae and other monocot families and also through spore-drop tests under controlled conditions in Brazil and Australia. Its release in Australia and New Zealand now depends on the availability of funding for the final stage of evaluation and reporting. It is expected that the taxonomic affinity of *Kordyana* with *Entyloma*, the agent of white smut of mistflower (*Ageratina riparia*) that has proved so successful in New Zealand, and the similarity of the diseases caused by these two fungi, will also prove equivalent in terms of their impact on the target-weed after release in Australia and New Zealand.

Keywords: Biological invasions, Plant pathology, Taxonomy

Stimulant dependent host specificity of root parasitic weeds (*Phelipanche* and *Orobanche* spp.) (652)

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Broomrapes are among the most economically damaging parasitic weeds, posing major constraints on the productivity of important crops. We examined the germination response specificity in three broomrape species by quantifying their ability to germinate in the rhizosphere of sunflower and of tomato, examining their germination response to root extracts of these crops, and developing their dose response curves with strigolactones (SLs) and sesquiterpene lactones (STLs), which are known to be exuded from host roots. We further computed the germination rate log of the median effective dose (ED50) values for each stimulant/parasite combination, which enabled classifying the parasites' response to stimulants into specificity groups. Response to stimulants exhibiting very low ED50 rates, ranging 10^{-11}M to 10^{-10}M, is highly specific; response to stimulants with ED50 between 10^{-10}M and 10^{-8}M has low specificity, while lower ED50 values considered non-specific. Accordingly, the *Orobanche cernua* response to the SLs orobanchol, 2'epiorobanchol, 5-deoxystrigol and fabacyl acetate was highly specific, consistent with the extract profile of tomato and other Solanaceae crops that serve as its common hosts and with its germinability in their rhizosphere. There was no *O. cernua* response to the examined STLs dehydrocostus-lactone and costunolide, which are exuded from sunflower roots. *O. cumana*, a specific parasite of sunflower, does respond to these STLs at high specificity and uniquely germinates in the sunflower rhizosphere. *O. cumana* response to the examined SLs was less specific. *Phelipanche aegyptiaca* has a much wider host range, parasitizes both sunflower and Solanaceae crops, and has higher ED50 rates indicating its less specific response to the examined stimulants. These results created precise tools to study germination specificity mechanisms of the above broomrape species.

Keywords: Broomrape, Dose response, Stimulants, Sesquiterpene lactones, Strigolactones

The poster in a PDF version is available here.

Effect of aboveground and underground insects on *Cirsium arvense* growth from the native and invasive area (720)

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This work studied the effect of single natural enemies and their combinations on *Cirsium arvense* on plants from the native and invasive ranges. To do this we performed a common garden experiment. Herbivore insects were added to *Cirsium arvense* was planted in March 2008 from seeds collected in USA (invasive range) and Europe (native range). The treatments where aboveground insects were added included leaf herbivores, stem herbivores and floral/seed head herbivores, individually and in combination. Another treatment simulated root herbivory. Soil nutrients were manipulated to study how herbivores affected plant performance. Our hypothesis was that plants from the invasive range would suffer less and be bigger than those from the native range, as the Enemy Release Hypothesis says. We also supposed that plants growing in different soil types would have a different growth and response to herbivory. In plants with the addition of all aboveground insects (*Cassida rubiginosa*, *Urophora cardui*, *Rhinocyllus conicus*), aboveground biomass, number of flower heads and flower head biomass were higher, but this difference was larger in 2008 than in 2009 and larger in the native range than in the invasive. Flower head biomass and number of flower heads were not significantly different in combination with all aboveground insects as compared to single insect additions. These results partially support the complementary herbivore hypothesis since the effect of adding insect groups was bigger than when insects were added separately. The effect was, however, not always significant suggesting that the insects are complementary under some circumstances but not under others.

Keywords: *Cirsium arvense*, *Rhynocillus conicus*, *Cassida rubiginosa*, Cleonis pigra, native and invasive range

Herbicidal characteristics of secondary metabolites from *Streptomyces* sp. KRA14-329 and their possible mode of action (746)

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Approximately 600 Actinomycete strains were isolated from soil samples collected from forests in Korea. The isolates were assessed for their herbicidal activities, and KRA14-329 was found to have strong herbicidal activity. Based on 16S rRNA gene sequence analysis and morphological characteristics, KRA14-329 was confirmed to be *Streptomyces* sp. NMR and ESI-MS analyses of the *Streptomyces* identified cyclohexamide compounds, 329-M1 and 329-M2, which contained glutarimide moiety in their structures. This study was conducted to determine characteristics and mode of action of these two active herbicidal compounds isolated from KRA14-329. To evaluate herbicidal activity of the isolates, 329-M1 and 329-M2 were applied at 62.5, 125, 500 μg mL^{-1} as a foliar application to four grass species, *Sorghum bicolor, Echinochloa crus-galli, Agropyron smithii,* and *Digitaria sanguinalis*; and four broadleaf species, *Solanum nigrum, Aeschynomene indica, Xanthium strumarium*, and *Calystegia japonica*. Application of 329-M2 at 125 μg mL^{-1} provided complete control of broadleaf species by seven days after treatment while, at 250 μg mL^{-1}, it provided complete control of all treated plants. Plants treated with 329-M2 showed visible symptoms of herbicidal effect within 24 hours, starting with wilting which advanced to burndown followed by desiccation and death. Levels of electrolyte leakage, chlorophyll contents, and malondialdehyde production were measured in the 329-M2 treated plants and compared to those of plants treated with non-selective herbicides, paraquat and glufosinate-ammonium. The effects of 329-M2 were found to be dose- and time-dependent in all three measurements and were approximately half the levels of effects caused by paraquat or glufosinate-ammonium. Thus, the herbicidal action mechanism of 329-M2 does not appear to be direct disruption of cell membranes. The results of this study showed that 329-M2 isolated from *Streptomyces* KRA14-329 has potential as a biocontrol agent and may be used as a lead compound for development of a natural herbicide.

Keywords: Streptomyces, Secondary Metabolites, cyclohexamide, natural herbicide

The poster in a PDF version is available here.

Phytotoxic metabolites produced by *Phoma chenopodicola* as potential natural herbicides (595)

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Chenopodium album L., also known as common lambsquarters or fat hen, is a weed of arable crops such as sugar beet and maize worldwide. Difficulties in managing this weed have prompted interest in searching for alternatives, such as fungal pathogens as biocontrol agents, or for their bioactive, secondary metabolites as novel natural herbicides. *Phoma chenopodiicola*, a pathogenic fungus, has been proposed as a potential mycoherbicide for the control of the weed. When grown *in vitro*, from the organic extract obtained from the culture filtrates was isolated a new unrearranged *ent*-pimaradienediterpene, named chenopodolin, which displays phytotoxic activity, causing necrotic lesions on leaves of fat hen and of several other weeds. The structural features responsible for this activity were highlighted by a structure-activity relationship study carried out with five toxin derivatives. A successive investigation of the organic extract enabled us to isolate three new tetra-substituted- furopyrans, named chenopodolans A, B and C, together with the well-known fungal metabolite (-)-(*R*)-6-hydroxymellein. Additionally, three other metabolites were isolated and named chenopodolin B, chenopodolan D and chenisocoumarine, being structurally related to chenopodolin, chenopodalans and 6-hydroxymellein, respectively. Furthermore, the organic extract showed phytotoxicity higher than that expected and upon further analysis, we found other bioactive metabolites that may explain the high level of phytotoxicity.

Keywords: *Chenopodium album*, *Phoma chenopodiicola*, fungal pathogen, bioactive metabolites

The poster in a PDF version is available here.

Phytotoxic metabolites produced by *Colletotrichum gloeosporioides* as potential natural herbicides for the control of *Ambrosia artemisiifolia* (594)

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Ambrosia artemisiifolia L., (common ragweed) is a native to North America that has become a widespread and troublesome invasive weed of cultivated and uncultivated areas all over the World. Besides the difficulties of its management as a weed, the major concern is its pollen grain that is carrier of noxious allergens which cause sensitization of the allergenic human population, generating huge medical costs. Searching for alternatives to the classic methods of controlling this weed, a strain of the fungal pathogen *Colletotrichum gloeosporioides*, responsible for necrotic spots on *A. artemisiifolia* leaves and stems, was studied for the possible production of toxic metabolites that might be used as natural herbicides against the weed. When grown in a defined liquid medium the fungus produced phytotoxic filtrates that were exhaustively extracted with EtOAc. The organic extract, retaining the phytotoxicity, was purified by column chromatography affording four phytotoxic fractions. The residues of these four fractions were purified by several TLC steps yielding two pure metabolites. These were assayed on punctured detached *A. artemisiifolia* leaves and induced wide necrosis very similar to those caused by the pathogen; the same metabolites also on excised plants showed high phytotoxicity.

Keywords: *Ambrosia artemisiifolia*, *Colletotrichum gloeosporioides*, phytotoxins, biocontrol

The poster in a PDF version is available here.

Phytotoxic activity of sesquiterpene lactones of *Bidens sulphurea* (660)

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Bidens sulphurea (Cav.) Sch. Bip. is a species introduced in Brazil, able to establish into the environment as a dominant plant, due to its allelopathic potential. This attribute of *B. sulphurea* is a potential source of natural herbicides (allelochemicals). Due to the activity previously evaluated in dichlorometane leaf extract, we employed a reversed-phase column chromatography, and isolated three sesquiterpene lactones as major components: reynosin, costunolide and santamarin. Sesquiterpene lactones are one of the most abundant families of natural products. These are found in plants mainly in the Asteraceae family, which *B. sulphurea* belongs. It is widely reported in the literature that these compounds have a variety of biological and pharmacological activities. When wheat coleoptile bioassay was carried out, at concentrations of 1000, 300, 100, 30 and 10 µM, it was observed that these three lactones showed inhibitory effect on the elongation of wheat coleoptiles over 90% at the highest concentration, 1000 µM. Costunolide proved to be the most active one, with a reduction of 88% even at a concentration of 100 µM. Phytotoxic study with these sesquiterpene lactones is being carried out for evaluating germination and seedling growth of Standard Target Species (*Lepidium sativum* – cress, *Lactuca sativa* – lettuce, *Allium cepa* – onion and *Lycopersicum esculentum* – tomato) and weeds (*Amaranthus viridis, Brachiaria decumbens*, *Echinochloa crus-galli* and *Panicum maximum*).

Keywords: Allelochemicals, Reynosin, Costonulide, Santamarin, Cosmos sulphureus

The poster in a PDF version is available here.

Insect as a biocontrol of *Ambrosia artemisiifolia* (484)

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Common ragweed (*Ambrosia artemisiifolia*) is an invasive alien species indigenous to North America. Ragweed is a big threat to agriculture and has a serious impact on human health. The species is an excellent target for biological control. However, impact of native herbivores as well exotic ones in invaded areas is poorly known. We investigated the regional and habitat differences in ragweed's insects during 2013-2015. The emphasis was to compare the composition and structure of the herbivore communities among populations over large areas (Slovakia, Italy, and Switzerland). Hereto, the identical sampling protocols were used to survey insect across various populations. The field surveys were complemented with open field simulating herbivory experiments in the garden. These field experiments helped to detect impact on ragweed growth. In addition to the native herbivores, one alien insect species was in the spotlight. The ragweed beetle, *Ophraella communa* LeSage (Coleoptera: Chrysomelidae) is a North American species which was first time noted in North Italy (Lombardia) and South Switzerland (Ticino). Most of the common ragweed populations in this area are heavily attacked by *O. communa*. This species is regarded as a successful biological control agent against *A. artemisiifolia* in China. However the threat to closely related wild or crop species and the level of their damage under field conditions remain unclear. Here we investigated the potential of *O. communa* to feed on non-target host plants in the field. The most examined non-target plants were *Artemisia vulgaris* L., *Conyza canadensis* (L.) Cronq., *Helianthus annuus* L., *H. tuberosus* L., *Inula* spp., *Persicaria maculosa* S. F. Gray, *Xanthium strumarium* L. and *Zea mays* L.. All of the research topics will be discussed and potential of insects for biological control highlighted. *Financial support: Scientific Grant Agency VEGA 1/0827/14 and COST action FA1203 SMARTER.*

Keywords: Common ragweed, native herbivores, ragweed beetle, Ophraella communa, herbivore communities

Prospects of biotechnology in enhancing weed management (483)

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Current applications of biotechnology in agriculture have already resulted in increased yields, reduced pesticide use and saving of farmers' time and money by using techniques like recombinant DNA, genetic engineering, tissue culture, clonal propagation. Currently biotechnology also offers promising approaches to solve emerging problems in weed control. There is an enormous rush to discover effective, economically feasible and environment-friendly herbicides. Bioherbicides containing plant pathogenic viruses, bacteria and fungi are often natural herbicides and effective where weeds are augmented by massive inoculation of the pathogen with enhanced disease-causing potential. Similarly, naturally-occurring phytotoxic compounds derived from plants such as sorghum and parthenium have allelopathic potential against weeds. Several biocontrol agents are being used to control different weeds. The application of biotechnology to enhance biocontrol agents will undoubtedly lead to better control options that will compete successfully with their chemical counterparts. Biocontrol agents may become more effective, as well as safer, when rendered hyper-virulent, yet non-problematic, by biotechnology. Application of tissue culture and genetic engineering into plants to make them transgenic with resistance to herbicide is a significant application of biotechnology in weed management. The particular advantage that genetic engineering offers is that the desired genes can be transferred without co-transfer of undesired characters and it enables transfer of genes across species barriers. Herbicide resistant crops containing transgenes that imparts resistance to non-selective herbicides such as glyphosate have been of considerable benefit. These products help the farmers to eliminate use of some of the more environmentally unsafe herbicides and use fewer herbicides to manage a spectrum of weeds. Thus application of biotechnology holds great promise in improving already existing biocontrol practices as well as adding new dimensions to the same.

Keywords: Enhancing biological control, biotechnology, bioherbicides

The poster in a PDF version is available here.

Phytotoxic activity of selected medicinal and aromatic plants (MAP's) (805)

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Medicinal and Aromatic plants (MAP's) have received much attention as sources of biologically active substances and for their useful bioactive compounds with particular emphasis on their antifungal, cytostatic, insecticidal and herbicidal activities. The species of the botanical genera *Origanum* and *Corydothymus* are widespread in the Mediterranean area. Both plants produce hydrosols containing traces of bioactive essential oils. The aim of this study was to evaluate the hydrosol phytotoxicity of the aforementioned MAP's focusing on their potential herbicidal use. Plant tissues (leaves, inflorescences) from *Origanum vulgare* spp. *hirtum* (L.) Letsw. and *Coridothymus capitatus* (L.) Reichenb. fil.were collected at full blooming, air dried and then subjected to hydrodistillation and chemotypical analysis of their essential oils. The hydrosols and aqueous dilutions of 100%, 50%, 25%, 12,5%, 6,25%, 3,125% v/v were tested for their phytotoxicity on the weed: *Lolium multiflorum* Lam. and on the bioindicators: *Avena sativa* L. and *Lemna minor* L. Petri dishes incubating assays (with 3 replications) were used to evaluate seed germination, the shoot and the radicle growth of *Avena* and *Lolium* and the fronds growth of *Lemna* in aqueous culture on a daily basis for 10 days. Estimating the Inhibitory Index ($I_{50\%}$) based on dose response curves, *Origanum* hydrosol appeared to be more phytotoxic compare to *Coridothymus* in both land species tested. Similarly, *Lemna* was highly inhibited by *Origanum* hydrosol. The experiment was repeated with the same results. Taking into account the increasing interest to obtain alternative new herbicidal agents for weed control, the data showed that the MAP's have potential as a new "phytochemical pool" that would produce environmentally acceptable, natural, biodegradable compounds.

Keywords: Phytotoxicity, hydrosols, Origanum, Corydothymus

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Differential responses of *Rubus armeniacus* and *R. praecox* to rust disease by *Phragmidium violaceum* in the USA (335)

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Five species of *Rubus fruticosus* Aggregate (Blackberry), i.e., *R. armeniacus*, *R. praecox* (published as "*R. anglocandicans*"), *R. laciniatus*, *R. vestitus*, and *R. ulmifolius*, are established along the West Coast of the United States (USA). The most widespread and invasive is *R. armeniacus*, occurring all along the Pacific Coast. A second invasive cryptic species, *R. praecox*, occurs commonly with *R. armeniacus* but only between northern California and Washington State. In 2005, *Phragmidium violaceum* was discovered in Oregon causing a rust disease. It is a candidate biological control agent for invasive blackberry in the USA, having been deployed previously in Australia with some success. Anecdotal observations at the time of discovery in the USA were that the disease had eliminated some blackberry thickets in Oregon. Even so, blackberry remains invasive and not all individuals within remaining populations are diseased. Objectives of this study were to determine the status of *P. violaceum* on invasive blackberry in Oregon and thus its potential as a biological control agent. Morphological characteristics useful in separating *R. armeniacus* from *R. praecox* facilitated field assessment of disease at >30 sites in Oregon and interpretation of data from artificial, greenhouse inoculation of blackberry collections from >15 representative sites by Elk River, Oregon with *P. violaceum*. *R. armeniacus* was not diseased either in our greenhouse tests or in the field, while *R. praecox* was. Thus, the most common species of invasive blackberry along the Pacific coast of the U.S., *R. armeniacus*, is unlikely to be affected by the rust disease in the USA. Also susceptible in these tests was *R. laciniatus*; *R. vestitus* was diseased in the field but not tested in the greenhouse. Not found in Oregon was *R. ulmifolius*. This is a critical first step in developing biological control or other strategies for management of invasive blackberry.

Keywords: Biological Control, Plant Disease, Rust Fungi (Uredinales), Invasive species

The poster in a PDF version is available here.

The bioactivity of phytotoxic compounds from, and mechanism of appressorium formation in, *Exserohilum monoceras* on the leaf of *Echinochloa crus-galli* and *Oryza sativa* (45)

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Barnyardgrass (*Echinochloa crus-galli* L.) is a problematic weed worldwide that reduces the yield of rice (*Oryza sativa* L.). The fungus *Exserohilium monoseras* (Drechsler) Leonard and Suggs is a potential biocontrol agent for the weed. The two aims of this study were (i) to isolate and identify the phytotoxic compounds from *E. monoceras* strain X27 and (ii) to determine the mechanism of appressorium formation on the leaves of barnyardgrass and rice. The fungus was cultured in potato dextrose (PD) media. A crude extract of X27 fermentation filtrate (5.0 g/L) inhibited the barnyardgrass shoot growth by 95% and root growth by 79%. The crude toxins in the fermentation filtrate were isolated using thin-layer chromatography. Four compounds were isolated and identified by gas chromatography-mass spectrometry (GC-MS); oleic acid amide ($C_{18}H_{35}NO$), dibutyl phthalate (DBP; $C_{16}H_{22}O_4$), stearic acid ($C_{16}H_{32}O_2$), octadecanoic acid ($C_{18}H_{36}O_2$). Of these 4 compounds, DBP showed the greatest effect, decreasing root growth by 84% and shoot growth by 76% at 1 g/L concentration. At the 3~4 leaf stage of barnyardgrass and rice infected by *E. monoceras*, the epicuticular wax was removed and analyzed by GC-MS. Four compounds were isolated and identified; fatty acids, primary alcohols, aldehydes, alkanes. The alcohol (C_{32}), aldehyde (C_{18}) and alkane (C_{33}) were main constituents by 18.96%, 14.61% and 14.83% in barnyardgrass epicuticular wax, and by 0.65%, 21.77% and 5.49% in rice. But alcohol (C_{30}) was present by 32.71% in rice epicuticular wax and by 9.43% in barnyardgrass. So, we suspect that the aldehyde (C_{18}) and alkane (C_{33}) have an effect on appressorium formation of *E. monoceras in* barnyardgrass leaves.

Keywords: *Echinochloa crus-galli*, *Exserohilum monoceras*, Mechanism, Oryza sativa

Herbicidal characteristics of crude extracts of *Cedrela sinensis* for a potential biocontrol agent (747)

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This study was conducted to determine the herbicidal characteristics of *Cedrela sinensis* extracts. Crude methanol extracts of *C. sinensis* were applied to *Digitaria sanguinalis* as a post-emergence foliar treatment at 2,500, 5,000, and 10,000 μg mL^{-1}, and its herbicidal activity was assessed 14 days after application. The extract provided 98, 100, and 100% control at 2,500, 5,000, and 10,000 μg mL^{-1}, respectively. Treated plants showed injury symptoms such as chlorosis and burndown followed by necrosis and eventual death. In another bioassay, *C. sinensis* extracts were applied at 1,250, 2,500, 5,000, and 10,000 μg mL^{-1} to five grass species and five broadleaf species. Fourteen days after application, *C. sinensis* extract at 10,000 ug mL^{-1} provided 100, 95, 30, 100, and 98% control of *Sorghum bicolor, Echinochloa crus-galli, Agropyron smithii*, *Digitaria sanguinalis*, and *Panicum dichotomiflorum*, respectively. On broadleaf weeds, the extract provided 70, 100, 100, 90, and 95% control of *Solanum nigrum*, *Aeschynomene indica*, *Abutilon avicennae*, *Xanthium strumarium*, and *Calystegia japonica*, respectively. The extract showed strong herbicidal activity particularly on *A. indica* and *A. avicennae*, providing 95 and 98% control, respectively, even at the lowest concentration of 1,250 μg mL^{-1}. The methanol extract of *C. sinensis* was fractionated into hexane, ethyl acetate, butanol, and water, and then the fractions were applied to *D. sanguinalis.* Out of the four fractions, the ethyl acetate fraction yielded high levels of herbicidal activity, providing 80, 90, 95, and 98% control at 250, 500, 1,000, and 2,000 μg mL^{-1}, respectively. It was identified that the ethyl acetate fraction contained two known quassinoid compounds and two new quassinoid compounds. The result of this study showed that *C. sinensis* extracts have potential for use as a bioherbicide and that the two newly-found quassinoid compounds may be used as lead compounds for development of a new herbicide.

Keywords: *Cedrela sinensis*, bioherbicide, quassinoid compounds, herbicidal activity

The poster in a PDF version is available here.

Separation of flavonoid components from *Mikania micrantha* by high speed countercurrent chromatography (829)

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Mikania micrantha is an invasive weed, however, this plant also produces bioactive compounds which might be beneficial for the purpose of weed control. Flavonoid components from weeds have considerable antibacterial bioactivities, and have been reported as allelochemicals. High speed countercurrent chromatography (HSCCC) was developed in 1980s and has been widely used for separation of natural products. HSCCC uses a type-J synchronous planetary motion in a multilayer coil separation column. The column holder rotates about its own axis and revolves around the centrifuge axis at the same angular velocity (ω) in the same direction. This planetary motion prevents twisting the bundle of flow tubes allowing continuous elution through a rotating column without risk of leakage and contamination. HSCCC technique uses a two-phase solvent system made of a pair of mutually immiscible solvents, one used as the stationary phase and the other as the mobile phase. Being a support-free liquid-liquid partition chromatography, eliminates irreversible adsorption of sample onto the solid support. This study examined whether HSCCC could separate flavonoids components from *Mikania micrantha*. In this work, a two-phase solvent system composed of either ethyl acetate-methanol-water (10:1:10, v/v) or n-hexane-ethyl acetate-methanol-water (1:1:1:1, v/v) was used with HSCCC. Analytical HSCCC used a coil volume 40ml and column diameter 0.85mm, of which maximum injection volume was 100mg. Semi-preparative HSCCC used a coil volume 220ml and column diameter 1.6mm, of which maximum injection volume was 1000mg. As a result, the quantity of flavonoid components gained by semi-preparative HSCCC was 5 times higher due to better resolution and bigger column volume. In addition, astragalin, quercetin, luteolin, baicalein and kaempferol were obtained by semi-preparative HSCCC with optimization using the two-phase solvent systems of n-butanol-acetic acid-water (4:1:5, v/v).

Keywords: *Mikania micrantha*, flavonoids, countercurrent chromatography

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Session 9
HERBICIDE RESISTANCE

Expression of genes encoding antioxidant enzymes in rice plants after application of different herbicides (388)

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The environmental stresses plant response is mediated regulation of gene expression. A main abiotic stress occurring in different cultures as well as weeds that infest agricultural arable fields is herbicide applications. The chemical weed management is the main tool adopted by farmers in rice fields, especially the use of post-emergence herbicides bentazone, penoxsulam and cyhalofop-butyl. Thus, the objective was to verify the gene expression of superoxide dismutase (OsSOD), catalase (OsCAT) and ascorbate peroxidase (OsAPX2) in rice plants subjected to herbicides: bentazone (960g a.i ha^{-1}), penoxsulam (60g a.i ha^{-1}), cyhalofop-butyl (315g a.i ha^{-1}) and control without application. Shoot collections rice were carried out at different times (12 and 24 hours after application (HAA). From the ΔCT values were calculated the Relative Quantification values (QR), using the following formula $QR = 2^{-\Delta\Delta CT}$, which were submitted to analysis of variance and then the averages for herbicides factors and collection times were compared by Tukey's test, with significance level of $p \leq 0.05$. Relative to the target gene OsSOD and OsCAT, there was interaction between herbicides and HAA and OsAPX2 was significant only for the HAA factor. For OsSOD and OsCAT gene expression was the greatest when applied basagram 24 HAA (RQ = 6.29 and 3.43, respectively) differing from 12 HAA (RQ =2.46 and 1.20, respectively). For SOD in 12 HAA period, the greatest expression occurred when applied cyhalofop-butyl (RQ = 4.53) and bentazone (RQ = 6.29) 24 HAA. In summary, the results indicated higher OsSOD and OsCAT expression after bentazone treatment indicating increased oxidative stresse after application of this herbicide when compared to penoxsulam and cyhalofop-butyl.

Acknowledgements
FAPEGS, CNPQ

Keywords: Oryza sativa, RT-qPCR, OsCAT, OSAPX2, OsSOD

The poster in a PDF version is available here.

RNA-Seq Characterization of non-target-site mechanisms in imidazolinone resistant sunflower (*Helianthus annuus* L.) (620)

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Imidazolinone resistance has been found in a sunflower wild population and successfully transferred to a cultivated sunflower inbred line, HA425. This resistance has been reported to be genetically controlled by two genes: Imr_1 (an allelic variant of *ahasl1 locus* that codes for acetohydroxyacid synthase catalytic subunit) and the modifier Imr_2. The mechanism of the resistance endowed by Imr_2 remains unknown but it could be related to non-target-site resistance such as xenobiotic metabolism.
The objective of this study was to characterize HA425 resistant sunflower gene expression in response to imazethapyr using RNA-Seq.
Previously, two assays were carried out to determine: (i) optimal herbicide treatment length (ii) acetohydroxyacid synthase *in vitro* activity to assess enzyme inhibition levels. Plants were grown in plastic pots (4cm x 5.5cm) filled with commercial perlite and watered by capillarity with 25% Murashige and Skoog's salts solution, in growth chamber under controlled conditions. After 7 days, plants were treated with 0 (control) and 1µM imazethapyr during 12 hours. Leaf RNA was purified and quantified. Stranded, pair-ended cDNA libraries were constructed with Illumina TruSeq Stranded RNA-Seq protocol and sequencing was performed in Illumina HiSeq2000. Local, with and without multihits mapping was carried out using Bowtie2/Sam2Count over a reference *de novo* transcriptome. After normalization and FastQC quality assessment, expression levels were analysed with EdgeR. Seventeen interesting contigs were verified by RT-qPCR.
An important number of xenobiotic metabolism genes were found: cytochromes P450s, ABC transporters, glycosyltransferases, UDPglucuronosil/glucosyltransferases and glutathione S-transferases. Tissue expression patterns were analyzed using HeliaGene tools. None of these genes showed differential expression between 1µM imazethapyr and control plants ($P>0.05$).
These results suggest that non-target-site resistance mechanisms may contribute to herbicide resistance in sunflower and they could be related to the modifier Imr_2. RNAseq analysis allowed to detect constitutively expressed detoxification genes potentially related to imidazolinone resistance in sunflower.

Keywords: *Helianthus annuus* L., non-target-site resistance, imazethapyr, xenobiotic metabolism, RNASeq

The poster in a PDF version is available here.

Potential weediness of transgenic restorer rice line T1c-19 with stacked *cry1C*/bar* genes and its gene flow to cultivated rice and weedy rice (581)

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Potential weediness of stacked transgenic rice (*Oryza sativa* L.) T1c-19 with *cry1C*/bar* genes, its receptor rice MH63 and a local two-line hybrid *indica* rice (Feng-liang-you-xiang-1) cultivar (used as a control) were compared under field conditions without the relevant selection pressures. Additionally, gene flow from T1c-19 to Minghui63 (MH63) and wild relative weedy rice (*O. sativa*) was assessed using alternating and adjacent planting arrangement. Three weedy rice accessions were included: Maoming (WRMM), Taizhou (WRTZ), and YIyang, (WRYY). In wet direct-seeded and transplanted rice fields, T1c-19 and its receptor MH63 performed similarly regarding vegetative growth and reproductive ability, but both of them were significantly inferior to the control. T1c-19 did not display weedy characteristics; it had weak overwintering ability, low seed shattering and failed to establish volunteers. Exogenous insect and herbicide resistance genes did not confer competitive advantage to transgenic rice T1c-19 grown in the field without the relevant selection pressures. The maximum gene flow from T1c-19 to WRYY and WRTZ ranged between 0.11 to 0.23% in both planting arrangements. However, no gene flow was detected from T1c-19 to WRMM in either system. Gene flow frequency from T1c-19 to MH63 was 0.92% in the alternating planting experiment. Therefore, transgenes of T1c-19 may escape to weedy rice if T1c-19 is released in field. If this happened, weedy rice with both transgenes could have a fitness advantage under herbicide and insect pressure. Thus, prevention measurements of gene flow should be adopted if the transgenic rice is commercially released.

Keywords: Stacked transgenic rice, T1c-19, Weedy rice, Weediness, Gene flow

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Expression profile of selected genes in GR *Conyza bonariensis* following glyphosate application (753)

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Confirmed glyphosate resistant (GR) *Conyza bonariensis* biotype [about 30-fold than a glyphosate sensitive (GS) biotype] was further studied particularly for genes response to glyphosate application. No Pro106 substitution in the EPSPS enzyme was detected in this GR biotype. Further supporting evidence of its EPSPS sensitivity was obtained by shikimate analysis. The GR plants accumulated shikimate (although lower levels than the GS plants) following glyphosate application. Reduced translocation as a possible non-target site resistance (NTSR) mechanism was rejected by ^{14}C-glyphosate experiments: GR plants demonstrated a similar pattern of ‚source to sinks' translocation as the GS plants. Quantitative determination (qRT-PCR) of EPSPS revealed no change in the RNA expression level of GR plants after glyphosate treatment while in the susceptible ones, EPSPS transcript was decreased over time. Eventually, 24HAT, GR plants had twice EPSPS transcripts versus GS plants. Transcript expression analysis of three vacuole transporters showed a rapid response (24 HAT), demonstrated as increased response to glyphosate treatment in GR plants as compared with GS plants. These data indicate that glyphosate might abnormally sequestered in the vacuoles due to an overexpression of vacuole transporters. These results support the hypothesis that the herbicide loaded on the assimilate flow, moves from cell to cell but does not enter the chloroplast in appropriate amounts or/and for a long time, therefore EPSPS is not sufficiently inhibited. The EPSPS decreasing levels followed by glyphosate treatment in GS plants may emphasize the complexity of NTSR mechanisms. More quantitative analysis of other transporter expression and vacuole content would apparently define this assumption.

Keywords: Gene-expression, time intervals, vacuole transporters

The poster in a PDF version is available here.

Gene flow between different forms of sunflower (*Helianthus annuus* L.) (244)

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Growing sunflower hybrids tolerant to herbicides inevitably results in seed dispersal and problems with volunteer plants in next crop. Volunteer plants can also contain genes responsible for tolerance to herbicides that can persist in progeny. Genetic compatibility and flowering overlapping between different forms of sunflower allow hybridization and gene flow. In this study we examined spontaneous hybridization between herbicide tolerant hybrids of sunflower (Rimi tolerant to imazamox and Sumo 1PR tolerant to tribenuron-methyl) and volunteer, weedy plants and not-tolerant hybrids of sunflower. Two experiments were set up, one for each hybrid. The experiments were linear type (four rows) where first 50 m was herbicide tolerant hybrid and below 2 rows of not-tolerant hybrids (Velja and Dusko), one row volunteer plants, and one row weedy sunflower plants. Plants and heads of different forms of sunflower (which overlapped in flowering time) were marked at different distances from tolerant hybrids. In next experimental year F1 progeny was obtained and when it reached the stage of 2 pairs of leaves, plants were treated with herbicides. For progeny from hybridization between Sumo 1PR and other forms of sunflower, Express 50SX (a.i. tribenuron-methyl) was used and, for progeny from hybridization between Rimi and other forms of sunflower, Pulsar40 (a.i. imazamox) was used. Both herbicides applied at manufacturer's recommended rate (tribenuron-methyl 45g/ha, imazamox 1.2 L/ha). Average survival of F_1 progeny was 8.4% after treatment with Express 50SX and 29.7% after treatment with Pulsar 40. Some progeny originating from individual plants which was on different distance from tolerant hybrids had very high percent of survival (90%) which is probably caused by gene flow, but some progeny were not tolerant. Progeny tolerant hybrids*weedy sunflower after treatment with herbicides showed apical meristem necrosis, but after 28 days plants recovered and had stronger branching which may be caused by some other gene.

Keywords: Herbicide resistance, hybridization, weedy sunflower

The poster in a PDF version is available here.

Transgenic hybrid rice poses a higher transgene escape risk than varieties by reverse gene flow (814)

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Gene flow between transgenic herbicide-resistant crops and their wild or weedy relatives is a major concern related to their potential ecological risks. Transgene flow from transgenic herbicide resistant rice to weedy rice can transfer the herbicide-resistance trait to weedy rice. Likewise, reverse gene flow, from weedy rice to transgenic herbicide resistant rice will transfer weediness traits to the cultivated rice. The potential risk of reverse gene flow has been seriously underestimated because non-shattering weed-crop hybrids growing in cultivated rice can be removed from fields preventing the build up of a soil seed bank. We report the results of a three-year study. Two transgenic glufosinate-resistant rice varieties (GTR) and two hybrids (GTHR) and the F2 progeny of the two GTHR were planted in six weedy-rice-free field plots adjacent to experimental weedy rice fields. Harvested rice seed (succeeding generations) were planted the following year into the same plots. Weedy-rice-like (WRL) plants, both resistant to glufosinate and with red-pericarp seeds, were initially found only among the F3 generations of the two GTHR but none in GTR offspring. Their progeny were more fit than their parents under common garden conditions. Hybrid rice progeny segregated into individuals with variable height and extended flowering. In a separate gene flow experiment, hybrid rice F2 generations (direct progeny of the hybrid rice cultivars) had significantly higher outcrossing rates (0.96-1.65%) than their progenitors (0.07-0.98%). The reverse gene flow from weedy rice to transgenic herbicide resistant hybrid rice will rapidly result in the evolution of herbicide resistant weedy individuals when grown adjacent to infested fields, despite weedy rice being controlled within the transgenic hybrid rice. The segregating progeny of transgenic hybrid rice has higher reverse outcrossing, thus posing greater agro-ecological risk than transgenic rice varieties. Transgenic herbicide-resistant hybrid rice should be subjected to stringent management practices in breeding and field production.

Keywords: Transgenic hybrid rice, Gene flow, Rice outcrossing rate, Herbicide resistance, Weedy rice

Characterization of glyphosate tolerance for two populations of *Lotus tenuis* with contrasting levels of salt tolerance and molecular variability (838)

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Glyphosate resistance in weeds is frequently caused by non-target site mechanisms, and association between abiotic stress tolerance and glyphosate resistance has been reported in *Echinocloa phyllopogon* and *Chenopodium album*. *Lotus tenuis* Waldst. et Kit. (ex *Lotus glaber*) is a widely used perennial forage species with great genetic variability and potential for providing quality forage in marginal environments. However, *L. tenuis* has very slow initial growth and bad competitive ability with weeds during establishment. Combination of salinity tolerance and glyphosate tolerance would be an advantage for weed control and successful establishment of *L. tenuis* in saline environments. The objective was to evaluate the response to glyphosate applications of two *L. tenuis* populations with different levels of salt tolerance and molecular variability. Dose-response curves were obtained for two half-sib families with contrasting salinity behaviour, and molecular variability, one tolerant and less variable and one susceptible and more variable. Eight glyphosate rates, from 0 to 6 kg a.e./ha, were used on potted plants in the greenhouse with six replicates. The experiment was repeated and results analysed separately. Twenty-one days after glyphosate application, plant survival percentage and above ground dry weight was determined. Survival percentage was greater for the salinity tolerant population than for the susceptible one: 60 vs. 40% for 1.5 kg a.e./ha and 50 vs. 17% for 3 kg a.e./ha, for the first and second experiment, respectively. Dry weight was reduced as glyphosate dose increased. LD_{50T}/LD_{50S} was 1.41 and 1.49 for the first and second experiment, respectively. We found greater survival to glyphosate applications in the salinity tolerant family, and an association between glyphosate and saline stress tolerance for *L. tenuis*, in these experiments. This association suggests that *L. tenuis* could be used as a model for studying association of glyphosate resistance and abiotic stress tolerance in weeds.

Keywords: Weeds, glyphosate resistance, resistance mechanism, abiotic stress, herbicides

The poster in a PDF version is available here.

Intra- and interspecific comparison of resistance factors of genotypes with target-site resistance to ALS-inhibitors (haplotype Leu574) (272)

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Focussing on genotypes with target-site resistance to ALS inhibitors due to a single point mutation at position 574 on the ALS-gene, this study determined the resistance factors for two ALS-inhibitors (mefenpyr-diethyl + mesosulfuron-methyl and florasulam + pyroxsulam) using three biotypes of the three grass weeds *Apera spica-venti*, *Alopecurus myosuroides,* and *Lolium* spp. All biotypes represented field populations whose resistance status was confirmed via biotest and molecular analysis. Experiments were conducted under greenhouse conditions as complete dose response assays in an agar based whole-plant quick testing system with 14 doses and 7 replicates/dose. In order to exclude any sensitive individuals and plants that have a slight metabolic resistance or shifting towards increased tolerance, all biotypes were pre-selected with a foliar application of recommended doses of the ALS-inhibitors prior to the bioassay. The set of survivors was used for the whole-plant quick test. The resistant (pre-selected) plants were analysed for their genotype via SNP analysis and data from quick test and SNP analysis were allocated. Dose-response curves were modelled for root length responses and resistance factors (RF) calculated based on internal standards for sensitive biotypes. Finally, RFs were intra- and interspecifically compared by *F*-test.
Experiments are still ongoing, however, we believe that this work will provide an insight into the following three important research questions: (1) are RF-values in plants with determined genotype concerning TSR to ALS-inhibitors significant and reliably different between ALS-herbicides?; (2) how does the ALS-TSR genotype frequency of a population influence the RF-value?; and (3) are RF-values for specific ALS-herbicides and populations with determined ALS-TSR genotypes significant different between species and biotypes? We believe that answering these questions will be rewarding for modelling herbicide resistance evolution and for developing rational management strategies in future worst case scenarios.

Keywords: Acetolactate synthase, *Alopecurus myosuroides*, Apera spica-venti, *Lolium* spp., quick test resistance detection

The poster in a PDF version is available here.

Beyond glyphosate resistance: adaptation of *Amaranthus palmeri* populations to cropping systems (775)

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Amaranthus palmeri (Palmer amaranth) is the most important weed species in the Southern United States of America. This weed species has evolved resistance to multiple herbicides including glyphosate. Because *A. palmeri* is a dioecious species (i.e. obligate outcrosser), it is believed that population differentiation is limited. However, genetic diversity bottlenecks created by herbicide selection paired with resistance evolution and the increase in relative importance of other selection forces within the cropping system, could favor adaptations in other life-history traits. We compared morphological and physiological parameters for 10 *A. palmeri* populations collected from different cropping systems in Georgia and Florida, USA. Glyphosate resistant populations (6 populations) came from cropping systems using glyphosate resistant (GR) crops, and all susceptible populations (4 populations) came from cropping systems with no glyphosate use history. When grown in the same area under controlled conditions, *A. palmeri* populations differed in multiple life-history traits including flowering timing, plant height, biomass, leaf shape, leaf area, canopy shape, branch number, foliar nutrient content, and response to fertilization. Glyphosate resistance was associated with many of the differences observed. For example, GR populations were taller, produced more biomass, had more branches, and had a higher nitrogen use efficiency than susceptible populations. The lack of susceptible populations from GR cropping systems prevented us from determining whether the differences in life-history traits are a direct consequence of glyphosate resistance evolution or the result of adaptations to other selection forces present in GR cropping systems. The present study suggests that *A. palmeri* populations might be adapting to selection forces in the cropping system exhibiting a more aggressive growth, and this adaptation might be related to GR cropping systems. Our findings highlight the importance of studying weed evolution beyond herbicide resistance, especially considering population diversity.

Keywords: Resistance, evolution, adaptation, diversity

Growth, fecundity, and competition between aryloxyphenoxypropionate herbicide-resistant and –susceptible Asia minor bluegrass (*Polypogon fugax*) in China (144)

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Asia minor bluegrass (*Polypogon fugax*) is an important annual grass weed of winter crops in Sichuan province, China, where a population has evolved multiple resistance to aryloxyphenoxypropionate herbicides. Greenhouse experiments were conducted to study the noncompetitive growth and fecundity of aryloxyphenoxypropionate herbicide-resistant (AR) and –susceptible (AS) Asia minor bluegrass. When grown alone, the AR Asia minor bluegrass developed more rapidly than the AS weeds, as evidenced by their earlier bolting, flowering, and seed set; the AR Asia minor bluegrass set seeds nearly 15 days sooner than the AS Asia minor bluegrass. The AR and AS Asia minor bluegrass amassed similar aboveground dry matter before heading stage. After seed set, the relatively slow-developing AS Asia minor bluegrass had amassed 50% more shoot dry matter than the AR weeds at the same phonological stage. However, fecundity of the AR Asia minor bluegrass (8.57 g seeds plant^{-1} and 0.17 g seeds ear^{-1}) was greater (P<0.05) than AS plants (8.22 g seeds plant^{-1} and 0.13 g seeds ear^{-1}). Furthermore, relative competitiveness among the AR and AS Asia minor bluegrass biotypes was investigated by means of replacement series experiments. The AR and AS biotypes were compared under five mixture proportions (AR:AS=0%, 25%, 50%, 75%, 100%) of three densities (2 by 2, 3 by 3, 4 by 4 grids) in pots. No significant differences in competitive ability were observed between AR and AS biotypes on the basis of plant biomass. These results indicate that growth and development of this AR biotype were not affected relative to the AS plants. The greater fecundity of AR plants suggests that it is likely to become increasingly common and proper management strategies are necessary to prevent its further infestation.

Keywords: ACCase mutation, fitness, herbicide-resistance, relative competitiveness

Glyphosate resistant weeds – a threat to conservation agriculture (31)

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Glyphosate-resistant weeds are now present throughout the Southeast. Hundreds of thousands of conservation tillage cotton acres, some currently under USDA Natural Resources Conservation Service (NRCS) conservation program contracts, are at risk of being converted to higher-intensity tillage systems. The shift to higher-intensity tillage facilitates burial of small weed seed as well as use of preplant incorporated herbicides for control of problematic weeds, especially in dry-land cotton production. NRCS defines conservation agriculture as cropping systems that maintain a minimum 30% residue on the soil surface. Recent NRCS programs such as EQIP, the Conservation Security Program and the recently enacted 2008 Farm Bill Conservation Stewardship Program offer incentive contracts rewarding conservation. Cropping systems with higher resource conservation receive higher payments; in many states, use of high residue cover crops increase payments.
Since the mid 1980's, conservation tillage has been recognized as a beneficial alternative to conventional tillage practices. Despite definite advantages over traditional tillage practices, conservation tillage adoption remained sluggish through the 80's and mid 90's due, in large part, to unreliable weed control options in conservation tillage systems. Subsequently use of the broad-spectrum herbicide, glyphosate, in conjunction with glyphosate-resistant cultivars offered a successful alternative to conventional weed management that could be incorporated into conservation agriculture systems. Best management practices recommend rotating crops and chemicals to avoid the development of resistance in weeds, insects, and diseases. Unfortunately many producers have had little economic opportunity to grow different crops for a number of reasons. In addition, the system of glyphosate-resistant crops has become so prevalent that rotation of crops does not ensure that chemical weed control choice will change when crop are changed. Currently, glyphosate resistant Palmer amaranth is common throughout the Mid-South and Southeastern US and use of intensive tillage is increasingly common threatening gains in soil conservation.

Keywords: Conservation Tillage, Resistant Weeds

The poster in a PDF version is available here.

Response of glyphosate-resistant and glyphosate-susceptible Palmer amaranth plants to herbicides and crop interference (180)

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Experiments to compare the biology and management of glyphosate-resistant (GR) and glyphosate-susceptible (GS) biotypes of Palmer amaranth have been conducted with varying levels of success. One challenge in many experiments is that the GR and GS biotypes were collected from different locations. Effect of glyphosate resistance could be difficult to discern in these experiments due to the confounding contribution of location. To eliminate the question of geography, a segregating population of Palmer amaranth collected in North Carolina during 2010 was used as a plant source for both GR and GS traits. Clones of individual plants from this collection were made from cuttings and half of them were treated with glyphosate at 840 g ae/ha. Remaining clones of treated plants that were either GS or GR were grown to maturity in separate greenhouses with seed from these plants collected to compare biology and control of GR and GS progeny. In the first experiment, plants with 4 leaves were treated with postemergence applications of atrazine, dicamba, fomesafen, glyphosate, glufosinate, paraquat, tembotrione, thifensulfuron, and 2,4-D. In a second experiment, GR and GS plants were grown in the presence of corn, cotton, and peanut for 45 days. The third experiment was designed to determine recovery of GR and GS plants grown alone or with cotton from drought stress beginning 20 DAP for duration of up to 12 days. Following exposure to drought, plants were grown under optimal moisture conditions until harvest at 40 DAP. Control by postemergence herbicides (except glyphosate), crop response to interference by Palmer amaranth, and recovery of Palmer amaranth from drought stress were similar for both GR and GS plants collected from a common location.

Keywords: Glyphosate, herbicide resistance, weed control, interference

The poster in a PDF version is available here.

Topramezone efficacy for controlling prodiamine-resistant goosegrass (84)

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Prodiamine is a dinitroaniline herbicide labeled for goosegrass (*Eleusine indica*) control in warm- and cool-season turfgrass. In 2013, poor goosegrass control (< 20%) was reported on several golf course roughs (Maryville, TN USA) following prodiamine treatment at 1120 g ha^{-1}. Prodiamine had been applied for preemergence weed control at these locations for over eleven consecutive years without rotation. Suspected prodiamine-resistant (PR) and prodiamine-susceptible (PS) goosegrass biotypes were harvested from the field and exposed to increasing concentrations of prodiamine in hydroponic culture. Exposure to prodiamine at 0.001 mM reduced root growth of the PS biotype to 15% of the non-treated check. Comparatively, exposure to 0.001 mM prodiamine had minimal effect on the PR biotype as root growth was 96% of the non-treated. IC_{50} values for the PR and PS biotypes were 8.42 x 10^{-3} and 3.22 x 10^{-10} mM, respectively. Topramezone is an inhibitor of *p*-hydroxyphenylpyruvate dioxygenase (HPPD) registered for weed control in corn (*Zea mays*) and cool-season turfgrasses. In field experiments conducted during 2014 and 2015, postemergence applications of topramezone at ≥ 25 g ha^{-1} controlled this PR goosegrass biotype 85 to 89%, greater than foramsulfuron at 29 to 44 g ha^{-1}. Reductions in goosegrass plants per square meter with topramezone at ≥ 25 g ha^{-1} averaged 83% compared to only 5 to 19% for foramsulfuron. Topramezone treatment injured desirable bermudagrass (*Cynodon dactylon*) from 7 to 14 days after treatment (DAT). Injury ranged from 40 to 60% during this time period and was characterized by foliar bleaching of leaf tissue. This response was transient in both years of the study as injury from 28 to 50 DAT measured ≤ 5%. Our results indicate that topramezone is a possible new option for managing prodiamine-resistant goosegrass if transient injury to desirable bermudagrass turf can be tolerated.

Keywords: Turf, Herbicide, Resistance, HPPD, Golf Course

The poster in a PDF version is available here.

Arylex™ active (halauxifen-methyl): A new herbicide for post-emergence control of broadleaf weeds including ALS-inhibitor resistant biotypes in cereals (503)

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Dow AgroSciences is a global leader in developing and introducing new crop protection products. ALS inhibitors are the most commonly used herbicide mode of action to control broadleaf weeds in cereals. Dow AgroSciences has developed Arylex™ active, a novel arylpicolinate herbicide (HRAC group O; WSSA group 4) for post-emergence control of some hard to control broadleaf weeds. Herbicide concepts, GF-2819 (12 g ae/L of Arylex + 280 g ae/L of fluroxypyr) and GF-2818 (30 g ae/L of Arylex + 25 g ae /L of aminopyralid) are being developed for post-emergence applications in the spring in cereals.

Efficacy and crop selectivity of Arylex-containing herbicide product formulations, GF-2819 and GF-2818, were determined in field trials according to EPPO guidelines during the past five years in Europe.

Arylex is effective at low rates (5 to 6 g ae/ha) and efficacy is frequently enhanced when applied with an adjuvant. Arylex controls a broad spectrum of weeds including CHEAL, CONOR, DESSO, FUMOF, GAETE, GALAP, GERSS, LAMSS and PAPRH and biotypes resistant to ALS inhibitors. GF-2819 can be used up to crop growth stage BBCH 45 at a maximum rate of 0.5 L/ha to broaden control spectrum to include CAPBP, CENCY, STEME, POLCO, POLAV and volunteer potatoes. GF-2818 at the maximum rate of 0.2 L/ha is highly selective up to crop growth stage BBCH 32 and broadens control to include POLCO, POLAV, LACSE, VICSA, CENCY. GF-2818 is especially effective in the control of all PAPRH biotypes and controls noxious weeds like AMBEL. Both formulations include a safener (*cloquintocet-mexyl)* to ensure crop safety.

Arylex™ active and both herbicide products offer effective post-emergence control of many broadleaf weed species including herbicide-resistant biotypes at low rates in the spring in cereals.

Keywords: Arylex, broadleaf weeds, cereals, new herbicides, resistant biotypes

Herbicide resistance in littleseed canarygrass and its management in wheat (665)

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Littleseed canarygrass *(Phalaris minor)* is the most troublesome weed of wheat which is significantly affecting its productivity and profitability in India. Resistance to isoproturon (PSII) during the early 1990s caused complete crop failures and therefore new herbicides were introduced. Now again, wheat growers in northern India are not able to control *P. minor* with repeated applications either alone or in combination of several herbicides. After recent reports of multiple herbicide resistance in *P. minor*, it was considered important to quantify the herbicide resistance and to develop an effective herbicide program for its management. Pot and field studies were conducted at university farm and resistant affected farmers' field in Haryana state (India) during the winter season of 2014-15. *P. minor* populations were collected from fields having uncontrolled history with different herbicide and herbicide resistance profiles were studied through bioassay in pots. Dose-response experiments confirmed that isoproturon resistant *P. minor* has attained multiple resistance to ACCase and ALS inhibitors; however the levels of resistance and resistance pattern of different herbicides varied among the populations. Few populations have a very high level of resistance to clodinafop (14.2 fold more resistant than susceptible) and sulfosulfuron (8.2 fold) while moderate resistance to mesosulfuron+iodosulfuron (2.7 fold). *P. minor* resistant to sulfosulfuron showed cross-resistance to mesosulfuron+iodosulfuron. Similarly, clodinafop resistant population exhibited cross-resistance to pinoxaden. Field experiment carried out at resistance affected farmer's field using herbicides mixtures and their sequential application revealed that pendimethalin 1.5 kg/ha PRE followed by tank mix pinoxaden+metsulfuron 64 g/ha or mesosulfuron+iodosulfuron 14.4 g/ha POE provided excellent control of *P. minor* as well as broadleaf weeds. Though there are not many new herbicides in pipeline, sequential use of PRE followed by POST herbicides and their mixtures can be an effective strategy to manage multiple herbicide resistant *P. minor*.

Keywords: Multiple herbicide resistance, Phalaris minor, Wheat, Herbicide mixtures, Pendimethalin

Efficacy of auxin herbicides on 2,4-D-resistant and susceptible common waterhemp (*Amaranthus rudis* Sauer) populations (541)

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There is currently only one reported biotype of 2,4-D-resistant common waterhemp (*Amaranthus rudis* Sauer) in the world. Because of the rarity of this biotype, and 2,4-D-resistant weeds in general, there is limited data regarding its cross resistance to other synthetic auxin herbicides. The objective of this study was to determine if cross resistance to other synthetic auxin herbicides existed in a 2,4-D-resistant waterhemp population. This study was conducted in a greenhouse at the Pesticide Application Laboratory (PAT Lab) in North Platte, NE. Resistant and susceptible waterhemp populations were treated with seven auxin herbicides at six rates. The herbicides used were 2,4-D (Weedar 64 SL®), dicamba (Clarity®), aminopyralid (Milestone®), clopyralid (Stinger®), fluroxypyr (Starane®), picloram (Tordon®) and triclopyr (Garlon®). The rates used were 0.125x, 0.25x, 0.5x, 1x and 2x where 1x was 53, 105, 139, 280, 399, 560 and 2242 g ae ha $^{-1}$ for the previously mentioned herbicides, respectively. The spray solutions were applied using a AI9502EVS nozzle at 414 kPa and 7.8 km h^{-1} to deliver 94 L ha^{-1}. Visual estimations of injury were recorded at 7, 14, 21 and 28 days after treatment (DAT). The plants were harvested at 28 DAT by severing the plant at the base of the stem. Fresh weights were recorded at the time of harvest and plants were dried for 72 h at 65° C prior to recording dry weights. Control of 2,4-D-resistant common waterhemp depends on herbicide and herbicide rate. Triclopyr was most efficacious of the synthetic auxin herbicides on waterhemp, controlling a majority of both populations of common waterhemp by 14 DAT. Cross-resistance was observed in fluroxypyr and potentially triclopyr.

Keywords: Cross-resistance, synthetic auxin, dicamba, clopyralid, herbicide-resistance

The poster in a PDF version is available here.

Evaluation of pinoxaden and prosulfocarb efficacy for control of *Apera spica-venti* populations resistant to sulfonylurea herbicides in the Czech Republic (812)

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Herbicide resistance in weedy grasses has been spreading rapidly in the Czech Republic, especially in *Apera spica-venti* and *Alopecurus myosuroides*. There are a number of herbicides on the market, but the problem is that most farmers prefer the use of cheaper and user friendly herbicides, often with the same mode of action such as sulfonylureas and triazolopyrimidines. Syngenta has been working since 2004 in conjunction with the Czech University of Life Sciences on the identification of herbicide resistance in *Apera spica-venti* in the Czech Republic and solutions for control of resistant populations. One part of the project was an evaluation of performance of Syngenta herbicides for control of *Apera spica-venti* biotypes resistant to sulfonylurea herbicides. Performance of pinoxaden and prosulfocarb was tested in small plot trials in winter wheat with resistant *Apera* according to EPPO guidelines and on selected farms affected by herbicide resistance to ALS inhibitors. Herbicides containing pendimethalin or isoproturon were included as standards and ALS inhibiting herbicides (chlorsulfuron, sulfosulfuron and iodosulfuron) as negative standards. Efficacy of ALS inhibiting herbicides ranged between 4-59 % depending on year, population, and timing. Both pinoxaden and prosulfocarb as well as their combinations with tested mix partners controlled successfully all ALS resistant biotypes regardless of prevailing type of resistance (TSR/NTSR). Both pinoxaden and prosulfocarb showed similar or better efficacies than standards. Use of pinoxaden was more reliable in all trials with efficacy 95-99% in small plot trials and 95-100% on farms. Prosulfocarb had an efficacy between 85-100% in both small plot trials and on farms but the lower limit of range was caused by dryness in one of the experimental years. Multiple resistance (ALS/ACCase) has not been found in our experiments and is not a bigger issue in the Czech Republic, although first cases are reported from surrounding countries.

Keywords: ALS inhibitors, ACC inhibitor, Silky bent grass

Management of large glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) in corn (811)

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With the prevalence of glyphosate resistant Palmer amaranth it is vital that new control strategies be developed to optimized weed control in corn production systems. Therefore, field studies were conducted in 2013 and 2014 in Jackson, TN to evaluate non-atrazine herbicide weed control programs in corn for the control of glyphosate resistant Palmer amaranth greater than 21 cm in height. Treatments consisted of herbicides applied alone and tankmixed with dicamba plus diflufenzopyr. Herbicide applications were applied postemergence to corn between V5 and V6 growth stages. Dicamba plus diflufenzopyr controlled Palmer amaranth greater than 91% 28 DAA. The herbicides applied alone or tankmixed did not improve control (<76%) over dicamba plus diflufezopyr alone. Due to environmental conditions, corn yield was not adversely affected by Palmer amaranth interference.

Keywords: Glyphosate resistant, Palmer amaranth, late-season

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Session 10
BIOLOGICAL WEED CHARACTERISTICS

Determinations of genetic variation in *Sinapis arvensis* L. populations in wheat fields in Turkey using simple sequence repeat (SSR) markers (305)

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Wild mustard (*Sinapis arvensis* L.) is one of the most notorious weeds in wheat-planting areas worldwide. The objectives of this study were to determine the genetic diversity of populations collected in wheat fields from different geographical regions in Turkey. Simple sequence repeat (SSR) markers were used to assess the extent of genetic variation in wild mustard populations sampled throughout 30 different locations in the Turkey, including herbicide treated and untreated sites. Genetic differentiation and the relationships of wild mustard populations were analyzed using cluster analysis (UPGMA) and principle component analysis (PCA). Results showed high genetic variability among individual genotypes within geographic locations. The range of genetic variation was as high in the herbicide-treated populations as in those which were untreated. We conclude that genetic diversity is maintained in populations of wild mustard where rotational cropping and herbicide use is practiced and that SSR is useful for the determination of genetic variation in outcrossing species where no prior genotypic knowledge is available.

Keywords: *Sinapis arvensis*, molecular marker, SSR, genetic diversity, Wild mustard

The poster in a PDF version is available here.

Transcriptomic dynamics in abiotic stress tolerance in *Echinochloa crus-galli* accessions (285)

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Echinochloa is a major weed that grows almost everywhere in farmed land. This high prevalence results from its high adaptability to various water conditions, including upland and paddy fields, and its ability to grow in a wide range of climates, ranging from tropical to temperate regions. Three *Echinochloa crus-galli* accessions (EC-SNU1, EC-SNU2, and EC-SNU3) collected in Korea have shown diversity in their responses to flooding, with EC-SNU1 exhibiting the greatest growth among three accessions.
In the search for molecular components underlying adaptive diversity among the three *Echinochloa crus-galli* accessions, we performed *de novo* assembly of leaf transcriptomes and investigated the pattern of differentially expressed genes (DEGs). Although the overall composition of the three leaf transcriptomes was well-conserved, the gene expression patterns of particular gene ontology (GO) categories were notably different among the three accessions. Under non-submergence growing conditions, five protein categories (serine/threonine kinase, leucine-rich repeat kinase, signaling-related, glycoprotein, and glycosidase) were significantly (FDR, $q < 0.05$) enriched in up-regulated DEGs from EC-SNU1. These up-regulated DEGs include major components of signal transduction pathways, such as receptor-like kinase (RLK) and calcium-dependent protein kinase (CDPK) genes, as well as previously known abiotic stress-responsive genes.
Our results therefore suggest that diversified gene expression regulation of upstream signaling components conferred the molecular basis of adaptive diversity in *Echinochloa crus-galli*.
This work was carried out with the support of “Next Generation BioGreen21 Program for Agriculture & Technology Development (Project No. PJ01126901),” Rural Development Administration, Republic of Korea.

Keywords: *Echinochloa,* Transcriptome, RNA-seq, Abiotic stress tolerance, Differential gene expression

Development of chloroplast DNA markers for *Echinochloa* weeds (82)

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The genus *Echinochloa* (Poaceae) includes numerous problematic weeds over a wide area of the world. For example, barnyardgrass (*E. crus-galli*) is considered as a major weed for many crops. To date, taxonomic confusion remains in this genus and different taxonomic systems have been proposed. Molecular markers are helpful for species identification and genetic relationship analysis on the genus *Echinochloa*.
Previously, we have obtained the entire chloroplast genomes of two *Echinochloa* species (*E. crus-galli* and *E. oryzicola*) based on high-throughput sequencing data. In this study, we further developed seven chloroplast molecular markers based on divergent chloroplast regions of *E. crus-galli* and *E. oryzicola*. Additionally, the marker *psbA* with the primer pair of GTGCCTACTCGGCATTTCAC and GTTGATAGCCAAGGTCGCGT was examined in more than 200 *Echinochloa* lines together with the *trn*T-L-F marker developed by Aoki and Yamaguchi (2008).
The *psbA*-based phylogenetic tree showed that the marker could group these *Echinochloa* accessions into four clades. Three different *E. crus-galli* varieties (*E. crus-galli* var. *crus-galli*, *E. crus-galli* var. *praticola*, and *E. colona*) were successfully distinguished by this marker.
The developed molecular markers contribute to better understanding of the genetic relationship of the *Echinochloa* genus.

Keywords: Chloroplast genome, *Echinochloa oryzicola*, *Echinochloa crus-galli*, Molecular marker

The poster in a PDF version is available here.

Physiological and molecular basis of flooding adaptation in *Echinochloa* species (106)

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Echinochloa species which include about 50 species are the most problematic weeds that cause the considerable yield loss of various crops. This species exhibits adaptive diversity to various soil water conditions from dry to flooded conditions, but this aspect was not much well studied. Therefore, this work was conducted to investigate growth and physiological responses of *Echinochloa* to several flooding levels and to uncover the molecular basis of different flooding tolerance through expression analysis of genes associated with signal transduction pathway.
We used four accessions, one *E. oryzicola* (EOZ) and three *E. crus-galli* accessions (EC-SNU1, EC-SUN2, and EC-SNU3) and at the three leaf stage, gave different flooding treatments to them from 0 cm (waterlogging, control) to full submergence for 16 days. Based on growth and physiological analysis through plant height and fresh weight, EOZ and EC-SNU1 had greater tolerance to flooding stress than EC-SNU2 and EC-SNU3. In gene expression analyses, receptor-like kinases (RLKs)-encoding genes were up-regulated in all cases of control and submergence of EOZ and EC-SNU1, compared to EC-SNU2 or EC-SNU3. These genes are known as major components of signal transduction pathway, which play important role on abiotic stress signalling.
The results that RLKs-encoding genes were significantly up-regulated in EOZ and EC-SNU1 relative to EC-SNU2 or EC-SNU3 showed positive correlation with growth and physiological responses to flooding stress. Our results may thus contribute to understanding the molecular basis of diverse environmental adaptation in *Echinochloa* species.

Keywords: *Echinochloa* spp., Submergence, Receptor-like kinase, Adaptive diversity

The evidence of the host-to-parasite gene transfer in *Orobanche* (817)

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The close physical association between the parasite and host seems to be the major source of horizontal gene transfer (HGT) among flowering plants. In Orobanchaceae, one of the largest family of parasitic plants, HGTs were reported only rarely. Our studies provided the first evidence of the host-to-parasite mitochondrial gene transfer in this family. It was detected in *Orobanche coerulescens* belonging to the section *Inflatae* (subsection *Coerulescentes)* which contains also such aggressive and noxious crop weeds like *O. cumana* and *O. cernua*, that are responsible for considerable economic losses, especially in southern and eastern Europe or central and southern Asia.
The phylogenetic approach used in our studies was based on the analysis of gene trees obtained for representatives of all Eurasian *Orobanche* and *Phelipanche* subsections and plants belonging to families infected by those holopasites. Molecular analyses were performed on the mitochondrial *atp6* gene and the plastid *trnL-trnF* sequences.
The obtained *trnL-trnF* tree reflected the well-established species relationships but the *atp6* gene tree showed the location of *O. coerulescens* within the cluster containing its host species, *Artemisia campestris* and some other representatives of the family Asteraceae. This cluster was clearly separated from all other *Orobanche* and *Pelipanche* species. So far we have not detected the original *Orobanche atp6* gene in *O. coerulescens* which suggests that it was replaced by the gene acquired from its host.

Keywords: Horizontal gene transfer, HGT, Orobanche, atp6, holoparasite

The poster in a PDF version is available here.

Genetic diversity and phylogenetic relationship of wild C4 perennial grass *Miscanthus* species (276)

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Although miscanthus (*Miscanthus* species) has been studies as a potential bioenergy grass in Europe and USA, it has been regarded as a wild weedy perennial grass in East Asia including Korea, China, and Japan. Recently miscanthus has attracted many general public's attentions due to its multifunctional utility for biomass production, conservation, landscape management, ornamental use, etc. Therefore, we collected 286 miscanthus accessions mainly in Korea and some in neighboring countries to investigate their genetic diversity and phylogentic relationship using 24 selected SSR markers.
SSR analysis showed genetic similarity within 286 miscanthus accessions and three relative species ranging from 0.31 to 0.87. Miscanthus accessions were classified into two main phylogenic groups and showed good genetic diversity. The first group was mainly composed with *M. sacchariflorus* and divided into sub-groups by their ploidy levels (2n=2X or 4X). *M.* × *giganteus* and *M. lutarioriparius* were closely grouped with *M. sacchariflorus*. Another group consisted of *M. sinensis* and *M. floridulus*.
Our results suggest that SSRs analysis with the selected markers is effective for diversity assessment and identifying phylogenic group of *Miscanthus* species. And these highly diverse phylogenetic groups will provide effective parental selection for future breeding to utilize miscanthus as bioenergy feedstock. This work was carried out with the support of „Next-Generation BioGreen21 Program for Agriculture & Technology Development (Project No. PJ01126901)", Rural Development Administration, Republic of Korea.

Keywords: *Miscanthus sinensis*, *Miscanthus sacchariflorus*, genetic diversity, SSR

Genetic diversity of Korean *Miscanthus* based on morphological trait analysis (233)

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Miscanthus is a C_4 perennial grass native in Korea. It used to be considered as a noxious weed in orchard and non-cropping areas, but is now considered as a valuable grass due to its multifunctional utility for biomass production, conservation, landscape management, and ornamental use. Although *Miscanthus* species such as *M. sinensis* (2n=2X) and *M. sacchariflorus* (2n=2X or 4X) are native in Korea, little effort has been made to investigate their genetic diversity based on morphological trait analysis.
Therefore, we collected 280 accessions of *Miscanthus* species from Korea and neighboring East Asian countries and conducted morphology-based phenotyping using twenty morphological traits in leaf, stem, and inflorescence. Among 20 morphological traits, we found that four major traits, namely the presence of awn in spikelet, rhizome growth habit, new shoot emergence in autumn, and the ratio of callus hair to spikelet are the key traits to distinguish between *M. sinensis* and *M. sacchariflorus*.
Phylogenetic analysis showed their associations in morphological similarity and genetic diversity. Principal coordination analysis of morphological traits revealed intermediate accessions, some of which were found to be hybrids between *M. sinensis* and *M. sacchariflorus*. Further works are in progress to understand this perennial native wild grass for domesticating for multifunctional use in the future. This work was carried out with the support of „Next-Generation BioGreen21 Program for Agriculture & Technology Development (Project No. PJ01126901)", Rural Development Administration, Republic of Korea.

Keywords: *Miscanthus* spp., morphological trait, phylogenetic analysis, genetic diversity

Comparative anatomy of *Myosoton aquaticum* and *Stellaria media* and its systematic significance (555)

Zuren Li *(Hunan Academy of Agricultural Sciences, Changsha, China),* ***Haimin Liao*** *(Guizhou University, Guiyang, China),* ***Lianyang Bai*** *(Hunan Academy of Agricultural Sciences, Changsha, China),* ***Xiaomao Zhou*** *(Hunan Academy of Agricultural Sciences, Changsha, China)*

Our objective was to provide insight into the phylogenetic position of *Myosoton* Moench. by comparing the anatomy of *Myosoton aquaticum* and *Stellaria media* using light microscopy and scanning electron microscopy (SEM). Key revelations about the anatomy of *M. aquaticum* and *St. media* are: (1) root is composed of uniseriate epidermis, parenchyma cortex, endodermis, pericycle and central cylinder, and primary xylem of root is tetrarch; (2) stem epidermis is arranged in closeness and parallel, and has distinct shuttle-shape tuber; (3) leaf is composed of dorsiventral mesophyll with palisade layer and spongy parenchyma; (4) anomocytic type of stomatas are found in the epidermis of the leaf, stem and sepal; (5) pollen is single and spheroidal; (6) a number of germ pores are completely sunken, papillate and polypantoporate; (7) Crassuliod type of seeds have simple papillae and no strophiole is observed; (8) seed coat is rounded shape minute secondary sculpturing with an outer surface formed by foveolate epidermal walls; (9) from the globular floral primordium develop to complete bisexual flower, the process of floral initiation is nearly the same. These results support the idea that the higher similarity in organ anatomy and floral ontogeny of *M. aquaticum* and *S.media*, justifies the inclusion of *Myosoton aquaticum* in *Stellaria*.

Keywords: *Myosoton aquaticum*, *Stellaria media*, anatomy, floral ontogeny, systematic

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Evidence of biochemical effect of invasive *S. canadensis* on germination responses (4)

Ligita Baležentienė *(Aleksandras Stulginskis University, Kaunas distr., Lithuania),* ***Marek Renčo*** *(Parasitological Institute of Slovak Academy of Sciences, Košice, Slovakia)*

Do the biochemical compounds of invasive *Solidago canadensis* have a harmful effect on germination and thus supress the recruitment and regeneration of the recipient plant community? In addition, does the allelochemical interaction act as a driver of the distribution success of some exotic plants?
The objectives were to evaluate phytotoxicity of *S. canadensis* on *Lolium perenne* (perennial ryegrass) and *Brassica napus* (spring rapeseed) germination.
The biochemical parameters of *S. canadensis* (total phenolics content along plant parts and growth stages) and their influence on seed germination were assessed photocolourimetrically ex situ in the laboratory. The total phenolics content (TPC) ranged from 0.97 to 23.6 mg ml^{-1} depending on the plant growth stage, plant part and extract concentration. The highest TPC was observed in leaves at flowering stage (r = 0.8). The lowest TPC was observed in seeds in accordance with plant resource allocation theory, which states that some ontogenetic developments are restricted at plant maturity stage. Nonetheless, TPC remains high in roots at this growth stage, possibly due to most intensive conversion of synthesized materials. Even so, the mean extract TPC rate (10.33 mg ml^{-1}) was higher in roots than in shoots (6.42 mg ml^{-1}), tending to increase gradually from 9.08 at rosette to 10.86 and 11.06 mg ml^{-1} at flowering and maturity, respectively.
Phenolics extracts significantly inhibited the germination of rapeseed (r =-0.8) and ryegrass (r =-0.5) across different levels of TPC. Complete inhibition of germination was observed in rapeseed in 0.2% shoot at rosette, leaf at flowering and seed extracts, while for ryegrass it occurred only in 0.2% leaf extract at flowering.
Due to accumulated allelochemicals, the invasive *S. canadensis* might acquire distribution advantage in new territories outside its native habitat range, through the inhibitory effects on germination of plant species of invaded habitats.

Keywords: Allelopathy, phenolics, germination, phytotoxicity, Solidago canadensis

The poster in a PDF version is available here.

Evolution of liana weeds in sugar cane plantations in Ivory Coast (286)

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The fight against weeds is a major problem in sugarcane culture. The diversity of soils, climate, weed species encountered, the duration of the campaign, farming methods, and the time of intervention forced to conduct operations that contribute to the highly variable situations in the grassing sugar complexes.
Inside each elementary surface (48 m2 or 64 m2) as a function of the study station (cultivation area), we note the following features on each weed liana: the presence, frequency and its effects on the physiology of sugar cane (tillering, height, stem circumference, length of the sheet). Then we consider the degree of harmfulness of the weed by assigning a value of from 1 to 5.
The floristic surveys have identified, between 2000 to 2014, 25 species liana weeds, of which 17 were already present in 2000, thus pointing the appearance of 6 new liana species.
Among the latter 6 have a degree of harmfulness between 4 and 5. It is to these degrees of harmfulness that weeds do more damage on sugar cane. Indeed, there are less tillering, stem remains withered and stunted resulting in a lower yield of sugarcane. These weeds are mainly: *Ipomoea eriocarpa* R Brown., *Ipomoea heterotricha* Didrichsen; *Dioscorea lecardii* De Wild.; *Dioscorea praehensilis* Benth, *Dioscorea preussii* Pax, *Dioscorea quartiniana* Rich.

Keywords: Liana, harmful, weeds, Côte d'ivoire

Microscopy of pollen grains for some alien weeds (196)

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The wide-scale spreading of alien weeds can be harmful to human health. For example, pollen of *Ambrosia artemisiifolia* L. and *Cyclachaena xanthiifolia* (Nutt.) Fresen is the source of allergic pollinosis. Nonetheless normal aeropalynologic monitoring allows for identification any taxon mostly on genus level, while information about the pollen morphology for species level is inadequate.
We have studied the pollen of 17 alien weeds belonging to 7 families in Hungary, Slovakia and Russia in 2010-2015. „Calendar of blooming" for the Middle Russia was made. Morphometric features of pollen grains have been investigated by means of digital microscope Keyence VHX-1000. Characters of pollen's size and shape were described for examined taxa.
Only *Echinocystis lobata* (Michx.) Torr. et Gray has pollen grains with polar axis length 49.0-82.5 μm; according G.Erdtman (1969) this pollen is belonged to the large-pollen group. *Helianthus tuberosus* L., *Aster novi-belgii* L., *A. salignus* Willd., *Solidago canadensis* L., *S. gigantea* Ait., *Chamomilla suaveolens* (Pursh) Rudb., *Reynoutria japonica* Houtt., *Amelanchier alnifolia* (Nutt.) Nutt. are characterized by pollen grains with polar axis length 25-50 μm; their pollen is classified as medium-sized group. Small pollen grains (up to 21.6 μm) is observed for *Ambrosia artemisiifolia*, *Cyclachaena xanthiifolia*, *Erigeron annuus* (L.) Pers., *Amelanchier spicata* (Lam.) C. Koch, *Acer negundo* L. and *Fraxinus pennsylvanica* Marsh.
Alien self-pollinated species (*Erigeron annuus, Chamomilla suaveolens*), likely give less risk to sensitive individuals because their pollen is mostly inside the flower.
All examined species of Asteraceae family (*Solidago canadensis, S. gigantea, Helianthus tuberosus, Aster* spp. et al.) have the same exine's echinate ornamentation as ragweed. These species producing a lot of pollen grains in August – September, requires a more detailed study for detection their opportunity to cause an allergic reaction.

Keywords: Alien weeds, pollen grains

The poster in a PDF version is available here.

Morphology of achenes and traits for identification of some invasive species of genus *Bidens* section *Psilocarpea* (419)

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Fruits (achenes) of species of *Bidens* are often found in various types of plant products imported into Russian Federacion. As a rule, these species belong to the section *Psilocarpea* (*Bidens pilosa*, *B.alba*, *B.bipinnata*, *B.subalternans*, *B.subalternans* var.*simulans*). *Bidens pilosa* fruit penetrate the hair and skin of animals and as a result this species is a quarantine subject in the Russian Federation. The purpose of our work was to study the morphology of *Bidens* fruits to find suitable species-specific traits in morphological structure that would allow *Bidens pilosa* to be separated from the other species of *Bidens*. We used comparative morphological and growing methods. Achenes were taken from imported products (soybeans, meal, wool, etc.) and germinated in a quarantine greenhouse. The plants were grown to flowering and fruiting growth stages. Then several morphological features of adult plants were carefully studied (especially inflorescences and fruits). It was found that plants of genus *Bidens* (section *Psilocarpea*) are hard to differentiate from each other using only traits of the achenes. We found only a few features that allow differentiation. In particular, the white ray flowers of *Bidens pilosa* and *B.alba* can be used to differentiate these two species from *Bidens bipinnata, Bidens subalternans* which have yellow ray flowers.

Keywords: Invasive plants, quarantine object, *Bidens pilosa*, methods of identification

The invasive weed *Ipomoea hederacea* (L.) Jacq. is included in a list of pests of quarantine concern for the Russian Federation (426)

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Ivy morning glory *Ipomoea hederacea* (L.) Jacq is a very dangerous weed included in “List of Pests of Quarantine Concern” in the Russian Federation. We assessed the risk of potentially invasive species in greenhouse conditions. In spring in greenhouse, 6 species of *Ipomoea* (*I. quamoclit*, *I. sloteri*, *I. nil*, *I. purpurea*, *I. tricolor* and *I. hederacea*) were sown. Observations of vigour, phenological stages of plant development were recoded. *I. hederacea* had all the characteristics expected of an invasive weed, such as high percent of germination (more than 90 %) quick early growth, long flowering and fruiting period and high seed production (more than 1000 seeds per one plant during vegetation.) *I. hederacea* is deservedly considered a dangerous quarantine weed capable of causing economic damage to agriculture in the Russian Federation.

Keywords: *Ipomoea hederacea*, invasive potential, quarantine weed

The poster in a PDF version is available here.

Determination of the presence of weed in manure pits in the Middle Black Sea region of Turkey (332)

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Weed seed transmission by livestock is a growing concern that requires addressing at local, national and international levels because there is a great risk of widespread weed seed dissemination in countries such as Turkey with its extensive grazing practices and significant amounts of livestock movement. The study was conducted to determine the amount of weed in livestock manure samples which was collected from 44 farm manure pits in the Middle Black Sea region in Turkey. Sampling was carried out in Çorum and Samsun provinces of the Black Sea region where intensive livestock grazing is practised. Samples of dung were randomly collected from 28 cattle and 16 sheep farms and brought to the greenhouse unit of the Agriculture Faculty of Ondokuz Mayis University. The experiment consisted of two treatment groups (cattle or sheep manure) with 5 replications in the experiment. Then samples mixed with sterile soil were allowed to germinate 28 days in greenhouse after which germinating weed seeds were counted. The data showed that species of Poaceae, Fabaceae, Brassiceae, Asteraceae, Polygonaceae families were among the most commonly found in the dung samples and that more occurred in cattle than in sheep dung. It was concluded that some weed seeds could be transported in animal faeces.

Keywords: Manure pits, weed, livestock, density, dispersal

The poster in a PDF version is available here.

Response of common waterhemp to water stress (372)

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Common waterhemp (*Amaranthus rudis* Sauer) is one of the most difficult-to-control weeds in the Midwestern United States. It is well known that environmental stresses like water deficiency restrict plants in achieving their maximum growth potential. However, limited scientific literature is available on the response of *Amaranthus* species to water stress. The objective of this study was to determine the effect of degree and duration of water stress on the growth and fecundity of two common waterhemp biotypes. Two separate experiments were conducted, one each for degree and duration of water stress, in the greenhouse at the University of Nebraska-Lincoln. The experiments were repeated in 2013 and 2014. The two biotypes responded similarly to degree and duration of water stress; therefore, data were combined. The water stress experiment had five treatments (100, 75, 50, 25, and 12.5% of field capacity), where the specific amount of water was applied at 2-d interval. The highest values for plant height (163 cm), number of leaves (231 plant^{-1}), growth index (4.4 × 10^5 cm^3), aboveground biomass (72 g plant^{-1}), and seed production (34,450 seeds plant^{-1}) were recorded at 100% of field capacity (no water stress). Five treatments (2, 4, 6, 8, and 10-d interval) were included in duration of water stress study and water equivalent to 100% field capacity was applied at each interval. The highest values for plant height (150 cm), number of leaves (210 plant^{-1}), and growth index (3.8 × 105 cm^3) were observed at the 2-d interval of water stress. However, seed production was similar at 2-d (36,549 seeds plant^{-1}) and 4-d (34,176 seeds plant^{-1}) intervals. This study revealed that common waterhemp can survive and produce substantial amount of seeds under a high level and duration of water stress.

Keywords: Aboveground biomass, field capacity, growth index, seed production

The poster in a PDF version is available here.

Growth, development and seed production of *Eleusine indica* (257)

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E. indica (goosegrass) is one of the five worst weeds in the world, because it is a worldwide problem and there are reports of multiple resistance to herbicides up to four mechanisms of action. The objective of this study was to evaluate the growth, development and seed production of goosegrass, in order to contribute to the biology and ecology of this species, and consequently with its integrated management.
The experiment was conducted in greenhouse during May to September, 2015. The evaluations occurred on 16 dates throughout the plant development cycle: 3, 10, 17, 24, 31, 38, 45, 52, 59, 66, 73, 80, 87, 94, 101 and 108 days after emergence (DAE). The experimental design was completely randomized, with four replications (pots of 3 dm^3). Growth analysis parameters (relative growth rate, absolute growth rate and net assimilation rate) were calculated from primary data (leaf area and dry mass of each part of the plant throughout its life cycle). *E. indica* required 12 days to germinate completely; tillering and seed production started at 9 and 38 DAE, respectively. On average, one single plant produces more than 120,000 seeds at 108 DAE. Between 38 and 43 DAE, there is a pronounced growth period, when tillering, total biomass and absolute growth rate increase substantially.
Based on plant growth and morphology, management of *E. indica* should be primarily before 38 DAE, due to exponential growth after that. By an early management, seed production and dissemination is also prevented.

Keywords: Relative Growth Rate, Absolute Growth Rate, Net Assimilation Rate, Biomass alocation, Leaf Area

The poster in a PDF version is available here.

Mineral uptake of lentil and kidney bean in competition with *Sinapis arvensis* and *Rumex crispus* under salinity stress (510)

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Information on uptake of minerals by weeds and crops is necessary in order to evaluate the outcome of competition under different scenarios such as salinity stress. Crops usually are less tolerant to salinity than many weeds and, therefore, crops are likely to be subjected to more weed pressure under saline than non-saline condition e.g. due to nutrient imbalance. A pot experiment was conducted to study the uptake of Fe, Cu, Na and K by *Sinapis arvensis* and *Rumex crispus* in competition with lentil (*Lens culinaris* medik) and kidney bean (*Phasaeolus vulgaris* L.). The treatments were ammonium phosphate (P) (0 and 50 mg/kg soil), salinity (0 and 3000 mg/L), weed species (2) and crop species (2) with three replicates. The results showed that P resulted in an increase in the uptake of Na and K and a decreased uptake of Fe by both weed species. It also resulted in increased dry weight in both weeds. The uptake of Na by lentil was higher than that of kidney bean and was higher in both crop species under the salinity treatment. It is concluded that weeds, but not the crops, were able to uptake more Na and K when ammonium phosphate is applied. Since the weeds were not affected by salinity, salinity may increase the adverse competitive effects of weeds on the crop.

Keywords: Competition, stress, salinity, weed, minerals

The poster in a PDF version is available here.

When does the compensation point occur in *Cirsium arvense*? (343)

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Cirsium arvense (L.) Scop., creeping thistle, is one of the world`s most troublesome perennial weeds and is native to Europe. Farmers are recommended to employ physical control strategies when *C. arvense* is most sensitive to disturbance. This occurs when the plant has reached the minimum below ground dry weight, i.e. compensation point. Earlier studies have shown that the compensation point occurs when the plant has developed 8-10 leaves. However, many farmers feel that this stage is too late to repeat control measures and that the control effects are inferior. An outdoor pot experiment was set up in Sweden to assess how competition from spring barley, planting depths (5 and 15 cm) and root weights (0.8 and 2.4 g) affect developmental stage at which the compensation point occurs in *C. arvense.* We hypothesized that: (i) the compensation point occurs before *C. arvense* has developed 8-10 leaves, regardless of the treatment employed, (ii) at the compensation point, the depletion rate of carbohydrate reserves in the roots is higher at a lower initial root weight compared to a higher initial root weight. The results showed that the compensation point for *C. arvense* at all treatments occurred before the plant had developed six leaves. Root fragments with lower weight as compared to those with higher weight, attained a larger depletion of carbohydrate reserves at the compensation point. The effects of planting depth were inconclusive. For agronomic practice, our results imply that the regrowth of *C. arvense* should be controlled earlier than previously recommended, and that root fragmentation (soil tillage) will further deplete the carbohydrate reserves when done before the compensation point occurs.

Keywords: Below-ground biomass, Organic farming, Perennial weed, Root fragmentation, Scandinavia

The poster in a PDF version is available here.

Determination and quantification of phyto-phenols (dormancy factor) present in the tubers of *Cyperus rotundus* (667)

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Cyperus rotundus (purple nutsedge) is a perennial weed that can have impacts continuously throughout the year in the tropical regions. This sedge propagates mainly by producing a complex underground system of rhizomes, basal bulbs and tubers. The tubers remain viable for more than three years and their dormant buds enable the species to survive during harsh weather. The bud dormancy in tubers is due to the presence of inhibitors in the tuber. A laboratory experiment was carried out at the Department of Nano Science and Technology, Tamil Nadu Agricultural University to quantify the different phenolic compounds (germination inhibitor) present in the *Cyperus rotundus* tubers. This study revealed that the tubers contain five major phenolic compounds: caffeic, ferulic, hydroxybenzoic, vanillic and chlorgenic acids. Similar quantification was repeated with artificial stress-induced tubers. Compared to normal tubers, stress-induced tubers exhibited 3.1, 3.0, 2.5, 2.0 and 1.7 fold increase of vanillic, caffeic, ferulic, chlorogenic and hydroxyl benzoic acid, respectively. The raised level of phenols suppressed the germination of buds present in the tuber during the harsh weather condition. This is the reason for the dormancy of *C.rotundus*.

Keywords: *Cyperus rotundus*, dormancy, phenol, weed

Session 11
WEED MANAGEMENT IN CROPS AND NON-AGRICULTURAL LAND

Elephant grass response to amino-acid synthesis inhibitor herbicides (24)

Alexandre Brighenti *(Embrapa Dairy Catlle, Juiz de Fora, Brazil)*

The research for new sources of renewable energy has been growing steadily due to the increasing of global energy demand. The elephant grass (*Pennisetum purpureum* Schum.) is considered one of tropical forages with higher dry matter yield potential that can range from 10 to 80 t ha^{-1} per year. Besides being an excellent animal feed, used in dairy production, the elephant grass can also be suitable as raw material for alcohol production and generation of electricity. One of the major limitation of the implementation and conduct of elephant grass fields is related to weed interference. Experiments were conducted at different locations in Brazil to evaluate the tolerance of elephant grass plants to amino-acid synthesis inhibitor herbicides in order to provide subsidies to weed control in elephant grass crop. The herbicide treatments were as follow (g ha^{-1}): metsulfuron-methyl (7.8 and 15.6), chlorimuron-ethyl (15 and 30), halosulfuron (112.5 and 225), ethoxysulfuron (150 and 300), nicosulfuron (60 and 120) and an untreated check. The herbicides metsulfuron-methyl, chlorimuron-ethyl, halosulfuron and ethoxysulfuron caused mild symptoms of injury in elephant grass plants even in higher doses. The younger leaves presented slight chlorosis that disappeared at 21 days after herbicides application without reducing forage biomass. The nicosulfuron caused considerable damage on elephant grass plants with forage productivity losses. The symptoms consisted of leaf discoloration and wrinkling of the middle portion of the blade of the central leaves of the whorl that were undergoing expansion at the time of application. The herbicides metsulfuron-methyl, chlorimuron-ethyl, halosulfuron and ethoxysulfuron were selective to elephant grass plants, being a potential practice for controlling weeds on elephant grass fields. The nicosulfuron caused serious injury on elephant grass pasture.

Acknowledgements
Financial support of CNPq and FAPEMIG is highly acknowledged.

Keywords: Napier grass, weeds, forage, selectivity, tolerance

The poster in a PDF version is available here.

Evaluation of efficacy of herbicides for weed control in early-planted sugarcane in Tamil Nadu (647)

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Sugarcane (*Saccharum officinarum.* L.) is cultivated in an area of 4.40 million hectares and in Tamil Nadu, India, with a productivity of 105 ton ha^{-1}. Among the various factors limiting cane production, weed infestation is one of the major biotic constraints. The extent of loss in cane yield caused by weeds is varied from 10-100% depending upon composition and diversity of weed infestation. Hence, a field experiment was conducted during early season of 2015-16 at Tamil Nadu Agricultural University, Coimbatore, India, to evaluate herbicide, tembotrione (420 SC) with and without surfactant against grassy and broad leaved weeds. Experiment was laid out in randomized blocks design with three replications. Treatments comprised of herbicides *viz*., tembotrione, atrazine, ethoxysulfuron and metribuzin evaluated alone at different doses and in combination with surfactants and other herbicides. Predominant infestation of *Setaria verticillata*, *Dinebra retroflexa*, *Chloris barbata*, *Panicum javanicum, Dactyloctenium aegyptium* and *Cynodon dactylon* among grasses*, Trianthema portulacastrum*, *Cleome gynandra*, *Digera arvensis* and *Parthenium hysterophorus* among broad-leaved weeds and *Cyperus rotundus* the only sedge was observed. Grass weeds dominated throughout the cane growth period followed by broad leaved weeds and sedges. At 30 days after planting (DAP), total weed density and weed dry weight were significantly lower in early post-emergence application of tembotrione at 120.75 g a.i. ha^{-1} + surfactant (Stefes mero-rapeseed oil methylated) at 1000 ml ha^{-1} + metribuzin at 1050 g a.i. ha^{-1} with higher weed control efficiency of 87.2%, which was on par with pre-emergence application of atrazine at 500 g a.i. ha^{-1}. It is concluded that the application of tembotrione at 120.75 g a.i. ha^{-1} + surfactant(Stefes mero-rapeseed oil methylated) at 1000 ml ha^{-1} + metribuzin at 1050 g a.i. ha^{-1} applied at 2-4 leaf stage was effective to control weeds in early planted sugarcane.

Keywords: Sugarcane, Herbicide mixtures, Tembotrione, Weed density & Dry weight, Weed control efficiency

The poster in a PDF version is available here.

Weed management in lady palm, *Rhapis excelsa* in palm nurseries (498)

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Palms such as *Rhapis excelsa* (Thunb.) Henry are among the most wanted ornamental plants in Turkey. There have been several nurseries to produce palm saplings/trees. These plants kept almost ten years in nurseries, which increase production costs. Weeds are one of the important plant protection problems in this production, which competes and acts as alternate hosts for diseases and insects. The most common weeds in Lady Palm plantations are *Imperata cylindrica, Cynodon dactylon, Sorghum halepense, Cyperus* spp.*, Chenopodium* spp.*,* and *Juncus* sp. Many other weeds of minor importance can be found in a palm nursery. Weeds are plants that grow with Lady Palm and act as competitors for food or serve as alternate hosts for insects and diseases. Numerous studies have established that weeds cause more damage than insects and fungi combined. Due to negative effect on lady palms, chemical weed control has not been recommended. Various mechanical and cultural control methods are mostly preferred but these elevate labor costs.

Keywords: Lady Palm, *Rhapis excelsa*, weed managament, non chemical methods, nursery, sapling

Eucalyptus responses to glyphosate and phosphorous (446)

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As phosphorus deficiency occurs in many soils worldwide, to study the effects of phosphate levels and possible interaction between phosphorus and glyphosate is essential. The aim of this study was to evaluate chlorophyll content, quantum efficiency of photosystem II, as well as glyphosate, aminomethylphosphonic acid (AMPA) and shikimic acid contents in *Eucalyptus urograndis* clones (GG100 and I144) grown with phosphorus levels (0.5X; 1X; 1.5X where X equals the recommended phosphorus level) and submitted to glyphosate doses (0.0%, 0.6%, 2.5% and 10.0%, corresponding to 0.0; 0.034; 0.144 and 0.576 g ae). The chlorophyll content and the fluorescence of chlorophyll are indicative of photosynthetic stresses, such as happens with glyphosate drift. Clone GG100 showed higher reductions in chlorophyll and fluorescence of chlorophyll when compared to clone I144, and therefore was considered the most sensitive to glyphosate. Glyphosate, AMPA and shikimic acid contents are indicative of glyphosate effects and eucalypt detoxification capacity. Clone I144 showed less glyphosate accumulation and larger amount of AMPA, indicating better detoxification capacity when compared with GG100 clone. Together, this information can collaborate with selection of clones “more tolerant” to glyphosate or that degrade glyphosate quickly and therefore are “less susceptible” to accidental drift effects. In the present work, this clone was I144. We concluded the photosynthetic apparatus of plants supplied with lower phosphorus levels was reduced faster for both clones. The largest glyphosate content were quantified in plants grown with lower phosphorus levels, indicating that low levels of phosphorus helped glyphosate transport and increased glyphosate effects.

Keywords: Chlorophyll, photosynthetic apparatus, phosphate, shikimic acid, transporters

Herbicidal activity of chlorimuron-ethyl associated with metribuzin on sugarcane weeds and its effects on soil agrochemical properties in Burkina Faso (119)

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The efficiency and selectivity of chlorimuron-ethyl 107 g /kg associated with metribuzin 643 g/kg, against weeds which causes big damage to sugar cane, have been studied on the sugar cane field of Bérégadougou, in Burkina Faso. The experimental design was a Latin rectangle with eight treatments in four replications including an untreated control, manual weeding, a control product (trifloxysulfuron-sodium 1.85% + ametryn 73.15%) and five rates of chlorimuron-ethyl associated with metribuzin. Density and dry weight of weeds were recorded in four sugarcane lines. The biological efficiency coefficients were also determined. The soil nitrogen nitrate was evaluated on a spectrophotometer, those of assimilable phosphorus by Bray method and available potassium on a flame photometer. Some cases of phytotoxicity were observed on high doses of chlorimuron-ethyl associated with metribuzin. The biological efficiency coefficients this herbicide, at different doses, varied from 12, 41 to 100, according to their dry biomass. High rates showed the best coefficients. At the sugar cane complete maturation, the higher rates of herbicide led to an accumulation of nitrogen nitrate content and lower available phosphorus and potassium contents, compared to the untreated control. These different factors allowed at the different doses of chlorimuron-ethyl associated with metribuzin, an increase of machining canes number from 25% to 29% and a sugar cane yield increase from 13.34% to 22.52% compared to the untreated control. The rate of 1.20 kg/ha could be an acceptable dose to apply against weeds and less toxic to the soil.

Keywords: Chlorimuron-ethyl, metribuzin, weeds, Agrochemical properties, sugar cane

The poster in a PDF version is available here.

Weed control with residual herbicides in established sugarcane plantations: The basis for sustainability sugarcane production in Cuba (535)

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The sprouts represent the largest area in Cuba in agricultural extension and which provides large volume of raw materials to industry, and essential in the production of sugar, but unprotected in weed control. Since 2004 a program of integrated weed management, consisting of the use of residual herbicides as a basis for management of weeds from the seed to the use of active ingredients and Indaziflam Isoxaflutole or the formulation of both mixed with attachment name Total commercial Merlin SC 60%, combined with postemergence treatments and machining work and manual cultivation. The program established sustainability premised on increasing cane production, the decline in the percentages of weed infestation, change in the concept of weed management and contribute to food production companies that produce cane as main line. The results show that since the implementation of the program in 2004 there is an upward progression in its development over the years established, covering all units or farms cane production in the country and stability between 39 and 43% of the area of cane, primarily protecting the shoots dry period where he shows his strength and kindness, change the concept of curative preventive control, reducing weed infestation in the target areas and the sustained increase in agricultural yields in these units or farms. Concluding that the program contributes to the sustainable production and sugar cane and has established itself as development perspective.

Keywords: Cane sugar, Isoxaflutole, Merlin Total, suckers, weeds

Evaluation of saflufenacil to control of *Ipomoea grandifolia* and *Euphorbia heterophylla* in raw cane agricultural systems (433)

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The effectiveness of herbicides on raw cane system is directly influenced by the amount and distribution of straw in the area – which may intercept the herbicide before it reaches the ground – and by occurrence of rain after application. This study aimed to evaluate the selectivity of the herbicide saflufenacil to the sugarcane in the raw cane system and its efficiency for *Euphorbia heterophylla* and *Ipomoea grandifolia* control. The study was carried out in the field and evaluated seven doses of saflufenacil applied 50 days after sugarcane harvest (on 12 t ha^{-1} straw on the ground): saflufenacil (0.050 kg ha^{-1}), saflufenacil (0.070 kg ha^{-1}), saflufenacil (0.140 kg ha^{-1}), saflufenacil + Dash (0.050 kg ha^{-1} + 0.5% v/v); saflufenacil + Dash (0.070 kg ha^{-1} + 0.5% v/v); saflufenacil + Dash (0.140 kg ha^{-1} + 0.5% v/v); and mesotrione + Assist (0,3 L ha^{-1} + 0.5% v/v). In addition it was carried out a treatment without application of herbicides (control). The sugarcane variety was RB867515 (after the third cut), planted in a 1.5 m spacing between rows, where *E. heterophylla* and *I. grandifolia* seeds were sown. At 3, 7, 15, 30 and 45 days after application (DAA), the control effectiveness of the weed species, as well as the selectivity of the treatments to sugarcane were evaluated. By the harvest of sugarcane, the yield and technological components – Brix, Yield Stems, Reducing Sugars Total and Yield of Sugar – were also evaluated. All the treatments were more efficient for control of *I. grandifolia* than *E. heterophylla* in all assessment periods, being the treatment with saflufenacil + Dash (0.070 kg/ha^{-1} + 0.5% v/v) the most effective. None of the treatments affected in a negative way the technological components of the variety of sugarcane studied and so were selective to sugarcane.

Keywords: Herbicides, morning glory, wild poinsettia, Saccharum spp

Behavior of the main sugarcane cultivars in Cuba applied with the herbicide indaziflam plus isoxaflutole (534)

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In order to know the behavior of the main cultivars of sugarcane in Cuba with the application of a new herbicide, Indaziflam 150 gL^{-1} + Isoxaflutole 450 gL^{-1} 60 SC, the present study was developed soil Ferralitic Red Compacted, in the Provincial Research Station of Sugarcane INICA, located in the municipality Jovellanos Matanzas province. The product was applied at the time of planting 59 sugarcane cultivars, with doses of 0.25 Lha^{-1} and a final solution of 245 Lha^{-1}. Phytotoxicity were evaluated every 20 days, using the scale of EWRS. At 20 days after application (daa) showed mild, clearly visible symptoms (grade 3) 10 cultivars, 18 complete absence of symptoms (grade 1) and 31 with symptoms very mild (grade 2), these symptoms were noticeable to 60 daa and 120 daa was observed normal development in all cultivars. With respect to total control weeds and he observed 80 days after application daa.

Keywords: Varieties, herbicide, sugarcane

Efficacy of pre-emergence herbicides for controlling Chinese violet (*Asystasia gangetica* (L.) T. Anderson) in pineapple plantations (724)

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During the last five years, Chinese violet (*Asystasia gangetica* (L.) T. Anderson) was found to be a major broadleaved weed in some pineapple plantations grown in southern Thailand. As there was no herbicide recommendation for Chinese violet control, efficacy of pre-emergence herbicides for controlling Chinese violet was evaluated in two farmers' fields in Phattalung province during October 2011 – September 2012. Nine treatments of pre-emergence herbicides were arranged in Randomized Complete Block (RCB) with four replications. Treatments consisted of single and tank mixture of pre-emergence herbicides i.e tebuthiuron+pendimethalin, flumioxazin, hexaxinone/diuron, alachlor+diuron, pendimethalin+dimethenamid, tebuthiuron+oxyfluorfen, pendimethalin+diuron, metribuzin and bromacil+diuron at the rates 0.781+1.031, 0.125, 3.750, 2.0+2.0, 1.031+1.406, 0.781+0.150, 1.03+2.0, 0.875 and 3.5+3.500 kg a.i./ha respectively, and untreated check. The results showed that the applications of tebuthiuron+pendimethalin, flumioxazin, hexaxinone/diuron, alachlor+diuron, pendimethalin+dimethenamid, tebuthiuron+oxyfluorfen, pendimethalin+diuron, metribuzin and bromacil+diuron, provided a good control of Chinese violet for 60 days without crop injury. However, one follow up with post-emergence application would be required to provide a longer period of weed control.

Keywords: Chinese violet, *Asystasia gangetica*, pineapple, weed control, pre-emergence herbicide

The poster in a PDF version is available here.

Sustainable long-term weed control strategies with glyphosate programs in hazelnut (550)

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Hazelnut (*Corylus avellana* L.) is native to the Black Sea coast of Turkey as a tree or shrub on the steep slopes. Weed management is critical in hazelnut production to reduce competition and improve hand harvesting efficiency. Different experiments were designed for control of *Rubus canescens*, *Pteridium aquilinum* and *Convolvulus arvensis* at both greenhouse and field conditions. Field experiments were initiated in spring 2014 and conducted through 2015 in three different (Samsun, Giresun and Düzce) hazelnut orchards through the Black Sea Region of Turkey with *R. canescens*, *P. aquilinum* and *C. arvensis* problems on a sandy clay soil. In field experiments, 13, 8 and 8 different treatmens have been applied to control *R. canescens*, *P. aquilinum* and *C. arvensis*, respectively in different application time. The reuslt from greenhouse experiment showed that, the most prominent treatment was glyphosate 1,8 kg ha^{-1} + MCPA 1,8 kg ha^{-1} to control *R. canescens*, *P. aquilinum* and *C. arvensis* at 56 DAT. In the field in both years, different herbicide treatments have considerable variations in the susceptibilities of weed species. *R. canescens* were susceptible to the mixture of glyphosate 1,08 kg ha^{-1} + MCPA 1,08 kg ha^{-1} application in March then other treatment and it only appeared to be controlled well by this application. *P. aquilinum* was controlled by glyphosate 1,08 kg ha^{-1} + MCPA 1,08 kg ha^{-1} or glyphosate 1,08 kg ha^{-1} plus carfentrazone 25 g ha^{-1} but this species re-grew from glyphosate 1,08 kg ha^{-1} plus carfentrazone 25 g ha^{-1} in plots after 56 DAT. Consequently, the combination of a glyphosate 1,08 kg ha^{-1} + MCPA 1,08 kg ha^{-1} application in March, included as a standard herbicide mix ST+glyphosate 2,16 kg ha^{-1} in early August that is commonly used in hazelnut, was the most effective treatment overall.
This project has been supported by MONSANTO EUROPE S.A.

Keywords: Weed mangement, invasive weed species

EWRS Working Group on "Herbicide Tolerant Varieties" (735)

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The working group Herbicide Tolerant varieties (HT) is a newer working group within the EWRS organization and was established in November 2012. HT varieties obtained via mutagenesis as well as obtained via genetic improvement are considered within this working group. The development and commercial introduction of the HT varieties in Europe goes hand in hand with periodically very polarized and emotional discussions. The situation in Europe as related to HT crops underwent a rather dramatic change for some of the technologies used in these cropping systems since the start of the working group. The members of this working group are committed to looking for a scientific and balanced evaluation of the agronomic impact of these herbicide-tolerant varieties and attempt to translate these into related benefits and potential risks. Impacts to be studied include weed management in these cropping systems, impact on overall crop rotation, advantages and/or disadvantages for the rotational systems, economic as well as agronomic sustainability. An update of the activities will be provided.

Keywords: Herbicide tolerant varieties, weed managment

The poster in a PDF version is available here.

Unmodified coverage of waste sugar harvest efficient and sustainable practice in the management of weeds (531)

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Results achieved in experiments and in commercial plantations of sugarcane in rainfed conditions where the practice of cover crop residue undisturbed on the soil surface is reported settled. The pilot-scale research was conducted in Cristino Naranjo sugar mill on Vertisol soil where an experiment with a randomized block design with 3 treatments and 5 replicates was planted, while the extensive studies were developed in Puerto Rico Libre, Jesus Suarez Gayol and Jesus Rabi sugar mills on Ferralsol ground. Weed cover assessments at 30, 60, 90 and 120 days after harvest that fall within the critical period of competition and measurements of the components of agricultural output length, diameter and number of stems per meter were performed. The data was processed by statistical analysis through Stagraphic plus 5.0 and multiple comparison of means by Tukey to 95%. Only the length of the stems reach significantly higher values than the standard treatment of traditional farming and agricultural performance was also superior to the use of this practice. Furthermore a significant effect on weed control for the effect of cover crop residue and a significant reduction in costs for the reduction of work in their control was obtained, so that its implementation in soil and climatic conditions similar to this study can be considered as a conservation and sustainable management.

Keywords: Sugarcane, unmodified coverage, weed control

Peanut response to weed and disease management strategies in Ghana (181)

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Weed interference and impacts of diseases continue to reduce peanut yields in many regions of Africa. Although availability and price of pesticides limit utility for small farmers, considerable interest exists among farmers and those recommending pest management practices in determining the utility of pesticides in peanut. Field experiments were conducted in peanut during the rainy seasons of 2009 and 2010 in Ghana at the CSIR-Savanna Research Institute at Nyankpala and on-farm at Bagurugu to determine peanut and pest response to management strategies including fungicides to control disease (caused by leaf spot) and the combination of herbicide and hand-removal of weeds. Two hand weedings or application of pendimethalin preemergence with one supplementary hand weeding combined with fungicide sprays resulted in the lowest weed density and severity of both early and late leaf spot diseases. These combinations generated the highest number of pods, biomass, and pod yield of peanut. The predominant weed flora at time of harvest was broadleaf weeds followed by annual grasses and sedges. The study demonstrated the importance of proper weed management and fungicide treatments for increased peanut yield in Ghana.

Keywords: Weed management, pest management, peanut, groundnut, integrated pest management

The poster in a PDF version is available here.

Troublesome weeds control in peanuts in Israel (672)

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Weed control in peanuts is based on herbicides which provide a wide spectrum of weed control e.g. *Tribulis terrestris*, *Solanum elaeagnifolium*, *Trianthema portulacastrum*, *Portulaca oleracea*, *Amaranthus blitoides, A. retroflexus* and *Cyperus rotundus*. Preliminary studies have found imazamox to be effective when applied on *T. terrestris* as pre-emergence (PRE), post-emergence (POST), and pre-planting incorporation (PPI) at a rate of 32 g a.i. ha^{-1}. The objectives of this study were a) to evaluate the efficacy of imazamox applied PRE in peanuts and to evaluate its selectivity when applied at five rates between 0-64 g a.i. ha^{-1}; and b) to evaluate the impact of formalin applied as soil disinfection on imazamox efficacy and selectivity to peanuts. Experiments were conducted during 2013 and 2014 in the Negev located in the south part of Israel and in Heffer Valley located near the central Mediterranean coast. The control efficacy and peanuts selectivity to the herbicides examined in this study were compared to the commercial treatment of a tank-mix of terbutryn with *S*-metolachlor at rates of 500 g a.i. ha^{-1} + 915 g a.i. ha^{-1} respectively. The following herbicides were examined: imazamox 16-64 g a.i. ha^{-1}, bentazon 1440 g a.i ha^{-1} with pyraflufen-ethyl 10 g a.i. ha^{-1}, imazapic 48 g a.i. ha^{-1}, flumioxazin 75 g a.i. ha^{-1} and aclonifen 1800 g a.i. ha^{-1}. It was found that imazamox applied PRE at 16 g a.i. ha^{-1} and 32 g a.i. ha^{-1} with and without formalin did not injure peanuts. However, the application of imazamox PRE at 48 g a.i. ha^{-1} and 64 g a.i. ha^{-1} resulted in a significant injury and yield reduction compared to the non-treated control. Imazapic and aclonifen effectively controlled *Ipomoea* spp. and purple nutsedge. All herbicides were selective to peanuts except the 1800 g a.i ha^{-1} aclonifen applied POST.

Keywords: Ground nut, Herbicide, Portulaca oleracea, *Tribulis terrestris*, Weed management

Performance of imidazolinone herbicides in green gram (*Vigna radiata* L.) and their carryover effect on succeeding mustard crop (681)

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In south-western Haryana, green gram is the most important *Kharif* pulse crop. Being a short duration crop, it is subjected to heavy weed competition. Thus, it is necessary to manage weeds at proper time with suitable methods for good harvest. Non-availability of labour and its poor efficacy due to long window of weed emergence in the rainy season, chemical weed management offers excellent scope for effective weed management in green gram. Some herbicides can have harmful carryover effects on subsequent sensitive crops. Therefore, a correct sequence of herbicides, their mixtures or rotations together with crop selection is vital for effective weed management. Keeping this in view, experiments were conducted during 2014-15 and 2015-16 at Agronomy Research Farm of CCS, HAU Hisar India. Pendimethalin and pendimethalin+imazethapyr (ready mixture) 1000 g/ha pre-emergence (PRE), imazethapyr pre-plant/PRE/post-emergence (POE) and imazethapyr+imazamox (RM) PRE and POE at 70 and 80 g/ha were applied using a knapsack sprayer fitted with a flat-fan nozzle delivering 500 l/ha water volume. Pendimethalin+imazethapyr 1000 g/ha provided 80% control of *Trianthema portulacastrum* and *Echinochloa colona* up to 45 days after sowing (DAS), without any crop suppression. At 30 DAS, visual weed control was more than 95% in all PPI and PRE treatments of imazethapyr and imazethapyr+imazamox 80 g/ha, but with POE herbicides it was only 15-40% at 60 DAS. Weed control efficiency decreased in all PRE treatments due to the emergence of a second flush of weeds after rains. At 60 DAS, maximum WCE (85%) was recorded with imazethapyr 80 g/ha as PPI. Imazethapyr and imazethapyr+imazamox 70 and 80 g/ha POE provided poor efficiency against *T. portulacastrum* when applied at the 4 leaf stage. Imazethapyr applied alone was more persistent compared to its ready-mixture with pendimethalin or imazamox in causing toxicity on the succeeding mustard crop.

Keywords: Herbicide persistence, Crop phytotoxicity, Herbicide mixture, Weed Control efficacy, Green gram

Phytosociology of weeds occurring in cowpea in northeast of Pará-Brazil (562)

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The culture of cowpea (*Vigna unguiculata* (L.) Walp.) is traditionally developed in the North and Northeast of Brazil, is a source of food rich in protein, vitamins, and nutrients. In the Brazilian Amazon, the crop is usually produced by family farmers as a subsistence crop in both lowland area as in land division. The northeast of Pará State stands out in the production of cowpea. Weeds are one of the factors that most influence the growth, development, and productivity of the cowpea crop because they compete for light, nutrients, and water, which is reflected in quantitative and qualitative reductions in production. In order to avoid weed interference in the production of cowpea, it is necessary to know first the weeds occurring in the area and thus indicate the best management technique. This study aimed to carry out phytosociological survey of the species of weeds occurring in a cowpea in a crop area in northeast Pará. The assessment of weeds was performed 30 days after emergence of cowpea, using a square inventory 1 x 1 m, thrown randomly into the acreage. It performed the counting and identification of weed species occurring and evaluated: frequency, density, abundance, relative frequency, relative density, relative abundance, and importance value index of species. Fifteen species of weeds belonging to six botanical families were identified. Botanical families were Cyperaceae, Euphorbiaceae, Fabaceae, Malvaceae, Poaceaee, and Rubiaceae. Species with larger parameters was *Paspalum maritimum* including the importance value index. Vegetatively propagated species such as: *Cyperus rotundus*, *Eleusine indica, Sida rhombifolia* and *S. cordifolia*, had high incidence and concern because much of the soil preparation in the region is carried out in a conventional manner, using plow and grade.

Keywords: *Vigna unguiculata*, Family farming, Grain production in the Amazon, Beans

Response of peanut (*Arachis hypogaea* L.) varieties to weed management strategies in Sudan savanna of Nigeria (788)

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A *trial was conducted during the 2014 rainy season at Bayero University Kano (BUK) Research and Agricultural Research Station Minjibir in Sudan savannah zone of Nigeria to study the response of peanut varieties to different weed management strategies. The trials consisted of two varieties of peanut (SAMNUT 24 and KAMPALA) and 12 weed control treatments (pendimethalin at 1.5 kg a.i. ha^{-1}, benzothiadiazinone at 2.0 kg a.i. ha^{-1}, hoe weeding and weedy check among others). The treatments were factorially arranged and laid out in a split plot design. The results from the study revealed that hoe weeding at 3, 6 and 9 weeks after sowing (WAS), hoe weeding at 3 and 6 WAS and pendimethalin plus hoe weeding at 3 and 6 WAS resulted in a significant increase in stand count and plant height. Likewise, crop injury score, weed cover score, and weed dry weight were significantly reduced by the aforementioned treatments. Pod yield, 100 kernel weight, and haulm yield were significantly increased using hoe weeding at 3, 6, and 9 WAS, hoe weeding at 3 and 6 WAS and pendimethalin plus hoe weeding at 3 and 6 WAS. Production of SAMNUT 24 resulted in the highest growth and yield parameters and lowest weed infestation. From the results of this study it can be concluded that SAMNUT 24 produced higher pod and haulm yields than KAMPALA. In both locations hoe weeding thrice at 3, 6 and 9 WAS and hoe weeding twice at 3 and 6 WAS* or use of pendimethalin at 1.5 kg a.i ha^{-1} in combination with any of the two hoe weeding efficiently controlled weeds and resulted in high peanut yield.

Keywords: Groundnut varieties, Weed control, Growth characters, Yield characters

The poster in a PDF version is available here.

The use of correlation and path analysis to identify traits that contribute to yield of irrigated groundnut (*Arachis hypogaea* L.) varieties under the influence of poultry manure and weed control treatments (6)

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In order to identify characters that contribute to yield of groundnut under the influence of poultry manure and weed control methods in irrigated conditions, field trials were conducted during the 2012/2013 and 2013/2014 dry seasons at the Irrigation Research farm of the Institute for Agricultural Research, Kadawa, Nigeria. The treatments consisted of three levels of poultry manure (0, 1.5, and 3 tonnes ha^{-1}), five weed control treatments (54, 108, and 162 g a.i ha^{-1} of haloxyfop-R-methyl ester, weedy check, and two hoe weedings at 3 and 6 weeks after sowing) in three varieties of groundnut. The treatments were laid out in a split plot design with a factorial combination of the weed control methods and poultry manure occupying the main plots while the varieties were allocated to the subplots. The strength of the relationship between growth and yield parameters was studied using correlation coefficient analysis. The direct, indirect, individual, and combined contributions of growth and yield components to total pod yield were determined using path analysis. Pod yield was positively and highly correlated with number of branches, numbers of pods, pod weight, and 100-seed weight but was negatively correlated with haulm yield. Pod weight had the highest direct contribution, while number of leaves had the lowest direct contribution. The highest percent individual contribution was from pod weight. The combined effect of pod weight and 100 seed weight gave the highest combined contribution while the combined contribution of number of branches and number of pod ranked second. The least combined contribution was from number of leaves and number of pods and plant height and canopy spread that resulted to negative values. This study has confirmed that all the growth and yield characters considered made significant contribution to pod yield and thus constitute important characters when breeding for high yielding groundnut varieties.

Keywords: Correlation, path analysis, direct contribution, percentage contribution, groundut

Best weed management options for irrigated Kodo millet (*Paspalum scrobiculatum* L.) (117)

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A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* 2014 to evaluate best weed management options against control of complex weed flora in irrigated kodo millet. The experiment was laid out in a randomized block design with three replications. The treatments comprised of different weed management practices *viz*., pre-emergence (PE) pendimethalin 500 g/ha *fb hand weeding (*HW) at 40 days after sowing (DAS); PE bensulfuron + pretilachlor 660 g/ha; PE isoproturon 500 g/ha; PE pendimethalin 500 g/ha *fb* twin wheel hoe weeder weeding at 40 DAS; PE bensulfuron + pretilachlor 660 g/ha *fb* twin wheel hoe weeder weeding at 40 DAS; PE isoproturon 500 g/ha *fb* twin wheel hoe weeder weeding at 40 DAS; PE isoproturon 750 g/ha *fb* HW at 40 DAS; hand weeding twice at 20 and 40 DAS; twin wheel hoe weeder weeding at 20 and 40 DAS weed free check; and unweeded control.
Hand weeding twice at 20 and 40 DAS and PE application of isoproturon 750g/ha fb HW at 40 DAS augmented the growth and yield of irrigated kodo millet (2842 and 2796 kg/ha, respectively) by virtue of reduced weed growth and nutrient depletion by weeds and increased nutrient uptake by the crop. PE application of isoproturon 750g/ha *fb* HW at 40 DAS resulted in higher net return and B:C ratio along with PE application of isoproturon 500g/ha *fb* twin wheel hoe weeder weeding at 40 DAS. Hence, all these methods can be recommended for effective weed control options during critical stages of irrigated kodo millet.

Keywords: Kodo millet, Weed Management, Pre emergence herbicides

Soybean (*Glycine max* L.) cultivars susceptibility as affected by carryover of increasing rates of imazapyr+imazapic herbicide (98)

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Soybean crop in flooded areas may be an option to reduce red rice seed bank, but there are few studies about soybean tolerance to imazapyr plus imazapic carryover in flooded rice cultivated in the Clearfield® system. The work hypothesis was that imazapyr plus imazapic herbicides carryover causes more phytotoxicity to CD249STS (sulfonylurea-tolerant) and NA5909RR (Roundup Ready®) cultivars than BRS382CV (imidazolinones-tolerant) cultivar. The objective was to evaluate soybean cultivars (STS, RR and CV) tolerance as affected by imazapyr plus imazapic herbicides carryover, applied previously in flooded rice crop. The experiment was performed in flooded field in two growing seasons. In the first season, 2012/13, rice was seeded and imazapyr plus imazapic herbicides were sprayed at increasing rates. In the second season, 2013/14, soybean was seeded and phytotoxicity was evaluated at 10, 20, 30, and 67 days after crop emergence. The experimental design was in strips, in factorial scheme, with four replications, where factor A was soybean cultivars BRS382CV, CD249STS, and NA5909RR; and, factor B, imazapyr plus imazapic carryover 0; 0.5; 1.0; 2.0 and 4.0 times (X); it's labelled rate was 140 g ha^{-1}. There was an interaction between the factors studied. At 140 g ha^{-1} carryover rate, RR cultivar was more susceptible compared to STS or CV. A linear increase in phytotoxicity was observed as herbicide carryover elevated; increments of 400 and 500% in phytotoxicity in STS and RR cultivars, respectively, for each unitary increase in the herbicide rate. It is conclude that BRS382CV soybean cultivar has tolerance to imazapyr plus imazapic carryover, applied previously in flooded rice conducted in the Clearfield® system, while CD249STS and NA5909RR cultivars are susceptible.

Keywords: Sulfonylureas, imidazolinones, injury, flooded area

The poster in a PDF version is available here.

Assessment of weed management practices in Hungarian soybean production (245)

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Hungarian soybean (*Glycine soja*/L./Siebold et Zucc.) production is increasing, and it has been planted on over 40,000 hectares annually in recent years. High weed density in a soybean crop usually causes significant yield losses, and its weed control system demands a high level of technological knowledge from farmers.
262 soybean fields were surveyed across Hungary at the seasonal peak of summer annual weed vegetation between 2013 and 2015. In the course of this survey crop management information was obtained directly from the farmers.
In total, 66.4% of the surveyed fields were subjected only to chemical treatments, on 30.9% of the fields herbicides were combined with mechanical practices, while 2.7% of them were managed only by mechanical methods. Altogether, 60.7% of the surveyed fields were treated with both pre- and post-emergence herbicides, while the proportion of the fields where only either of the technologies was applied represented 19.1% pre-emergence and 17.6% post-emergence, respectively. Altogether, ten pre-emergence herbicides were used, among them the most frequently applied and their proportions were as follows: flumioxazin (24.6%), dimethenamid-P (22.2%), pendimethalin (19.2%) and S-metolachlor (18.2%). The proportion of post-emergence herbicides was represented by imazamox (43.1%), tifensulfuron-methyl (26.2%), different graminicides (20.4%) and bentazon (10.2%). Wider row spacing increased the potential possibility of using mechanical practices, thus 8.3% of the fields with 12-24cm row spacing was subjected to mechanical weed control treatments, while that was 74% in 30-50-cm rows, and 95% in 76-cm rows. Our survey suggests that many Hungarian farmers consciously used both pre- and post-emergence herbicides potentially combined with mechanical weed management practices as essential elements in successful soybean production.
This work was supported by project OTKA K111921.

Keywords: Weed control, herbicides, weed survey

The poster in a PDF version is available here.

Glyphosate-resistant soybean injury from dicamba and 2,4-D spray tank contamination (177)

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The anticipated availability of dicamba- and 2,4-D-resistant crops will increase the potential for crop injury to non-dicamba or 2,4-D-resistant soybean due to dicamba or 2,4-D spray tank contamination. A total of sixteen field trials (8 separate trials with each herbicide) were conducted in a completely randomized block design with four replications in Ontario, Canada during 2012-2014 to determine the response of non-dicamba and 2,4-D -resistant soybean to dicamba or 2,4-D spray tank contamination of 0.25, 0.5, 1.0 2.5, 5, 10 and 20% v/v tank contamination applied postemergence (POST) at the V2-3 (2-3 trifoliate) or R1 (1st flower) stage. Dicamba applied at R1 caused 23, 28, 36, 40, 48, 61 and 73% visible injury in soybean at 0.75, 1.5, 3, 6, 15, 30 and 60 g a.e. ha^{-1}, respectively. The predicted dose of dicamba to reduce soybean seed yield 1, 5, 10, 20 or 50% was 1.1, 5.8, 11.8, 25.2 and >60 g a.e. ha^{-1} when applied at V2-3 and <0.75, 1.0, 2.0, 4.3 and 11.5 g a.e. ha^{-1} when applied at R1, respectively. There was no difference in soybean injury between V2-3 and R1 stages from 2,4-D spray tank contamination. There was a significant drop in seed yield at 84 and 168 g a.e. ha^{-1} contamination doses; however, there was no significant differences for any the yield components including soybean pods per plant, seeds per pod, seeds per plant and 100 seed weight. The predicted dose of 2,4-D to reduce soybean seed yield 1, 5, 10, 20 or 50% was 4.5, 22, 46, 97 and >168 g a.e. ha^{-1}. Results show that dicamba spray tank contamination of as little as 0.75 g a.e. ha^{-1} and 2,4-D spray tank contamination of 46 g a.e. ha^{-1} and higher can cause significant crop injury in non-resistant soybean.

Keywords: Crop injury, Glycine max, sensitivity, tolerance, yield

The poster in a PDF version is available here.

Integrated weed management in potato (*Solanum tuberosum*) (115)

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Weeds are considered as a major factor in decreasing potato production. Over using of herbicides causes creation species become resistant to herbicides and environmental contamination. In order to evaluate different management treatments on weed structure and potato yield, an experiment was conducted in a private farm in Ardabil. Treatments included weedy (check), weed free (check), Metribuzin as a preplant (standard), black polyethylene, white polyethylene, Trifluralin, Trifluralin + black polyethylene, Trifluralin + White polyethylene, cultivation, Trifluralin + cultivation. Statistical analysis showed that different agrochemical treatments had significant effect on weed covering percent, weed density, weed dry weight and potato yield. The results showed that weed densities were reduced in all treatments with lowest level in black polyethylene included treatments. The lowest weed dry weight was in treatments that included black or white polyethylene covering with Trifluralin. The most weed densities were in treatments with weed controlling just at first potato growing stage. Metribuzin preplant application was reduced weed dry weight in compare to weedy check. Results also showed that integrated management treatments reduced weed dry weight 10-folds. The highest yield production was in black polyethylene included treatments. In weed free treatment, potato yield was 33.8 % more than weedy check.

Keywords: White polyethylene, black polyethylene, metribuzin, trifluralin, cultivation

The poster in a PDF version is available here.

Comparison of some vegetative and reproductive traits of dominant weeds in cultivated tomato as influenced by metribuzin and non-living mulches (148)

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In order to investigate the time of emergence, flowering and seed shattering of weeds under six types of non-living mulches (black plastic mulch, clear plastic mulch, wheat straw, sawdust, coco peat and peat moss) and metribuzin in cultivated tomato, research was conducted in a randomized complete block design with three replications at College of Agriculture, Shiraz University in 2012. The longest and shortest time of weed emergence belonged to the clear plastic mulch (28 days after transplanting) and organic mulches and metribuzin (21 days after transplanting) respectively. Also, black plastic mulch and wheat straw showed the highest (66.80 days after transplanting) and the lowest (52.69 days after transplanting) time of weed flowering respectively and both treatments stimulated weed flowering compared to metribuzin (95.33 after transplanting). Weed seed shattering was another important characteristic that was affected by mulch treatment so that wheat straw showed weed seed shattering at 87.33 days after transplanting while black plastic delayed weed seed shattering until 101.73 days after transplanting. Mulch treatment and metribuzin showed significant differences in their effects on weed seed shattering. Metribuzin caused seed shattering at 131.29 days after transplanting. In addition, mulch treatments was more effective than herbicide application by reducing the length of weed vegetative growth period. In conclusions, clear and black plastic mulches provides better weed control and higher tomato yield than metribuzin and the other mulches.

Keywords: Seed shattering, Emergence, Flowering

The poster in a PDF version is available here.

Invasive effects of *Humulus japonicus* on the vegetation and plant diversity (187)

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Humulus japonicus (Japanese hop) is a noxious annual vine weed with hook-like climbing hairs. *H. japonicus* emergences much earlier than many of other plants, and grows fast and vigorously, covering existing vegetation, which leads to destruction of the plant communities where *H. japonicas* invades. It also causes skin irritation when leaves and stem are touched and allergies during flowering due to pollen. Many studies on this plant have been conducted but mostly in relation with human health. Not many studies focused on its invasive effects on neighboring plant communities in natural and agricultural ecosystems. Therefore, our research focused on the evaluation of ecological damage by this plant. According to a survey of *H. japonicus* along the roadsides conducted in South Korea, *H. japonicus* dominated in the plant community, resulting in significant loss of plant diversity with monocarpic weeds monopolizing the sites. Even places where *H. japonicus* was removed by hand were still dominated with monocarpic weeds, suggesting that restoring plant diversity would take a long time and require many efforts to shorten that period.

Keywords: Humulus japonicus, Invasive weed, Vegetation, Plant diversity

Composition and impact of the weedy communities in the Apulian archaeological heritage (504)

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Weeds represent one of the most damaging agents in archaeological sites. Their management can be very difficult and among the major costs for the preservation of the historical heritages. Their impact is often underestimated because not only the weed density and invasiveness can be an important element determining their damaging properties, but also their biological and morphological properties, associated to the place where they grow. The Apulia Region, in the Southern Italy, has a very rich open-air archaeological heritage, but there is a lack of knowledge about potential threats to conservation and usability caused by weed infestations. For this reason, a large-scale survey was carried out in seven distinct archaeological sites, among the most important in the Apulia Region. Each site was surveyed during the two weed growth peaks (spring and autumn), recording the weed presence according to the different threatened areas, e.g. along or on walls, on pavements, and around stones. Weeds were identified and their mean abundance expressed by using an empiric index (1-4) corresponding to increasing coverage percentage and density. These data were then combined with the dangerousness degree (0-9), which takes in account the morphological characteristics and the life form of each plant (e.g. type of roots, plant vigor, and shape), fundamental elements of their damaging capabilities. The combined data allowed the creation of a newly named index, the "global impact" (0-5), which provides a better evaluation of the potential impact of the different species, and to identify the riskier situations. Considering all the sites surveyed, 164 species were found, belonging to 37 botanical families, with *Asteraceae* (36 species), *Poaceae* (18) and *Leguminosae* (17) the most represented. Species characterized by medium or high dangerousness degree (≥4) were 30, whereas species with medium or high global impact index (≥ 3) were 24.

Keywords: Archaeological sites, weed impact, Apulian region

The poster in a PDF version is available here.

Efficacy of herbicides on invading Parthenium weed (*Parthenium hysterophorus* L.) (42)

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Parthenium weed is an alien invasive weed in China. It poses a serious threat to crops, livestock, humans, and to biodiversity. Herbicides are one of the important methods of control. Reports of herbicide activity on parthenium weed in the field are lacking in China. Field experiments were conducted to determine the activity of eight pre-emergence (PRE) and 13 post-emergence (POST) herbicides on parthenium weed at the recommended China field rates. Fresh weight (FW) was measured at 90 days after PRE treatments, and 45 days after POST treatments. The results showed that clomazone PRE at 400 g ha^{-1} effectively controlled parthenium weed with a reduction of 92.3% FW, followed by rimsulfuron 20 g ha^{-1} with 87.4%. The other six PRE herbicides, acetochlor 1000 g ha^{-1}, mesotrione 150 g ha^{-1}, atrazine 1140 g ha^{-1}, mesotrione+ atrazine 742.5 g ha^{-1}, clomazone+ acetochlor 600 g ha^{-1}, acetochlor+ atrazine 1350 g ha^{-1}, provided < 50% FW reduction. The POST herbicides, tribenuron-methyl 20 g ha^{-1}, imazapyr 1125 g ha^{-1}, atrazine 1140 g ha^{-1}, mesotrione 150 g ha^{-1}, clopyralid 200 g ha^{-1}, picloram 1200 g ha^{-1}, mesotrione +atrazine 742.5 g ha^{-1} provided excellent control of the weed at both the 2-5 leaf and 5-8 leaf stages with FW reduction >97.2%. Isoproturon 1000 g ha^{-1} and topramezone 22.5 g ha^{-1}achieved good control of 90.3%~92.2% when sprayed at 2-5 leaf stage, but was reduced to 83.2%~85.3% when treated at 5-8 leaf stage. In contrast, rimsulfuron 20 g ha^{-1}, glyphosate 800 g ha^{-1}, triclopyr 2000 g ha^{-1} achieved 81.5%~97.6% FW reduction when sprayed at 5-8 leaf stage, but only controlled 49.2%~65.5% when sprayed at 2-5 leaf stage. Metribuzin 400 g ha^{-1} failed to control parthenium weed with 36.5%~49.3%.

Keywords: *Parthenium hysterophorus*, pre-emergence, post-emergence, herbicides, control

Control of *Ailanthus altissima* in a historical fortress (625)

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The Citadel of Alessandria is a military fortress built in the 18th century, located in the northwest of Italy. It spans over 70 hectares and is composed of buildings, bastions, roads, all enclosed by a moat. Since 2007, the fortress was abandoned and gradually became invaded by weeds. One of the most problematic weeds is *Ailanthus altissima*, a tree that colonized many areas in the fortress, including buildings and roofs, accelerating their deterioration. In July 2015, different control techniques were compared. In particular, cut stump and basal bark applications were tested in three areas of the fortress. The herbicides used were: glyphosate 360 g/l, fluroxypyr 20 g/l+triclopyr 60 g/l and aminopyralid 35.5 g/l+ fluroxypyr 144.1 g/l, each diluted 1:10 with water. For the cut stump application, the plants were first cut at the base and immediately sprayed on the cut surface. Herbicides were applied using a 2 l pressure spray bottle. Untreated cut plants were used as a comparison. For basal bark application, the lower 50 cm of the plants were sprayed with the herbicides by using a backpack sprayer. Fifty days after treatment, an efficacy assessment was performed by counting and measuring the height of the resprouts the cut stump application, and by observing the symptoms in the basal bark treatment. In the case of cut stump treatments, the number of resprouts ranked as follows: untreated > glyphosate > fluroxypyr+triclopyr > aminopyralid+fluroxypyr, with 4.7, 2.0, 1.3, and 0.06 resprouts per plant, respectively. The same ranking was observed for the height of the resprouts, with 20 cm observed for aminopyralid+fluroxypyr and up to 75 cm for untreated plants. For the basal bark application, very limited symptoms were observed on the treated plants.

Keywords: Cut stump application, basal bark application, invasive alien species, historical sites

The poster in a PDF version is available here.

Integrated management of *Phragmites australis* (common reed) along the platte river (173)

Stevan Z Knezevic *(University of Nebraska-Lincoln, Concord, United States)*

The non-native biotype of common reed (*Phragmites australis* subsp. *australis*) is an invasive species that is invading wetland habitats and other natural areas in many eastern states of the US, including Nebraska. This species can be found along the Platte River, from Wyoming to eastern Nebraska, and expanding. Therefore, a series of of studies evaluated common reed control along the Platte River using an integrated management approach based on herbicides (glyphosate or imazapyr), mowing, and disking, either applied alone or in combination. Total of three studies, disking followed by herbicide (study 1), mowing followed by herbicide (study 2), and herbicide followed by mechanical treatment (study 3) were conducted in over a 3 year period (2009-2011) at three locations in Nebraska. Visual ratings, flowering percentage and stem densities were collected to determine level of control. On the basis of visual ratings, disking and mowing alone did not provide adequate control of common reed whereas control was significantly improved and lasted for third season (817 DAT) when disking and mowing was followed with herbicide applications. All treatments in disking followed by herbicide and mowing followed by herbicide had good (≥84%) to excellent (≥92%) control, which significantly (P = 0.0001) suppressed common reed for 817 DAT. An addition of a mechanical treatment following herbicide application did not improve common reed control. sknezevic2@unl.edu

Keywords: Pasture, eastern red cedar, phragmites, rangeland, herbicide

The poster in a PDF version is available here.

Single and sequential applications of indaziflam for broadleaf control, long-term annual grass control, and turfgrass tolerance in warm-season turfgrass (172)

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Studies were conducted at the University of Florida West Florida Research and Education Center, Jay, FL from 2008 through 2015 to determine turfgrass tolerance and the effectiveness of indaziflam for broadleaf and long-term annual grass control in warm-season turfgrass. Plots (1.5 m by 3 m) were established in turfgrass naturally infested with the weeds under study. Herbicides were applied with a boom sprayer operated at 140 kPa and calibrated to deliver 190 L ha^{-1}. Treatments were arranged as a randomized complete block and replicated four times. Indaziflam applied preemergence once at 30 g a.i. ha^{-1} provided 80% control of goosegrass (*Eleusine indica* (L.) Gaertn.) 4 mo after treatment while indaziflam at 40 or 50 g ha^{-1} provided 90 to 95% control. When indaziflam was applied twice at 50 g ha^{-1} with a 12 mo interval between applications, goosegrass control was 85% 24 mo after initial treatment. Prodiamine applied twice at 0.8 kg ha^{-1} or oxadiazon applied twice at 3.6 kg ha^{-1} at 12 mo intervals provided less than 60% goosegrass control 24 mo after initial treatment. A single early-season indaziflam application at 35 g ha^{-1} provided less than 60% doveweed (*Murdannia nudifolia* (L.) Brenn) control 90 days after treatment. Three applications of indaziflam at 10 g ha^{-1} provided 95% doveweed control 60 d after initial treatment and 80% at 133 days. A single indaziflam treatment at 30 g ha^{-1} controlled chamberbitter (*Phyllanthus urinaria* L.) at 100% for 90 d after treatment. Control decreased to 80% by 123 d after treatment with no advantage of three applications at 10 g ha^{-1} over a single application at 30 g ha^{-1}. More turfgrass injury was observed in sandy soil, however, irrigation intensity appeared to have little impact on turfgrass tolerance.

Keywords: Indaziflam, Eleusine indica, turfgrass tolerance

Integrated management of giant smutgrass (*Sporobolus indicus* var. *pyramidalis*) in Bahiagrass (*Paspalum notatum*) pastures in Florida, USA (25)

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Sporobolus species (smutgrass) is a perennial weed that affects many improved perennial grass pastures in Florida and throughout the southeastern United States. The two varieties of smutgrass predominant in Florida are *Sporobolus indicus* (small smutgrass) and *Sporobolus indicus* var. *pyramidalis* (giant smutgrass). Previous research indicates that single management techniques do not provide long-term smutgrass control; however, it is likely that integration of management techniques will provide long-term control. Therefore, three field experiments were conducted from 2008 to 2012 to evaluate the effect of integrated long-term management strategies using cultural and herbicide inputs for giant smutgrass control in *Paspalum notatum* (bahiagrass) pastures. The results from these experiments indicate that cultural treatments did not provide satisfactory smutgrass control; however, cultural treatments succeeded by hexazinone application the following year appear to provide an acceptable level of control for at least 12 months. Complete renovation with glyphosate is not an option for smutgrass control because smutgrass density 12 months after treatment was at least 12-times higher than with hexazinone or fall roller chopping. Renovation or fall roller chopping followed by hexazinone reduced smutgrass density the initial year, but re-infestation was approximately 2 times higher than with a sequential application of hexazinone 36 months after treatment. Additionally, applying nitrogen 2 weeks after hexazinone appears to have greater impact on reducing smutgrass reinfestation than hexazinone alone, indicating that promoting bahiagrass growth after hexazinone application may increase the competitive ability of bahiagrass over giant smutgrass. Lastly, data from the sequential hexazinone experiment indicated that hexazinone applied at 0.56 kg ha^{-1} or 0.84 kg ha^{-1} in two applications over a period of 2 years appears to be more cost-effective for providing a long-term control up to 2 to 3 years. Overall, it appears that sequential applications of hexazinone may have more impact than implementing tillage for long-term smutgrass management.

Keywords: Hexazinone, nitrogen, sequential herbicide application, cultural practices

The poster in a PDF version is available here.

Eragrostis plana management in native pastures in southern Brazil (241)

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Eragrostis plana Ness is one of the most important weed problems of native pastures in southern Brazil, presenting high invasive potential, low nutritional quality and poor acceptance by the animals. Embrapa has worked with a selective applicator called "Campo Limpo" (CL) that controls adult weed plants through the contact of wet ropes with glyphosate herbicide, without touching the native pasture. Nevertheless new plants are recruited from soil seed bank causing new infestations. The objective of this research was to evaluate the efficacy of *E. plana* control using CL in the summer season and spraying atrazine in the spring, as well the selectivity of atrazine to *Lolium multiflorum* and the native pasture. A previous experiment in a greenhouse with *E. plana* and native pasture grasses sprayed with 0, 1, 1.5 and 2x the atrazine field rate of 3000g a.i ha^{-1} there was control of weed seedlings. However, the atrazine rates reduced shoot dry mass of the native pasture. A field experiment was conducted at Embrapa South Livestock Research Station, in 2010. The experimental design consisted of a split-plot with three replications. Glyphosate (900 g a.e ha^{-1}) or glyphosate (1800 g a.e ha^{-1}) was applied in the main plot and an untreated check or atrazine (3000 g a.i ha^{-1}) was the sub-plot. CL was used in February 2010 and atrazine was sprayed in September 2010. Glyphosate at 900 or 1800 g a.e ha^{-1} reduced the coverage (%), plant height (cm), regrowth (%) and shoot dry mass (g $plant^{-1}$) of *E. plana* in the spring (42 days after the atrazine spray). CL used in the summer (glyphosate at 1800 g a.e ha^{-1}) allowed the greatest shoot dry mass production of *L. multiflorum,* which indicates more forage available for the animals. Atrazine caused high phytotoxicity to the native pasture but did not affect *L. multiflorum*.

Keywords: Grasslands, glyphosate, atrazine, Eragrostis plana, livestock

The poster in a PDF version is available here.

Comparison of the ways of weed control in coniferous (*Pinus eldarica* Medw.) in forest nurseries in Fars Province-Iran (759)

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More than 2,000,000 forest seedlings are produced every year for development of park and forest in Forest nurseries in Fars Province. One of limiting factors in producing forest plant seedling is destruction of weed growth. An experiment with 6 treatments in 4 replications in a RCBD design was carried out on *Pinus eldarica* Medv. in a two – year survey in 2013, in Shahid Roosta forest nursery, Zarghan, Fars Province, Iran. The treatments were (1) weedy; (2) weed free; (3) one cultivation; (4) two cultivations; (5) one cultivation plus herbicide; (6) mulch – clover planted between the rows. The diameters of stem, lengths, fresh and dry weights of plants were parameters measured. All costs for applying treatments were accounted. Results showed that there were significant differences in the parameters of growth such as diameters of stems, lengths, fresh and dry weights of pine seedlings between weedy and weed free plots. However, there was no significant difference between mulch and weed free. The other treatments, 3, 4, and 5 were not different from each other. Economic evaluation with Partial Budgeting Method showed that the growth of seedlings using mulch was not only suitable for seedling growth but also had the least cost.

Keywords: Nursery-Pinups eldarica-Mulch-Cultivator

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Strategies for control of *Vulpia myuros* (395)

Solvejg K Mathiassen *(Aarhus University, Slagelse, Denmark)*

Vulpia myuros is a winter annual grass weed species belonging to the Poaceae family. *V. myuros* was first reported as a weed problem in red fescue in Denmark in 2000 and is now a significant weed problem in winter annual crops. *V. myuros* is hard to control due to a high natural tolerance to ACCase-inhibitors. Surviving plants have extensive growth and high fecundity. The objective of the present study was to examine the efficacy of different herbicides in pot trials and test herbicide strategies in subsequent field trials. Pot trials including more than twenty herbicides applied at two different growth stages showed the importance of timing however even at early timing the majority of herbicides had only low efficacy. The best control was achieved by pre-emergence and early post-emergence applications of pendimethalin, prosulfocarb and mesosulfuron+ iodosulfuron. Two years of herbicide screenings in field trials showed that also propyzamide, clomazone, glyphosate and diquat had high efficacy against *V. myuros*. Different herbicide strategies were tested in three years of field experiments in red fescue established in spring and winter cereals. Herbicides were applied pre- and post-emergence in the cereal crop, after harvest of the cereals, during the winter and in the spring before seed harvest. The highest efficacy was obtained combining autumn split applications of prosulfocarb or pendimethalin followed by mesosulfuron+iodosulfuron in the spring in the cereals with autumn applied prosulfocarb or pendimethalin in red fescue followed by diquat in the winter. However, even the best herbicide strategy did not sufficiently control *V. myuros*. Long term field experiments have shown that increasing the ratios of spring sown crops in the crop rotation and ploughing are viable options to reduce *V. myuros* infestations.

Integrated management of eastern red cedar in Nebraska's pasture (174)

Stevan Z Knezevic *(University of Nebraska-Lincoln, Concord, United States)*

Eastern redcedar (*Juniper virginiana L.*) is an invasive species that is invading pastures and rangelands of Midwestern states, including Nebraska. Therefore, a series of studies evaluated Eastern redcedar control using an integrated management approach based on herbicides and mechanical removal at three locations in Nebraska. Herbicides were applied either broadcast or as high volume foliar sprays to individual trees. Visual ratings of tree control at 30, 60, 90 days and 365 days after treatment were collected to determine the level of control. On the basis of visual ratings mechanical control provided up to 100% control and it was the most labor intensive method. Tree height was an important factor influencing level of chemical control in broadcast treatments. Treatment efficacy declined with increased tree height. Eastern redcedar control was greatest when picloram was a component of herbicide treatments either broadcast applied to trees or when individual trees were sprayed. Eastern redcedar control did not exceed 26% when triclopyr-containing treatments were applied. Broadcast applications of picloram + fluroxypyr at 5 pts/acre, picloram + 2,4-D at 6 and 8 pts/acre, and picloram used alone at 2 pts/acre provided excellent control (> 85%) of trees that were a foot or less in height. In contrast, these treatments provided poor control (< 60%) of trees that were more than 2 ft in height. Eastern redcedar control was excellent (> 85%) when individual trees were treated with premixes of picloram + fluroxypyr, or picloram + 2,4-D, applied at 1.5% and 2.0% (volume per volume) of product solution, and with picloram applied at 1.0 % solutions. sknezevic2@unl.edu

Keywords: Pasture, easter red cedar, phragmites, rangeland, herbicide

The poster in a PDF version is available here.

Application of herbicides in production of spruce seedlings (763)

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The application of herbicides, for weed control in forestry, is of increased significance. Weeds have multiple unfavorable effects reflected in the decrease of quality and quantity of seedlings. Also, weed control requires high financial inputs and labor force which increase the total cost of production. The application of herbicides in forestry reduces weed spread, especially in the initial phases of forest seedling development when the unfavorable impact of weeds on seedlings is the highest. For this reason during the period 2014 – 2015 experiments were established in order to investigate the possibility of herbicide application in production of spruce seedlings. The experiments were established on the two-year-old spruce seedlings at the Centre for Nursery Seed-Production (44^{0}45'09,74" N 17^{0}59'58,26" E) using randomized block design with three replicates. The post-emergence herbicides nicosulfuron, rimsulfuron and cycloxydim were investigated. The efficiency of investigated herbicides was evaluated 2, 4 and 6 weeks after treatments and selectivity of herbicides was estimated during the vegetation season. The study results showed that the herbicides significantly reduced number of weeds compared to control. The best efficacy in weed control was achieved by nicosulfuron (86.5% – 92.0%). Lower efficacy was achieved by rimsulfuron (84.00% – 89.5%) and cycloxydim (82.0% – 86.5%). The herbicides had no phytotoxic effect on two-year-old spruce seedlings. The results showed that nicosulfuron, rimsulfuron and cycloxydim can be applied for the control of weeds in production of spruce seedlings.

Keywords: Herbicide, weeds, spruce, seedlings

The poster in a PDF version is available here.

Juncus spp. – an increasing challenge in grasslands of Western Norway (616)

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Infestation by soft rush (*Juncus effusus* L.) and compact rush (*J. conglomeratus* L.) have increased along the western coastline in Norway during recent decades, causing a serious reduction in forage quality. We present three experiments: (i) seasonal variation of storage reserves in above- and belowground plant fractions (carbohydrate analyses), (ii) effect of cutting time and stubble height on regrowth capacity of soft and compact rush from western and eastern Norway (pot experiment in growth chambers), (iii) repeated mechanical cutting over two years using a brush cutter with different stubble height and combinations of cutting time during the growing season(field experiment).
Preliminary results showed that sucrose was the main reserve carbohydrate with maximum concentration in spring and minimum in late summer (mid-July – early August). Carbohydrate analysis correlated well with the results of the pot experiment where regrowth capacity was lowest in early August. The regrowth was also strongly dependent on temperature and stubble height, and the lowest biomass was recorded at 7.5 ° C for cutting to 1 cm. Mechanical treatment using a brush cutter reduced growth considerably in the summer or autumn and when rhizomes were cut, but the measure was ineffective when applied in spring or early summer. A pasture topper was less effective than a brush cutter, as too much aerial stem was left, but was more practical for larger areas.
Both the carbohydrate analysis and the pot experiment indicated a clear weak point in the lifecycle of rushes in late summer. Cutting with brush cutter and pasture topper seems to be an effective means to control the rushes. Mechanical treatment can be destructive if belowground parts are cut to 2 cm below the soil surface, otherwise cutting should be performed in late summer when the plants are most sensitive due to depleted carbohydrate reserves.

Keywords: Weed biology, weed control, perennial weeds, grassland

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Session 12
WEED ECOLOGY

Weed flora along the canal network of the Vojvodina Province (Serbia) (657)

Ana Andjelković *(Institute for Plant Protection and Environment, Belgrade, Serbia),* ***Dragana Marisavljević*** *(Institute for Plant Protection and Environment, Belgrade, Serbia),* ***Danijela Pavlović*** *(Institute for Plant Protection and Environment, Belgrade, Serbia)*

Watercourses act as transportation routes for the spread of weed species, enabling their long-distance dispersal towards a specific region. The propagule pressure of vegetative fragments is especially high along aquatic corridors, as water flow and floodwaters transport the propagules downstream. The canal network of the hydrosystem Danube-Tisa-Danube (DTD) is considered to be one of the greatest European hydrosystems. The construction of such an elaborate canal network further intensifies the transfer of species, eliminating their natural dispersal barriers, thus enabling their spread.This study aimed to analyze the floristic composition and dominant life forms of the weed flora present on the banks of the DTD hydrosystem. Field research was conducted along 100m long stretches, spread evenly along the length of the 5 major canals. Field data was collected during the June – September period of 2015. For all of the weed species, their local abundance and cover were recorded.The results have shown the presence of 185 plant species, belonging to 126 genera and 46 families. The most common taxa recorded were *Convolvulus arvensis, Salvia sylvestris* and *Daucus carota*, each present in 72% of the sites analyzed, followed by *Achillea millefolium*, *Cichorium intybus* and *Lolium perenne*, all recorded in 65.5% of the sites. When considering the dominant life forms, hemicryptophytes were dominant with 48%, followed by therophytes and phanerophytes with 26.6% and 17.5%, respectively.It is important to highlight that 10% of the species recorded along the canal network were alien (e.g. *Ambrosia artemisiifolia*, *Asclepias syriaca*, *Conyza canadensis*), with *Amorpha fruticosa* being the most widespread (recorded in 52% of sites). These results point to the importance of the DTD canal network system as a potential dispersal corridor for alien plant species in Serbia.

Acknowledgments
The authors acknowledge the support of the Ministry of Education, Science and Technological Development (Project No. 31018).

Keywords: Weeds, canal network, dispersal corridor, Vojvodina, Serbia

The poster in a PDF version is available here.

Digital book for weed identification (340)

Bruce A Ackley *(The Ohio State University, Columbus, United States),* ***Alyssa I Lamb*** *(The Ohio State University, Columbus, United States)*

Plant identification can be challenging and even intimidating for the inexperienced. Growers do not necessarily need to identify every weed in a field to be effective managers, but should be able to identify the major weeds that are important to their operations and goals. At first glance, learning how to identify weeds can seem like a daunting task given the number and diversity of species, but it is not as difficult as it may seem. Generally, there is a specific group of weeds that tends to dominate disturbed habitats within any native landscape. This iBook, "The Ohio State University Guide to Weed Identification", was created to help people better understand the nature of the weeds they are trying to control, and plant identification is a key component of that understanding. The iBook provides a new way to use an old tool – visualization – in the world of weed identification. Plant descriptions contained herein include key identification characteristics, photos of many species at different stages of maturity, and 360-degree movies for most species in the book. This book is not meant to be a compendium of all weedy plants in the U.S., but rather includes a number of the most common Midwestern U.S. weeds and the basic intellectual tools that are necessary to successfully identify plants.

Keywords: Identification, Digital, iBook, Pictures, Movies

The poster in a PDF version is available here.

Composition and biodiversity of weed flora in established olive groves of Crete, Greece: The effect of *Oxalis pes-caprae* L. invasion (808)

Christos Vlachos *(Agricultural University Of Athens, Athens, Greece),* ***Garifalia Economou*** *(Agricultural University Of Athens, Athens, Greece),* ***Kalivas Dionisis*** *(Agricultural University Of Athens, Athens, Greece),* ***Petros Vachamidis*** *(Agricultural University Of Athens, Athens, Greece)*

A weed survey of 40 olive groves located in two study areas of Crete in Greece (Peza and Meramvello) was conducted over a 2-year period in order to estimate the floristic biodiversity. Weed flora diversity was mainly assessed using the four common diversity indices: Shannon index, Simpson index, evenness index and species richness. Significant differences regarding the composition and the diversity of weed communities were observed between the two study areas and also between the 2 seasons of observations. Species richness was increased in 2014 in comparison to 2013. 5.2 weed species were recorded on average per olive grove in both study areas in 2013 and approximately 12.5 in 2014. Although a greater number of species and a more equitable proportion of various species in the population increases the diversity measured by Shannon and Simpson indices, the first gives greater weight to rare species while the second index gives greater weight to common species. Both these indices exhibited a different trend between years. The average values of Shannon index were greater in 2014 compared to 2013 surveys, whereas Simpson index decreased. Evenness index standardizes the relative abundance and it can vary from near 0 to about 1 whether, respectively, most of individual plants belong to a few species or when species are nearly equally abundant. In both areas evenness index was decreased in 2014 compared to 2013. Peza presented higher values in all diversity indices compared to Meramvello, especially during 2014 surveys. The most frequently occurring weed was *Oxalis pes-caprae* L. in all cases. It was demonstrated that its expansion resulted in a significant degradation of the floristic diversity of olive orchards and hence, led to a reduced habitat for native species. A linear negative relationship was observed between *Oxalis pes-caprae* density and the diversity measured by Shannon index.

Keywords: Biodiversity, Shannon's index, species richness, olive groves, Oxalis pes-caprae

The poster in a PDF version is available here.

A comparison of structure and floristic composition of weed seedbanks within and between single and integrated crop systems during two years (714)

Fernanda S. Ikeda *(Embrapa Agrosilvopastoral, Sinop, Brazil),* ***Lucas Menegatti*** *(Federal University of Mato Grosso, Sinop, Brazil)*

The aim of this study was to evaluate the structure and floristic composition of weed seedbanks within and between single an integrated crop systems. This study was conducted in a integrated crop-livestock-forest experiment of Embrapa Agrosilvopastoral, Sinop, Mato Grosso, Brazil. The experiment was arranged in a randomized block design with four replicates and five treatments: forest (1); crop (2); pasture (3); forest-crop system (4); forest-pasture system (5). Two samples composed of two sub-samples were collected manually and randomly at 0-10 cm depth with standard auger in each plot (or crop) of 100 m x 200 m. The annual collects were done during two years of the experiment (2012/2013 and 2013/2013). Fortnightly, the emerged seedlings were identified, counted and discarded, during three months. We calculated the relative importance index of weed species identified for each treatment. The most important species in all the treatments was *Eleusine indica*, except in crop area of integrated crop-forest system at 2013/2014, where *Digitaria horizontalis* was the most important species. At 2012/2013, *Hyptis brevipes* was the second most important species in areas with shading (forest and single pasture), while *Cyperus* spp. was the second most important in areas with crop and pasture with forest. At 2013/2014 the second most important species vary according to the species: *D. horizontalis* (treatment 1 and 2), *Spigelia anthelmia* (treatment 3), *H. brevipes* (forest of treatment 4), *E. indica* (crop of treatment 4), *Spermacoce latifolia* (forest of treatment 5) and *Commelina benghalensis* (pasture of treatment 5). The number of species was higher in the second year when compared with the first one, except for the forest-pasture integrated system**.** The differences related to the importance of weed species on seedbanks were influenced by the crop areas in the first year and the differences among the treatments were higher in the second year.

Keywords: Crop, Digitaria horizontalis, *Eleusine indica*, forest, pasture

Seedling growth and distribution of *Ambrosia artemisiifolia* L. in the Czech Republic (757)

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Ambrosia artemisiifolia, an annual plant native to North America, was accidentally introduced to Europe in the 19th century. Because of its negative impact on human health, agriculture and biological diversity it is nowadays considered as one of the most dangerous European weeds. From the Czech Republic it has been known since 1883, up to the 1990s recorded in about 80 localities, while about 300 localities have been recorded in our database recently. Density of communication corridors, weather and land use were revealed by logistic regression comparing 145 occupied and 2405 non-occupied mapping grids (5.5 x 5.9 km) as the most important factors driving the species distribution. The occupied grids are characterised by more roads and railways, higher temperature, lower precipitation and higher proportion of industrial land. As an annual *A. artemisiifolia* is crucially dependent on the successful performance of the juveniles. To test the factors possibly responsible for its occurrence, we cultivated the seedlings at one of seven temperature regimes ranging from 10 to 34 °C, combined with three nutrient levels. All the temperature range enabled growth of the seedlings, with the development being faster under higher temperatures and nutrient supply with maximum biomass under 30 °C. Thus spread of *A. artemisiifolia* in the Czech Republic is highly likely supported by ongoing climatic changes and also by increasing propagule pressure due to the rapid increase in abundance of the species in a wider area of central Europe. To identify successful competitors to supress *A. artemisiifolia*, its growth has been compared with that of 10 native herbs and grasses under different temperature regimes. The preliminary results indicate that some of the natives have lower temperature optimum than *A. artemisiifolia.* This fact should be reflected if choosing the competing species for *A. artemisiifolia* suppression.

Keywords: *Ambrosia artemisiifolia*, ragweed, competitor, plant distribution, temperature

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The future of *Solanum elaeagnifolium* Cav. (silverleaf nightshade) in the Mediterranean basin (789)

Javid Kashefi *(USDA/ARS/ European Biological Control Laboratory, Thessaloniki, Greece),* ***Ahmet Uludag*** *(Duzce University, duzce, Turkey),* ***Gualbert Gbehounou*** *(FAO/AGP, rome, Italy),* ***Mohamed bouhache*** *(Institut Agronomique et Veterinaire Hassan II, rabat, Morocco),* ***Carl Bell*** *(Emeritus, University of California, san diego, United States),* ***Marie C Bon*** *(USDA/ARS/ European Biological Control Laboratory, montpellier, France),* ***Anastasia Lagopodi*** *(School of Agriculture, Aristotle University of Thessaloniki, thessaloniki, Greece)*

Solanum elaeagnifolium Cav. (silverleaf nightshade, SOEL) is a weed in agricultural and non-agricultural areas, which occupies arable, pastoral, urban and sub-urban areas. It is an invasive alien species in many countries of the Mediterranean Basin since its introduction in the mid 20th Century. Its features such as reproduction ways and capacity, dispersing, competitive ability so on make it one of the difficult to control weeds**.** Further invasions have been expected due to global change and lack of effective control measures. When water become more scarce due to climate change in the Mediterranean basin, it could have more impact on fragile ecosystems because its infestations are serious in both dry lands and irrigated croplands. The SOLEL task group which is established in 2013 by several organizations involved in SOLEL research and management throughout the Mediterranean sees the main solution on integrated management technique including biological control, chemical control and prevention and early detection. It has been hoped a common work will be started, otherwise problem will increase as today seen some protected areas.

Keywords: Integrated weed managament, biological control, solanum elaeagnifolium, invasive alien plant, impact

The poster in a PDF version is available here.

Potential distribution of introduced weeds of (*Asteraceae*) and their native congeneric relatives in Mexico (696)

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Biological invasions are one of the global problems that cause significant ecological and economic damage. However, only a fraction of invasive species introduced in a region succeed, and the prediction of which species will be problematic is still very difficult. With the purpose to know whether the taxonomic closeness between introduced and native species determines the success of the exotic one in a colonized area, we tested a prediction derived from Darwin's naturalization hypothesis, which poses that introduced species with close relatives will occupy areas where their relatives do not exist and will be absent where relatives are established. We modelled the potential distribution of seven pairs of Asteraceae species, each with congeneric native and introduced species, to assess the similarity of their potential distribution models. The selected introduced species were: *Lactuca serriola*, *Centaurea melitensis*, *Cirsium vulgare*, *Senecio vulgaris* and *Pseudognaphalium luteoalbum* with their respective native relatives. Georeferenced records from the following databases, Introduced Weeds in Mexico, Asteraceae of Mexico and Asteraceae in the Global Biodiversity Information Facility (GBIF), were obtained. Nineteen environmental layers obtained from WorldClim page were employed to generate potential distribution maps for each species with the MaxEnt software. The D index (ENMTools) and the Kappa statistic were used to calculate niche similarity between the maps of introduced and native species. The tested prediction was met for one pair of species (*L. serriola* and *L. intybaceae*), where D and Kappa indicated no niche overlap or very limited overlap and for two pairs (*L. serriola* and *L. graminifolia; S. vulgaris* and *S. mulgediifolius*) with low overlap of their potential distribution models. The rest of the pairs where significant overlap was detected for both indices, need further analysis to determine whether niche differentiation between the species in a pair exists in other non-macroclimate dimensions.

Keywords: Darwin's naturalization hypothesis, niche overlap, Maxent, exotics, natives

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Determination of weed species in railway lines (316)

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Weeds are not desired to grow in nonagricultural areas as well as in agricultural areas because of the damage they do. While the form of the damage may vary with respect to where they grow, it is known that weeds can create problems in airports, railways, historical sites, warehouses of flammable and explosive materials, and open storage yards. Weed control in railway lines is performed with glyphosate since long time and it is uttered that the herbicide effectiveness is decreasing within time depending on the ecological conditions. The aim of this study was to determine dominating problematic weed species in the Central Black Sea Region of Turkey. The work with that purpose has been done between July and October 2015. Throughout the line, an area of 250.4 km has been scanned and 150 locations have been surveyed in total. Existing species of weed, their frequency of occurrence (%) and their density (plant/m^2) have been identified. As a result of the survey, 86 species of weed which belong to 30 different families have been determined. The important families of Asteraceae, Boraginaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Poaceae are 59.3 % of the determined 86 species. Asteraceae with 22 %, Poaceae with 13 %, and Fabaceae with 7 % represent the three most important families respectively. The most important weed species were found to be *Conyza canadensis* (L.) Cronquist, *Centaurea cyanus* L., *Daucus carota* L., *Cynodon dactilon* L., *Lactuca sativa* L., *Rumex crispus* L., *Acroptilon repens* (L.) DC., *Rubus fruticosus* L., *Convolvulus arvensis* L. and *Lolium* spp.

Keywords: Railway lines, frequency of occurrence, density, weed species

The poster in a PDF version is available here.

Comparison of weed flora on arable land in the Czech Republic and Slovakia (687)

Michaela Kolarova *(Czech University of Life Sciences Prague, Prague, Czech Republic),* ***Jana Majekova*** *(Slovak Academy of Sciences, Bratislava, Slovakia),* ***Ludek Tyser*** *(Czech University of Life Sciences Prague, Prague, Czech Republic),* ***Josef Holec*** *(Czech University of Life Sciences Prague, Prague, Czech Republic)*

During the most of 20th century, Czech Republic and Slovakia were two states of one country (former Czechoslovakia). Agricultural policy and farming systems were similar with small differences due to different climate conditions in some regions. The aim of the study was to evaluate the influence of environmental variables onto weed occurrence in arable crops. Especially the west-eastern direction of the country shape gave us opportunity to investigate the influence of increasing continentalism of the climate (ca. 740 km from W. Bohemia to E. Slovakia). Three years surveys were conducted on arable land in 2006-2008 and totally 567 phytocoenological relevés were taken in cereals and wide-row spring crops. In each sampled field, one phytocoenological relevé of standard size of 50-100 m^2 was recorded in the central part of the field. The species coverage was estimated using nine-degree Braun-Blanquet cover-abundance scale. Differences in weed occurrence depending on different environmental conditions were studied using multivariate analysis. Geographical characteristics such as latitude, longitude and altitude significantly (p=0.05) affected composition of weed communities. On the base of our relevés, however, no differential species in relation to above mentioned variables were found, except for altitude. Typical species for lower and higher altitudes were identified the same for both countries. As species of low altitudes, *Amaranthus* sp., *Chenopodium hybridum*, *Solanum nigrum*, *Consolida regalis*, *Silene noctiflora* and some others were confirmed. *Stachys palustris*, *Galeopsis tetrahit*, *Myosotis arvensis*, *Persicaria hydropiper*, *Sonchus arvensis* and some more were characteristic species of higher altitudes. Further examination of the same dataset is still undergoing and an influence of other environmental variables is being studied.

Keywords: Weeds, Czech Republic, Slovakia, cereals, wide-row crops

The poster in a PDF version is available here.

The invasion of *Atriplex micrantha* in the Czech Republic (683)

Michaela Kolarova *(Czech University of Life Sciences Prague, Prague, Czech Republic),* ***Klara Novotna*** *(Czech University of Life Sciences Prague, Prague, Czech Republic),* ***Josef Holec*** *(Czech University of Life Sciences Prague, Prague, Czech Republic)*

Atriplex micrantha C.A. Mey. In Ledeb. (syn. *A. heterosperma* Bunge) is native to Central Asia. Steppes and semi-deserts are its natural habitats; the species is tolerant to drought and salinity. Adventive range of occurrence covers central and western Europe, North and South America. During 80th of 20th century *A. micrantha* started to spread along highways in Germany. Traffic helped *A. micrantha* to spread to neighbouring countries. In the territory of the Czech Rep., the species was recorded for the first time in 1967. Similar records from late 60th and 70th represent casual occurrence of *A. micrantha* as a wool adventive on waste places and disposal sites. In 2014, first study was published on *A. micrantha* occurrence in north-eastern part of CZ. At this time, *A. micrantha* was already widespread along highways, especially in the median strip between lanes. We observed six main highways in central Bohemia in September 2015 and we found *A. micrantha* occurring in the area of all of them at high population densities. Frequent occurrence in a large area of the country indicates that the spread has been very fast during the last decade. Since the very beginning of its spread, *A. micrantha* has been neglected and omitted by scientists. We have no data about early phases of its invasion. There are several reasons for this: Central reservation of highways is hardly accessible and for safety reasons, it is normally not possible to identify specimens there. Without closer look, *A. micrantha* can be misidentified as *A. sagittata* or when ripen as *A. oblongifolia*. We can predict future spread of *A. micrantha* along the roads and consequently its occurrence in disturbed habitats along the arable land. It can become common ruderal species in peri-urban zones. We do not expect it to become arable weed in the near future.

Keywords: *Atriplex micrantha*, Czech Republic, invasive species, highways

The poster in a PDF version is available here.

The state of invasive plants and its expanded probability in Iran (643)

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One of the most important issues in plant bio-terrorism topics is the risks of invasive plant. Invasive plant species that can enter new habitats without much help of humanity, successfully deployed and expanded. In recent years, deliberate or inadvertent incursions of invasive species into new areas, are severely threatened structure and function of biodiversity, and many of worlds' ecosystems. To study the status of invasive plants in Iran, a list of invasive plants around the world gathered and these plants were compared. The results showed that a total of 89 invasive plant species in different regions of the world exists in Iran. Of these, 26 species are cultivated in Iran, 22 weed species have been, and for the 63 species, there is not much information. Approximately 57 percent of the species are native to Asia and the rest, are from other regions. What is important in the future is to prevent the entry of invasive plants and attention to the foreign quarantine. Existence of 89 plant species with high risk of invasion in Iran such as quarantine and allergenic plant (*Ambrosia artemisiifolia* L) suggests that the issue of invasive plants and quarantine of plants should have more attention and consideration.

Keywords: Allergenic and quarantine plants, Bio-terrorism, risks of invasive plant

The poster in a PDF version is available here.

Alien species in sugar beet fields in Turkey (508)

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Sugar beet has kept its importance in Turkish agricultural production. It has been grown almost all regions of Turkey except coastal areas. Weeds are among important pests of sugar beet. Weeds in sugar beet fields in Turkey were compiled in a two-volume book, Weeds in sugar beet by Ozgur. Book contains 162 weed species belonging to 36 families. The species were reevaluated from the view of (invasive) alien species point. Among them 10 species are aliens. *Conyza canadensis* has been considered as invasive alien species. One of these aliens is a parasitic plant, *Cuscuta campestris*. Arceophytes such as *Amaranthus* spp. are among these alien species. In addition, some species such as *Chenopodium album* and *Datura stramonium* are cryptogenic species although some cases they have been shown as aliens.

Keywords: Invasive, alien plant, weed, sugar beet, Turkey

The poster in a PDF version is available here.

Alien species in hazelnut groves in Turkey (509)

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Turkey is leading producer and exporter of hazelnut, which has been grown in the Black Sea Region. Weed surveys, which have been carried out in hazelnut groves in the late 90's, covered all main producing provinces. In this paper, the results of two weed surveys were revisited and checked for alien species. Total 392 weed species have been recorded in both surveys. Only 12 species were alien for Turkey, which included both arceophytes and neophytes. Invasive alien species such as *Conyza canadensis* is among those. However, when phytogeographical regions in Turkey have been accounted, the number of alien species will be increased. The region is in Euxine sub-region of Euro-Siberian phytogeographic region. Although we were not able to determine phytogeographic regions of weed species, 34 Mediterranean and eight Irano Turanian species have been detected, which were other phytogeographical regions in Turkey. Furthermore, new introductions of alien species after 2000 which is apparent all over Turkey might have caused more aliens in the groves.

Keywords: Invasive, Alien plant, phytogeorography, hazelnut, Turkey

The poster in a PDF version is available here.

Occurrence and frequency of *Viscum album* L. in Aydin and Denizli provinces of Turkey (572)

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In this study, we have determined the frequency and density of parasitic weed *Viscum album* L., and the knowledge of growers about this weed in the Aydın and Denizli provinces of Turkey. For recording these data, we had surveyed the trees on highways of Aydin and Denizli at every 5 km, as well as randomly selected farmers' fields. The type of trees (where *V. album* was found) and the frequency of this weed were noted. Questionnaire was designed to inquire the farmers about their information regarding this weed. As a result of our survey, it was noted that *V. album* was present on wild pear, pear and almond trees in Aydin. This weed was noted most frequently on almond trees with a frequency of 67%, and it had a frequency of 40% and 14% on tress of wild pear and pear, respectively. In Denizli province, wild pear, acacia, pear, almond, black pine, plum, poplar, apricot and willow tree were the trees where *V. album* was recorded. Wild pear were the trees with highest *V. album* frequency (68%) followed by almond (46%), black pine (43%), pear (24%), willow tree (15%), acacia (13%), poplar (10%) and apricot (8%). The results of survey from farmers indicated that 33% and 76% farmers (from Aydin and Denizli provinces, respectively) had knowledge about this weed.

Keywords: *Viscum album* L., occurence, frequency, farmers awareness

Monitoring of the occurrence of *Conium maculatum* in Central Bohemia (793)

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Conim maculatum L. is an annual or biennial dicot reaching the height between 0.5-2.5 m. The species is highly toxic. In the area of the Czech Republic, *C. maculatum* is classified as an archaeophyte. Recently its occurrence in the CZ is increasing. It can be found along the roads and on waste places, and it also started to occur in agrophytocoenoses. It grows as an arable weed especially in field margins. Central Bohemia is a region with a long-term occurrence of *C. maculatum*. It is also an area with increased occurrence of this species. Its presence along the roads can affect water drainage systems, visibility for drivers and pedestrians and its control can increase the costs of roadsides management. When occurring on arable land, *C. maculatum* can lower the crop yields and increase the risk of intoxication of farm animals and humans. For direct control of *C. maculatum* on arable land monitoring of its occurrence is needed. The aim of our mapping of *C. maculatum* occurrence was to evaluate its presence along the roads and on arable land. Localisation along roads was realised using GPS navigation in moving vehicle. The speed of car (30-40 $km.h^{-1}$) and GPS system used enabled us to put GPS point every 8 m. The roads between two settlements were monitored in both directions. Obtained data were exported to Google Earth program. *C. maculatum* occurrence on arable land was monitored using drone with camera. Its occurrence on non-shaded places made this way of monitoring possible. Both above mentioned systems of monitoring were realised in summer period (2015) when *C. maculatum* plants were significantly taller than other vegetation incl. arable crops and they are easy to detect. We found *C. maculatum* most frequently in stands of winter oilseed rape, pulses, and sugar beet.

Keywords: *Conium maculatum*, Czech Republic, weed mapping

The poster in a PDF version is available here.

Invasive alien plant species in Russia (133)

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A group of Russian botanists is maintaining the list of invasive alien plant species in Russia. Due to extensive territory of Russia maintaining a single list for the country was considered inappropriate and unpractical. Thus, we support three main geographic blocks: European part of Russia, Siberia and Far East of Russia. The consolidated list comprises "black-lists" for 40+ administrative units of Russia. Species in regional lists are arranged in four groups, according to their invasive potential: (1) transformers; (2) alien species, actively spreading and becoming naturalized within disturbed, semi-natural and natural habitats; (3) alien species, spreading and undergoing naturalization in disturbed habitats; in the course of further naturalization, some of them will apparently be integrated in semi-natural and natural communities; (4) potentially invasive species, capable of reproduction in impact habitats or demonstrating invasive potential in adjacent regions. Invasive fraction of local flora is variable in species composition. Physico-geographical conditions, economic, historical and cultural peculiarities of the regions could influence/determine different invasive statuses of the same species. One species could be a component of natural flora in some regions, but act like archeophyte/neophyte, invasive, potentially invasive or not naturalizing alien species in other territories. For instance species-transformers of the European part of Russia and Far East *Bidens frondosa* and *Phalacroloma annuum* Dumort are not registered as invasive species in Siberia; native species for the European part of Russia *Humulus lupulus, Leontodon autumnalis* and *Leucanthemum vulgare* are aggressively invading natural plant communities in the Russian Far East. Twenty-four species are common for all three geographic blocks: *Acer negundo, Echinocystis lobata, Impatiens glandulifera, Solidago canadensis, Amaranthus retroflexus, Helianthus tuberosus, Conyza canadensis, Galinsoga parviflora, Lepidotheca suaveolens, Impatiens parviflora, Hippophae rhamnoides, Oenothera biennis, Senecio viscosus, Hordeum jubatum, Galinsoga quadriradiata, Xanthium albinum, Armoracia rusticana, Ambrosia artemisiifolia, Saponaria officinalis, Lactuca serriola, Symphytum caucasicum, Ulmus pumila, Kochia scoparia, Aster novi-belgii*.

Keywords: Invasive plants, Russia, black-list

The poster in a PDF version is available here.

Survey of spreading of *Ambrosia artemisiifolia* L. on an to Natura 2000 network belonging area in Slovakia (417)

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Ambrosia artemisiifolia is in the center of interest in Europe. In Slovakia, there is only data on its occurrence since 2008. Most studies have found that Natura 2000 protected areas contain fewer invasive species than their surroundings, but reverse findings are also reported. The Natura 2000 protected habitats in Slovakia could vary considerably in the level of invasion. On habitat of our interest, an actual management plan does not exist. Our surveys started on Ostrovné Lúky, to the Natura 2000 network belonging areas in 2015. On the prepared map, we placed a grid net. The randomly selected areas were wastes (6), stubbles (11), tilled stubbles (4), and sunflower fields (3). Each of the 24 explored sites were $10m^2$. GPS data, the infestation by *A.artemisiifolia* and most common accompanying species was recorded from 25 July to15 September. We used a 11-pont scale for the quantitative and a 5-degree qualitative rating. For further analysis we used ERI, ArcGIS ArcView 10.1. The number of ragweed plants on the sites were between 0 and 154. We noticed only 3 no infected areas. 3-3 sites had weak or medium infestation. The average infestation on the 24 sites had a middle-rate, but 15 areas had high or very high infestation. The average infestation was very high on the sunflower fields and high was on wastes. The infestation on the stubbles and tilled stubbles were middle high. In our survey the number of accompanying species is 35, between 1 and 11 species per sites. The average of this weeds is 4,79 pieces per sites. The most frequent accompanying weed was the *Chenopodium album*. The most of species are common and wide spride weeds. The further analysis is coming. Results of our mapping can be used in nature friendly, site specific vegetation management in Natura 2000 areas.

Keywords: *Ambrosia artemisiifolia*, Natura 2000, site specific weed management, weed survey in Slovakia

The poster in a PDF version is available here.

Water use efficiency of three native species of Carajás National Forest, Brazil, in competition with exotic invasive grass (610)

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The Carajás National Forest is a protected area located in the Brazilian Amazon region southeast of the state of Pará, which has infestations of invasive exotic grasses. Native plants with potential competition with alien species can serve as tools to control exotic plants. The efficiency of water use is characterized as the amount of water evapotranspired by a plant for dry matter production. Efficient plants produce more dry matter per gram of water transpired. This study aimed to evaluate the efficiency of water use of three native species of Carajás National Forest in competition with *Urochloa brizantha*. The experiment was carried out in a greenhouse, in a randomized block design with four replications. Pots were filled with fertilized and properly corrected soil. In the center of each pot was sown one of the following native species: *Bauhinia longipedicellata*, *Mimosa acutistipula* and *Solanum crinitum* and on the periphery of the pots the exotic species *Urochloa brizantha* in six densities: 0, 1, 2, 3, 4 and 5 plants per pot. Forty days after plant emergence, was realized the data collection by an infrared gas analyzer, and quantified the water use efficiency (WUE) by the relationship between the amount of CO_2 fixed by photosynthesis and the amount of water transpired. The data were submitted to regression analysis. It was observed high WUE for *M. acutistipula,* with values between 3.81 to 4.27 μmol CO_2 m^{-2} s^{-1} / mmol H_2O m^{-2} s^{-1}. *S. crinitum* and *B. longipedicellata* presented values below 2 μmol CO_2 m^{-2} s^{-1} / mmol H_2O m^{-2} s^{-1}. With the increase on density of exotic plants, the WUE for *M. acutistipula showed a steady behavior* and a slight decrease for *S. crinitum* and *B. longipedicellata. Thus,* the WUE was affected ocurring strong negative interference among the species when in competition.

Keywords: Degraded recovery mining areas, Water use, Competitive potential

Evaluation of outcrossing rate in barnyardgrass (*Echinochloa crus-galli*) and hybridization between *Echinochloa* sp. (145)

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The problems caused by barnyardgrass (*Echinochloa crus-galli)* have increased due to evolution of herbicide resistance, which is dependent, among other factors, on the matting system and seed production. Previous phylogenetic studies indicate common key traits and SNP (single nucleotide polymorphism) in *E. crus-galli, E. colona* and *E. crus pavonis*. The objectives of this study were to quantify the outcrossing rate of *E. crus-galli* and evaluate the hybridization among *Echinochloa* sp. The resistance to imidazolinone herbicides was used as a selective marker for quantifying the occurrence of cross-fertilization among an *E. crus-galli* biotype resistant to imidazolinones herbicides (ALS gene mutation Trp574) as pollen donor and susceptible biotypes of *E. crus-galli, E. colona* and *E. crus pavonis* as pollen receptors. The outcrossing rate was evaluated in 2.500 plants for each experimental area. The selection of individuals was performed by spraying imazethapyr at 100 $g.ha^{-1}$. The evaluations were performed at 21 days after herbicide application, where the survived plants were considered as resistant heterozygous. The percentage of cross-fertilization was calculated by dividing the number of seedlings that survived the herbicide application by the number of evaluated plants for each sample. The average outcrossing rate in the species of *E. crus-galli* was 3,46%, ranging from 2.96% to 4,41%. The production of E. crus-galli seeds reached 23.107 seeds per plant growing at field conditions at a plant density one plant m^{-2}. Hybridization among *E. crus-galli, E. colona* and *E. crus pavonis* was not identified. Although *E. crus-galli* is considered an autogamous plant, it has a high outcrossing rate. The outcrossing rate found could be related with to the rapid evolution of resistance to imidazolinone herbicides caused by altered target site and degradation enhancement that occurred in southern Brazil.

Keywords: *Echinochloa colona*, *Echinochloa crus pavonis*, Gene flow, Herbicide resistance

Survival time of rhizomes of invasive knotweed (*Fallopia* spp.) when above-ground shoot production is prevented (705)

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We are studying the survival time of rhizomes of invasive *Fallopia japonica* (Japanese knotweed) and *F.* x *bohemica* (Bohemian knotweed, hybrid knotweed), when shoot production is prevented. In field experiments, we covered cut stands of these weeds with woven geotextile in 2011. Different stands remained covered for varying durations (1 – 4 years). We removed the geotextile from two stands each year and recorded regrowth. While some stands were eradicated after being covered for three years, another stand still sprouted after four years of coverage. In order to examine more closely how long rhizomes can survive without shoot production, we started three new experiments in 2015. 1) *F. japonica* and *F.* x *bohemica* stands with undisturbed rhizome systems were cut down, and divided into quadrats. Shoots were counted on each quadrat, and covered with geotextile. Quadrats will be uncovered after different lengths of time to record regrowth. 2) A stand of *F.* x *bohemica* was cut down and divided in quadrats on which shoots were counted. In some quadrats, rhizomes were left undisturbed, whilst in others they were fragmented and their crowns were removed. The stand was then covered with geotextile. Quadrats will be uncovered after different lengths of time, and regrowth will be recorded, to find whether disturbance reduces the length of covering required for eradication. 3) *F.* x *bohemica* rhizomes of different size, and crowns with or without shoot production in the current year, were planted in the field at 20 cm depth and covered with geotextile. Rhizomes and crowns will be transplanted to pots after different lengths of time, and regrowth will be recorded. Increased knowledge about how long rhizomes of invasive knotweeds survive without shoot production, and about measures to reduce their survival time, would improve their control and soil-handling practices.

Quantifying maximum potential gene flow from *Brassica napus* to its male sterile relatives under greenhouse and field conditions (260)

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Gene flow from genetically modified (GM) crops to their relatives is one of the most important concerns in risks involved in growing and trading GM crops. GM crops are not approved for commercial cultivation in many countries, unintentional release and consequential establishment in agricultural and/or national ecosystems possess potential gene flow risks. Therefore, it is important to estimate potential maximum gene flow from GM crops to their relatives even without GM crops available. Therefore, a greenhouse and a field experiment were conducted to quantify maximum potential gene flow from *Brassica napus* to its relatives, which were male sterile (MS) relatives, MS *B. napus*, MS *B. juncea*, and MS *Raphanus sativus*. In the greenhouse condition, the gene flows from *B. napus* to MS *B. napus* and *B. juncea* were 20.13% and 1.19%, respectively, at 3 m distance and reached down to 1.96% and 0.06% at 24 m, while no gene flow to *R. sativus* was observed. In the field condition, the gene flows to MS *B. napus* and *B. juncea* were 37.38% and 34.59%, respectively, at 4 m and decreased down to 10.71% and 1.97% at 40 m, resulting in greater gene flows compared to those in the greenhouse condition, while no gene flow was detected from *B. napus* to *R. stativus* either. Even though gene flow rate was relatively lower in the greenhouse study than the field study, the gene flow estimated in the greenhouse condition still provide scientifically comparable and valuable estimation of gene flow and is still viable. The platform for gene flow study in the greenhouse can be used for risk assessment of gene flow where field study is unavailable. This work was supported by Rural Development Administration, republic of Korea (Project code PJ00837501; Project of LMO Environmental Risk Assessment Center).

Keywords: GM crop, *Brassica napus*, relatives, gene flow, pollinator

Phylogenic relationship of Korean *Phragmites japonica* (259)

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Phragmites japonica is one of the common perennial weed in *phragmites* genus, which is usually distributed in Northeast Asia. Despite the worth as biomass and Bioremediation plant, study about *Phragmites japonica* is limited. We have a collection of *Phragmites japonica* and *Phragmites communis* from all parts of Korea and from Russia, but one of the major problem in studying is to distinguish *Phragmites japonica* from *Phragmites communis* due to their similar morphology. To distinguish *Phragmites japonica* from *Phragmites communis*, we established the phylogenetic tree with both morphological traits and genomic DNA sequence of *matK* genes. We sequenced *matK* genes from *Miscanthus sinensis*, and seven phragmites species (3 *Phragmites japonica* and *4 Phragmites communis),* as well as *Oryza sativa,* and *Sorghum bicolor*, as the outgroups. As a result, we selected 1 *P. japonicus* collected in arboretum (Anyang, Korea). We also performed RNA sequencing using PacBio method of the selected *P. japonicas* by NICEM and identified EST-SSR markers from transcriptome analysis. The EST-SSR markers were then used to evaluate the phylogenetic relationship of Korean *P. japonicus* as well as those *collected* from neighboring countries such as China, Japan, and Russia. This work was supported by the grant entitled „The Genetic and Genomic Evaluation of Indigenous Biological Resources“ funded by the National Institute of BIological Resources (NIBR201503201) , Republic of Korea.

Keywords: *Phragmites japonica*, Phylogenic relationship

Phenotypic and genotypic investigation of natural hybrids between diploid *Miscanthus sinensis* and tetraploid *M. sacchariflorus* (262)

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Miscnahtus as tropical C_4 grass has a great potential to produce biomass. *Miscanthus* × *giganteus* is a promising bioenergy crop and has been only cultivated accession due to its high biomass. *M.* × *giganteus* is hard to be used for breeding, because it is triploid and its parent have not been identified. The discovery of new triploid *Miscanthus* is important in order to complement vulnerability of *M.* × *giganteus.* It is also useful that finding parent of triploid *Miscanthus*. Seven putative triploid *Miscanthus* were collected in Korea and selected four accessions which collected each other places. These triploid hybrid were confirmed by assessing morphological traits and cytological analysis. Except two candidate hybrids, SNU-M-108 and SNU-M-213 were finally discovered as candidate parental *Miscanthus*. Candidate parents were collected around triploid *Miscanthus* in each other provinces. SNU-M-108 and SNU-M-213 accessions have 11 *M. sinensis* and 8 *M. sacchariflorus,* and 45 *M. sinensis* and 5 *M. sacchariflorus* of each candidate parent, respectively. Sixty nine candidate parental *Miscanthus* were subject to flow cytometry, phenotyping, SSR marker, and chloroplast DNA sequencing analysis. In flow cytometry analysis, it was determined that ploidy level of all *M. sacchariflorus* accessions. In phylogenetic tree based on chloroplast DNA sequencing analysis, we confirmed that SNU-M-108 has a maternal parent of *M. sacchariflorus* and SNU-M-213 has a potential maternal parent of G-sa-03. Thus, chloroplast sequence-based phylogenetic analysis successfully identified the nearest genetic maternal accession candidates. Further studies are required for finding promising candidate paternal accession for successful breeding. This work was carried out with the support of „Next-Generation BioGreen21 Program for Agriculture & Technology Development (Project No. PJ01126901)“, Rural Development Administration, Republic of Korea.

Keywords: Miscanthus, triploid, candidate parent, phylogenetic tree, chloroplast DNA

Quantifying effect of osmotic and salt stress on germination of Egyptian spinach (*Corchorus olitorius* L.) and Asian spiderflower (*Cleome viscosa* L.) (773)

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Egyptian spinach (*Corchorus olitorius* L.) and Asian spiderflower (*Cleome viscosa* L.) are two of most important weeds in corn fields of Khouzestan province, Iran. The experiment was conducted to quantifying the effect of osmotic and salt stress on germination of these species. Seeds were exposed to eight levels of increasing salinity using NaCl solutions of 0, 50, 100, 150, 200, 250, 300, 400 and 500 mM. Effect of moisture stress on seed germination was assessed by incubating seeds in solutions with osmotic potentials of 0, -0.2, -0.4, -0.6, -0.8 and -1.0 MPa. Weibull hydrotime model and three parameter logistic equation were used for describing the effect of water potential and salinity levels on germination, respectively.The hydrotime constant (θ_H), the base water potential threshold ($\Psi_{b(0)}$) and the median base water potential ($\Psi_{b(50)}$) estimated to be 14.30 MPa h, -1.32 and -0.89 MPa for *C. viscose*and 11.85, -1.13 and -0.88 MPa for *C. olitorius*, respectively. Threshold response of 50% maximum germination reduction to salinity of *C. viscose* and *C. olitorius* were estimated to be 246.80 mM and 217.00 mM, respectively. Totally, seed germination of *C. viscose* and *C. olitorius* were partially tolerate and tolerant to osmotic stress and salinity, respectively.

Keywords: Ecology of Seed Germination, moisture stress, salinity, three parameter logistic equation, Weibull hydrotime model

Ecophysiology of effects of red/far-red light ratio on selected weed and crop species (44)

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Plants growing in canopies experience low light intensity as well as altered light quality [red/far-red (R/FR) ratio]. R/FR ratio, an initial signal of potential competition, triggers shade-avoidance responses in plants. In a combination of growth chamber and glasshouse studies, we have investigated growth and morphological responses of *Chenopodium album* L. (common lambsquarters), *Amaranthus retroflexus* L. (redroot pigweed) and *Lycopersicon esculentum* (tomato) to R/FR ratio, how plant age and leaf position affect leaf optical properties for red (660 nm) and far-red (730 nm) wavelengths, and if R/FR ratio influences response of *Zea mays* L. (corn) plants to UV-B radiation. Different R/FR ratios (0.3, 0.6, and 1.1) were achieved by using supplemental far-red LED lamps in growth chambers, while maintaining the photosynthetically active radiation. Reflectance, transmittance and absorptance of red and far-red wavelengths and the R/FR ratios of light reflected and transmitted from leaves, still attached to the stem, were measured using a CI-710 Miniature Leaf Spectrometer. Different UV-B radiation levels were achieved by passing radiation from UVB-313 fluorescent tubes through 1 (high UV-B), 2 (medium UV-B) and 3 (low UV-B) layers of cellulose acetate film in a glasshouse. Plant growth and morphological responses were monitored. Results showed that R/FR ratio influences several growth parameters of *C. album*, *A. retroflexus* and tomato and the leaf position and plant age affect leaf optical properties for 660 and 730 nm wavelengths. Species differed in these regards. Exposure to different R/FR ratios and the associated change in anthocyanin production did not alter the response of corn plants to UV-B radiation. These findings are significant to our understanding of plant-plant interactions in agro-ecosystems, where R/FR ratio and UV-B radiation levels are fluctuating.

Keywords: Red/far-red ratio, ultraviolet-B, Chenopodium album, Amaranthus retroflexus, tomato

Emergency flow of *Urochloa plantaginea* as affected by temperature and luminosity conditions (234)

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Weeds emergency time modifies the competition with the crop. Therefor the work hypothesis is that soil temperature elevation cause an increment in weeds emergency flow. The objective of this study was to evaluate the emergency flow of *Urochloa plantaginea* (alexandregrass) submitted to different conditions of temperature and luminosity. Two experiments were performed in completely randomized design, with four replicates. In the first experiment the treatments were composed by different levels of shading (0; 35; 50; and 80%), and, in the second by plastic film cover (without film, film only at the top, partially closed and fully closed). Alexandergrass emergency in the area was monitored during 10 days, performing daily counts. During the conduct of experiments were perform measurements of soil temperature, interception of solar radiation and soil moisture at the end of the experiment. To species analysis in each type and level of coverage were calculated the total number of emerged plants (EP) and the emergency speed index (ESI). Data were submitted to covariance analysis and, when was significant, we proceeded to do Tukey test ($p \leq 0.05$). Shading levels elevation in 50 and 80% increased EP and ESI compared without film. The 80% shading provided increase of 159% in EP and 299% ESI compared without film, enabling greater establishment of plants. In fully closed condition, there was an 8.5° C temperature increase, resulting in a 62% decrease of EP and 70% decrease of alexandergrass ESI. Solar radiation and temperature reductions increase EP and ESI, while soil temperature increasing decreases alexandergrass EP and ESI.

Keywords: Weed, Seed germination, Emergency speed index

Volunteer canola seedbank disturbance in western Canada: is timing everything? (455)

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Brassica napus L. (canola) is the most common oilseed crop grown in western Canada. Volunteer canola, a weed derived mainly from canola harvest losses, is the 14th most abundant weed in western Canada after in-crop herbicide application. Seedbank persistence of this weed (averaging three to four years) is longer than most conventional crop rotations practiced on the Canadian prairies. The retention of unwanted weediness traits (secondary dormancy and silique shatter) along with genetically-engineered herbicide-resistance, certified seedlot contamination, and weed seed return from unmanaged volunteers all contribute to volunteer canola seedbank persistence. In 2013-2016, a field study that evaluated the effect of timing and intensity of soil disturbance following canola harvest was conducted at five locations in Manitoba, Canada. Seedbank densities were quantified immediately following canola harvest and again the following spring to evaluate seedbank persistence over winter. Seedling recruitment was also evaluated throughout the first year after canola production. Preliminary research has shown that tine harrow before seeding winter wheat or tillage via tandem disk immediately after canola harvest resulted in approximately three-fold greater autumn seedling recruitment compared to zero tillage. These high disturbance treatments immediately after harvest also caused the greatest reduction in viable volunteer canola seed in the seedbank the spring after canola production (approximately two-fold compared to zero tillage). The proportion of the persisting spring seedbank differed among sites and was likely influenced by soil type, which, aside from biological properties, differed in textures ranging from sandy loam to silty loam to heavy clay (18%, 1%, and 8% of the initial seedbank, respectively). These results indicate that delayed tillage systems identified for managing volunteer *B. napus* seedbank dynamics in Germany and the United Kingdom may not be an effective management option in the agroecological environment of western Canada.

Keywords: *Brassica napus*, Seedbank dynamics, Seedbank persistence, Seedling recruitment, Soil disturbance

The poster in a PDF version is available here.

The effect of post-dispersal seed predation on *Echinochloa crus-galli* (L.) P.B. in maize fields (132)

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It is believed that growth of *Echinochloa crus-galli* and other annual weeds in agricultural fields are mainly seed limited. If so, seed predation by seed eating animals, such as granivorous mice and carabid beetles, will be an important tool to reduce weed growth. The objective of this study is to evaluate the importance of seed limitation, as opposed to microsite limitation. An experiment was conducted to investigate the number of seedlings that emerged from populations that had or had not been exposed to predation. On each of three maize fields in NE Germany, six blocks of 13.5 m by 10.5 m, each with 12 plots of 1.5 m by 1.5 m were setup. Half the plots were surrounded by a 60 cm high plastic frame, to prevent entrance of seed predators. *Echinochloa crus-galli* seeds at five densities (0, 300, 600, 1200 or 2400 seeds m^{-2}) were sown into the plots. From spring 2015 onwards, the number of emerged seedlings was counted and mortality monitored. Panicles were bagged before seed shed, such that no new seeds were added to the seed bank. In September 2015, the mature, reproductive plants and panicles were harvested. The populations will be followed for another season (2016). Results from 2015 will be presented.

We are grateful for the funding provided by the DFG of the project "Testing for the weed control potential of seed predators in agroecosystems" (WE 5040/2-1).

Keywords: *Echinochloa crus-galli*, seed predation, seed limitation, biological weed control

The poster in a PDF version is available here.

Wave riders: using seed dispersal characteristics to develop the surveillance programme for *Euphorbia paralias* (sea spurge) in New Zealand (263)

Frances G Velvin *(Ministry for Primary Industries, Wellington, New Zealand)*

Sea spurge (*Euphorbia paralias*) is a terrestrial coastal weed that was first detected on the west coast of the North Island in New Zealand in 2012. The weed has caused significant environmental impacts on coastal sand dunes in Australia and has the potential to have adverse effects in New Zealand. An eradication programme was established in 2012 and includes management of the detection site and coastline surveys to detect other populations of sea spurge. Sea spurge is dispersed by seed and the seed dispersal characteristics inform the design of the coastal surveillance programme. The seeds can survive and float in sea water for several months giving the species the ability to spread on ocean currents. During storm surges seed may be deposited on land well above the high tide mark where there is time to germinate and develop a deep tap root that prevents the plant from being washed back in to the sea during subsequent storm events. The surveys are based on identifying sites along the coastline where sea spurge seed is likely to be deposited and where there are suitable conditions for plant establishment. These locations are then inspected between the high tide mark and the highest reach of storm surges. An initial aerial survey by helicopter of high priority sites along 200km of the west coast was undertaken in 2012 to detect populations of sea spurge or large individual plants. Ground-based surveys are undertaken annually for risk sites within 15km of the initial detection site. The third year of the 10 year eradication programme has been successfully completed with no further populations detected. Coastline surveillance and management of the detection site will continue until the viable seed reserve has been depleted.

Keywords: *Euphorbia paralias*, sea spurge, surveillance, coastal weed, environmental impacts

The poster in a PDF version is available here.

Impact of crop rotation on soil seed bank (368)

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The proposed Common Agriculture Policy (CAP) reform for the period 2014-2020 covers agricultural practices that respect the environment („greening"), fundamental to preserve soil and biodiversity in agricultural systems. These stands out to traditionally cereals agro-ecosystem of the Lower Alentejo, as crop diversification, which results in crop rotation. The crop diversification contributes to the sustainability of agro-ecosystems by the impact of crop yields, soil conservation and ecosystem services. The floristic composition of the weed community and species adaptation can be assumed to follow the temporal pattern of environmental change, which results from the interaction of climatic variables with agronomic variables related to a particular region and farming practices. Our aim is to study the soil seed bank of the rotation crops (malting- barley, maize and sunflower) to assess the impact of each cultural system (monoculture or rotation) using the species of weeds as floristic biodiversity indicators. Soil samples were collected in October 2013 in a 10 x10 m grid, at a depth of 20 cm along the pivot irrigation system, corresponding to 15-20 subsamples per plot (total of 60 sub samples). Weed seedbank was analysed by the germination method with identification and enumeration of seedlings emerged from the soil under controlled conditions. Diversity indices and the diversity profile (Hill series) were determined for each crop and year.Preliminary results for the first two years of the rotation are presented. Floristic richness was low in every crop: sunflower (10); maize (11); barley (7), comprising the following species: *Amaranthusalbus; Anagallisarvenses; Chenopodium album; Daucus carota; Ditrichia viscosa; Conyza bonariensis; C. canadensis; Coronopus didymus; Papaver rhoeas; Lolium rigidum; Juncus bufonius; Oxalis cornicolata; Polygonumaviculare; Senecio vulgaris* and *Sonchus oleraceae.* Seed density was highest in sunflower (36 plants m^{-2}), followed by maize (20 plants m^{-2}) and barley (17 plants m^{-2}).

Keywords: Maize, sunflower, barley, diversity indices, Hill series

Do seeds of invasive plants persist longer in the soil than those of non-invasive alien species? (745)

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Seeds of 73 species that are alien in the Czech Republic (35 invasive and 37 non-invasive) were collected in the field, tested for viability and buried in nylon bags in the soil in a common garden at the Institute of Botany, Průhonice. Seeds were exhumed once a year (spring 2014, 2015), and the fraction of germinated or decayed seeds, and of non-germinated but viable seeds, was determined in each sample. This allowed us to ascertain seed persistence/ viability after 1.5, and 2.5 years of burial in the soil. We found that invasive and non-invasive species differed in seed persistence. Seeds of all invasive species were viable or germinated to some percentage after 1.5 year of burial in the soil, while 16% of non-invasive species did not survive during this burial period. Moreover, the majority of invasive species showed a high seed survival percentage (survival category 75-100%), while only low percentage of non-invasive species germinated or were viable after this period in this survival category. After 2.5 years of burial in the soil, the majority of invasive species showed a seed survival percentage ranging from 5-25%, while non-invasive species were distributed rather evenly among all other survival percentage categories, with only 5% species in highest survival category. These preliminary results suggest that invasive species tend to persist longer in the soil and have thus potential to form larger and long-term persistent soil seed banks then non-invasive species.

Keywords: Seed bank, burial experiments, invasive species, non-invasive species

The poster in a PDF version is available here.

Soil seed banks as predictors of invasiveness of alien plants (744)

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Identifying reliable predictors of plant species' invasiveness, the ability of a species to become established and spread in its non-native range, represents a pressing research question in invasion ecology. Soil seed banks are a major source of propagules and genetic diversity, thus playing a key role in the recruitment and persistence of many species reproducing by seeds. Yet, only recently the characteristics of the seed bank have started to be included among potential predictors of invasiveness. To assess the role of seed bank traits in plant invasions, (1) we compared the type (transient vs. persistent) and density of the seed bank of invasive congeners and non-invasive congeners, in their non-native range, and (2) in their native range; and (3) we compared seed bank traits of invasive species in their native and non-native range. To address these questions, we used a dataset comprising 15240 records, for 2002 species, including 149 genera for which seed bank data for invasive and non-invasive congeners are available (759 species), and 196 invasive species for which seed bank data are available in their native and non-native range. In their non-native range, invasive species had a higher probability to form a persistent seed bank than their non-invasive congeners, suggesting that seed bank persistence is an important determinant of plant species' invasiveness. Moreover, invasive species were more likely to form a persistent seed bank in their non-native rather than native range, suggesting rapid adaptive changes towards more persistent seeds. The final results of models of seed bank type and density accounting for taxonomy and phylogeny will be presented, providing insights into the role of seed bank traits as determinants of invasiveness and the importance of adaptation and pre-adaptation with respect to these traits in the successful establishment of alien species in their non-native range.

Keywords: Soil seed bank, invasive weeds, species invasiveness, persistence

Post-dispersal predation of weedy rice seeds in rice fields (750)

Robin Gomez *(University of Costa Rica, San Jose, Costa Rica)*

Weedy rice (*Oryza sativa*) is one of the most important weeds in rice production worldwide due to its morphological and physiological similarity to commercial rice varieties. Reducing the number of weedy rice seeds entering the seed bank by enhancing post-dispersal seed predation is a viable weed management strategy in rice fields in the tropics. A field study was carried out in three rice fields in Costa Rica to evaluate weedy rice seed predation as influenced by tillage, residue cover, and spatial distribution of weed seeds. Twenty groups of 30 seeds each were placed on the surface of plastic containers filled with soil in a 20x15 m grid in each field one week after rice harvest. Seven days later the seeds remaining in the containers were recovered. Average seed predation was similar in lightly tilled and non-tilled fields with no crop residue (20 and 24%, respectively), and also similar in non-tilled fields with (37%) or without (38%) residue. Georeferenced spatial distribution maps showed highest predation in the interior of the non-tilled field, whereas in the tilled field highest predation occurred both in margins and inner areas. Seed predation magnitude varied between 0 to 100% across each field. Main seed predators are presumed to be several species of birds associated with rice fields. Results suggest that weedy rice seed predation is an important ecological process that should be taken into consideration when designing management strategies for this weed.

Keywords: Weedy rice, seed predation, rice, Oryza sativa

The poster in a PDF version is available here.

Effects of different cultivation practices on the amount of seeds in the soils and seed production of *Cenchrus pauciflorus* Benth (799)

Weidong Fu *(Chinese Academy of Agricultural Science, Beijing, China),* ***Guoliang Zhang*** *(Chinese Academy of Agricultural Science, Beijing, China),* ***Zhen Song*** *(Chinese Academy of Agricultural Science, Beijing, China)*

In the present study, the amount of *Cenchrus pauciflorus* Benth seeds in the soils of natural grassland and farmland was measured. The effects of fertilization (low: urea 10g+KH_2PO_4 3g, middle: urea 20g+KH_2PO_4 6g, high: urea 30g+KH_2PO_4 9g), irrigation (200mm, 400mm, 600mm), plant-mowing (once a week, fortnightly, tri-weekly) and using replacement plant species (sunflower and Jerusalem artichoke) on *C. pauciflorus* were analyzed. From seeds of pasture and dry farmland soils, a total number of 25 plant species were identified, which fell into 24 genera of 12 families. The number of seeds of *C. pauciflorus* per square meter reached 12.923 in natural pasture soils and 8.960 in dry farming soils, which was 67.72%and 79.74% of the total seeds, respectively, from the two types of soils. In dry natural pasture soils, the seeds of *C. pauciflorus* were mainly distributed on the top 0-2.0 cm layer, being 45.71% of the total seeds. In dry farmland soils, however, the numbers of *C. pauciflorus* seeds were not significantly different on the 0-2.0, 2.0-5.0 cm and 5.0-10.0 cm layers ($P>0.05$). Experiments showed that seed production increased significantly at the low-dosage of fertilizer application ($P<0.05$), but it was much lowered at the intermediate and high dosages of fertilizer treatment. The seed yield of *C. pauciflorus* was positively related to the amount of water application in irrigation and it was 2 562.8 seeds per plant. Plant-mowing suppressed seeds production of the weed and a reduction of 97.69% of seeds was observed by mowing the weed once a week. Planting sunflower (*Helianthus annus* L.) or Jerusalem artichoke (*Helianthus tuberosus* L.) suppressed the growth and seed yield of *C. pauciflorus* plants significantly ($P<0.01$).

Keywords: *Cenchrus pauciflorus*, seeds in soils, seeds production, cultivation practices

The response of taxonomic and functional diversity of the seed bank to agriculture intensification and soil properties in two Mediterranean cereal areas (70)

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Weed seed bank diversity has been severely impacted by agriculture intensification. However, the functional consequences have been poorly studied in highly intensified agro-ecosystems. This study evaluated the importance of soil properties and agriculture intensification at local and at landscape scale on taxonomic and functional diversity and in the distribution of functional traits of plants represented in the soil seed bank in conventionally managed cereal fields in two Mediterranean regions of Spain, Andalusia and Catalonia. Local intensification was measured by means of position in the field (margin, edge and centre) which reflects different intensities of management practices. Intensification at the landscape scale was measured with percentage arable land cover within circular sectors of 1 km radius around the focus field. Functional diversity index and the distribution of functional traits were based on eight traits related to the whole plant life-cycle. In total, 175 and 116 species were recorded in the seed bank in Andalusia and Catalonia, respectively. We found that taxonomic and functional diversity, and the distribution of functional traits in the weed seed bank were unaffected by soil properties, position in the field or landscape structure in any of the two studied regions. The results suggest that intensity of management practices is a similar thorough the entire field and field margins flora is highly affected by adjacent crop management. The negligible impact of landscape structure may be due to arable land cover was high and the presence of (semi)natural habitats were scarce, therefore the availability of alternative habitats acting as a source of propagules is limited. This long-term intensification at local and landscape scale has led to the actual communities which are characterized by an extremely low functional diversity with functional traits adapted to recurrent disturbance and with a high reproduction capacity.

Keywords: Functional traits, arable weeds, Landscape, Field margin

Impacts of *Rottboellia cochinchinensis* an invasive alien weed in black cotton soils and its herbicidal management in Southern India (474)

Chinnusamy Chinnagounder *(Tamil Nadu Agricultural University,Directorate of Crop Management, COIMBATORE, India),* ***Prabhakaran Nachimuthu Krishnan*** *(Tamil Nadu Agricultural University,Directorate of Crop Management, Coimbatore, India)*

Rottboellia cochinchinensis is a rapidly spreading and is often the first colonizer of disturbed land. Sharp hairs on the leaf sheaths penetrate the skin of human labourers, causing infections. *R. cochinchinensis*, a C_4 species, is prominent in open well-drained places and common on contour banks and roadsides and is of some value for grazing. It is an extremely vigorous competitor in upland crops due to its rapid growth and spreading habit and heavy infestation can cause crop loss. The plant reproduces entirely by seeds and can continue to flower and seed year-round when moisture conditions are favorable a single plant can bear 2,000 seeds. *R. cochinchinensis* is observed to invade black soils of Southern India. It is a most problematic weed under rainfed conditions in crops like sorghum, pearl millet, pulses and cotton. Thorny nature of this weed hinders manual removal warranting herbicidal control. Glyphosate 2130 g a.i. ha^{-1} (Mera 713000 g) + Ammonium sulphate 4000 g ha^{-1}, Glyphosate 1230 g a.i. ha^{-1} (Round up 41 % SL 3000ml + Ammonium sulphate 4000 g ha^{-1}, Glyphosate 1420 g a.i. ha^{-1} (Mera 712000 g+ Ammonium sulphate 4000 g ha^{-1} and Glyphosate 1640 g a.i. ha^{-1} (Round up 41 % SL 4000 ml) + Ammonium sulphate 4000 g and all the treatments with 400 ml of surfactant per ha were the treatments in the fields of farmers. Before herbicide spray, the incidence of *R. cochinchinensis* was 48.5 %t of the total weed vegetation in the field. At 15 and 30 days after spraying of herbicide, glyphosate 1420 g a.i. ha^{-1}+ Ammonium sulphate 4000g of water recorded lower density and dry weight of all the weeds and this was followed by glyphosate 1640 g a.i. ha^{-1} + Ammonium sulphate 4000g observed with good control of weeds predominantly *Rottboellia cochinchinensis*.

Keywords: Alien Invasive weed, *Rottboellia cochinchinensis*, Herbicidal managment, Glyphosate, Post emergence

The poster in a PDF version is available here.

Weeds and their relation to mealybug species in orange orchards (161)

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Weeds are an alternative host and the food source of many harmful microorganisms and insects as well as mealybugs, Pseudococcidae (Hemiptera: Coccomorpha) in agroecosystems. For determining of the life cycle of main weed species in orange orchards, and also in order to determine the mealybugs on these plants, this study was conducted. Six orchards located in Adana province-Turkey, have been chosen with different ecological aspects, The orchards were visited periodically every two week intervals in whole years, and weed coverage and development stage of weeds was recorded to the data sheet by BBCH scale. To determine mealybug species, plants were pulled from the soil and checked for any mealybugs by looking to green parts, stem, root and root crown. Unknown weed species and collected mealybug species were taken to the laboratory and identified. Based on the results: (common purslane) *Portulaca oleraceae* L., (common mallow) *Malva slyvestris* L., (Canadian fleabane) *Conyza canadensis* (L.) Cronquist, (Johnsongrass) *Sorghum halepense* (L.) Pers., (barnyardgrass*) Echinochloa crusgalli* (L.) Link., (hearleaf cocklebur) *Xanthium strumarium* L., (corn butter cup) *Ranunculus arvensis* L., (redroot pigweed) *Amaranthus retroflexus* L., (field bindweed) *Convolvulus arvensis* L., (black night shade) *Solanum nigrum* L. were determined as important ten weeds in citrus orchards, according to their cover. Eight of these species were host for mealybug species. Five different mealybug species, namely: *Planacoccus citri* Risso., *Peliococcus turanicus* Kiritshenko., *Phenacoccus solani* Ferris., *Phenacoccus solenopsis* Tinsley. and *Chorizococcus rostellum* Lobdell. were found on 26 weed species belonging to 14 different plant families.

Keywords: Weed, Mealybug, Citrus

Impact of *Flaveria bidentis* litter on communities of invertebrates in soil in different habitats (800)

Guoliang Zhang *(Chinese Academy of Agricultural Science, Beijing, China),* ***Weidong Fu*** *(Chinese Academy of Agricultural Science, Beijing, China),* ***Zhen Song*** *(Chinese Academy of Agricultural Science, Beijing, China)*

An investigation was conducted to explore the impacts of *Flaveria bidentis* litter on the communities of invertebrates in soil in three different habitats including forestland, wasteland, and ditches. A total of 54315 individuals were captured in three habitats on October 23rd by cutting ring (diameter is 20 cm, height is 10 cm), which is divided into three sampling layers in this study. All of the individuals belong to 2 phyla 10 classes 17 orders, among which Arachnoidea and Collembola were the dominant orders in three habitats, and the relative abundance of other species were smaller. *F. bidentis* litter could provide the better habitats and food sources for invertebrates in soil, such as Arachnoidea, Collembola, Psocoptera and so on, thereby affecting their structure and diversity of community of invertebrates in soil which mainly related to growth conditions of *F. bidentis* community, which is characterized by its weaker growth conditions in forestland but stronger growth in wasteland land and ditches. In summary, *F. bidentis* plants and their litter provided habitat and concealment for the dominant species, and significantly changed content of nitrogen, phosphorus, potassium and organic matter in surface humus soil after the invasion of *F. bidentis* in three habitats, which cause the increasing of diversity of invertebrates in soil and also it trends to increase for the diversity of invertebrates in liter from top to bottom. Thus it laid a foundation for the influence of decomposition rate in *F. bidentis* litter on the diversity of invertebrate communities in soil.

Keywords: *Flaveria bidentis*, Litter, Soil invertebrates, Biodiversity

The role of weeds in supporting bee populations in agro-ecosystems (83)

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Recent concerns about the global decline in pollinators, as a result of agricultural intensification, has called for more knowledge about the drivers of bee diversity and abundance in agro-ecosystems. Weeds in field margins play a significant role in supporting biodiversity and ecosystem services, notably, by providing food sources and refuge for pollinators. This study investigates the role of weeds in field margins in supporting bee abundance and diversity in Mediterranean cereal agro-ecosystems, with a landscape perspective. The experiment was carried in 2014 and 2015, at 22 margins in Catalonia, Spain. Margins represented a range in surrounding landscape, from mainly agricultural to mainly forest. A plant species inventory was carried out within a 50m transect in each margin. Sampling took place on four different days, interspersed throughout the highest period of bee activity, May through July, and when weather was optimal. Sampling comprised bee trapping, observations of pollinator foraging activity and plant measurements (cover and height). Bees collected in traps were identified in the lab to Genus level. Functional relationships between margin characteristics and bee populations were modeled using linear mixed models. Margin characteristics included: weed species diversity, functional diversity, colour diversity, width, percent natural landscape (1km radius), etc. Furthermore, functional relationships between the morpho-physiological features of bee genera to function as pollinators (e.g., body characteristics, method of pollen collection) and associated weed floral traits present in the margin (e.g., size, shape, colour, nectar/pollen) were analyzed. Preliminary analysis has revealed positive correlation between bee population and species diversity, flower density, percent herbaceous vegetation, percent natural landscape and margin width. This research can provide important knowledge about the relationship between biodiversity and pollination, promoting a shift from conventional agricultural management to more sustainable farming, and more robust agro-ecosystems. This research was funded by Spanish Ministry of Education and Science and NSERC.

Keywords: Bees, pollinators, biodiversity, weed diversity, field margins

The poster in a PDF version is available here.

Management of invasive alien weeds in rice through climate resilient variety and herbicides (571)

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Studies to compare the impact of submergence tolerant rice varieties Sigappi and Swarna (sub 1) integrated with herbicides on the infestation of invasive alien weeds *Leptochloa chinensis* and *Marsilea quadrifolia* were taken up at Annamalai University. Lesser weed counts (34.19 m^{-2}), weed biomass (31.82 kg ha^{-1}) and highest weed control index of 67.51 per cent were recorded with submergence tolerant rice variety during 2014. This was significantly superior over conventional varieties by recording higher grain yield (4.09 t ha^{-1}) and straw yield (6.12 t ha^{-1}). Among the sub plot treatments, application of bensufuron methyl 0.06+ pretilachlor 0.6 kg ha^{-1} recorded the least weed counts (16.83 m^{-2}), weed biomass (10.64 kg ha^{-1}) and highest weed control index of 94.9 per cent, and this was on par with twice hand weeding. During 2015 also, lesser weed counts (32.72 m^{-2}), weed biomass (51.72 kg ha^{-1}) and highest weed control index of 80.67 per cent were recorded with submergence tolerant rice variety Sigappi. This was significantly superior to conventional rice variety that recorded higher weed counts, weed biomass and weed control index. The grain yield was also significantly higher in submergence tolerant rice, with 4.50 t ha^{-1}. Among the herbicide treatments, application of bispyribac sodium 0.02 kg ha^{-1} recorded the least weed counts (9.10 m^{-2}), weed biomass (15.91 kg ha^{-1}) and highest weed control index of 91.03 per cent, and this was on par with twice hand weeding. These treatments were significantly superior than the others (Unweeded control, hand weeding twice, butachlor 1.5 kg ha^{-1}, oxadiargyl 0.07 kg ha^{-1}, oxyfluorfen 0.025 kg ha^{-1}, metsulfuron methyl + chlorimuron ethyl 0.004 kg ha^{-1}, pyrazosulfuron ethyle 0.02 kg ha^{-1}) in reducing the weed infestation and ultimately increasing grain yield. The results indicate that stress tolerance as a biological or genetic trait in crops helps suppressing weeds.

Keywords: Submergence tolerance, Rice, Herbicides, Invasive weeds

The poster in a PDF version is available here.

The effect of microclimate on Arthropod biodiversity hedgerow in agroecosystem of field (615)

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Microclimatic conditions are very important for ground dwelling organisms. A major climatic factor are the influence of sunlight and the moisture influencing both the biodiversity of invertebrates associated with hedgerow and biomass of planted cultural plants.The experiment was performed in spring barley field close to village Budihostice in Czech Republic in 2015. Studied hedgerow was represented by dominant trees *Robinia pseudoacacia*, *Fraxinus excelsior* and *Ballota nigra* and undergrowth. Effect of microclimatic conditions (solar radiation, moisture, plant height, biomass, and distance from hedgerow) on community of ground dwelling spiders (Araneae) and other arthropods was studied. Arthropods were collected by pitfall traps with 2% formaldehyde solution and detergent. Thirteen orders of arthropods including nine families of spiders (35 species) were collected. Dominant spider families were Liniphidae (*Oedhotorax apicatus*) and Lycosidae (*Pardosa lugubris, Pardosa agrestis*). Results found significant effect of hedgerow orientation (north/south) on the biomass (fresh and dry condition), the height of the plants, temperature and diversity and abundance of ground dwelling invertebrates. *Pardosa lugubris* was the most abundant in hedgerow with canopies and *Pardosa agrestis* preferred the sunny south side toward the barley crop. *Oedothorax apicatus* occurred only in barley field with no preference of hedgerow side.

Keywords: Hedgerow, Biodiversity, Microclimate, Araneae, Arthropod

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Diversity and trophic structure of soil nematode communities are altered following *Heracleum sosnowskyi* plant invasion (584)

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Invasive species are a major threat to biodiversity and ecosystem processes in native communities and it is widely assumed that invasive plants cause a negative impact on native biota. Knowledge of the main effects of plant invasions on soil microfauna is essential for a better understanding of the process of these invasions. *Heracleum sosnowskyi* is the second most important invasive *Heracleum* species in Europe. We studied the composition of soil nematode communities in three different habitats invaded or uninvaded by *H. sosnowskyi*: abandoned land, grassland on a roadside slope and the edge of afforested land. We hypothesized that changes caused by the invasion of *H. sosnowskyi* in native habitats would reduce nematode abundances and species diversity and affect the trophic structure of the nematode communities. A total of 24 soil samples were collected, and 117 nematode species belonging to 77 genera were identified. Ecological indices and nematode community structure, abundance, dominance and taxonomic diversity differed significantly between invaded and control plots. Nematode abundance and species diversity were lower in the habitats where *H. sosnowskyi* had become established, and the taxonomic compositions of free-living and plant-parasitic nematode communities differed from those of the controls. Plant-parasitic nematodes were the trophic group that differed the most in all habitats, and bacterivorous and root-fungivorous nematode populations were significantly higher in the invaded habitats.

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Keywords: *Heracleum sosnowskyi*, Ecosystem, Soil nematode communities, Nematode species diversity, Trophic diversity

The poster in a PDF version is available here.

Environmental friendly management of *Ecballium elaterium* in almond orchards based on understanding the relationship between spatial distribution, weed biology and chemical control (590)

Nitzan Birger *(Agricultural Research Organization (ARO), Newe Ya'ar Research Center, Ramat Yishay, Israel),* ***Lior Blank*** *(Agricultural Research Organization (ARO), Volcani Center, Bet Dagan, Israel),* ***Hanan Eizenberg*** *(Agricultural Research Organization (ARO), Newe Ya'ar Research Center, Ramat Yishay, Israel)*

*Ecballium elaterium (*squirting cucumber) is a native weed to the Mediterranean region. It has unique seed dispersal mechanism which is based on ejection of the seeds from the fruit when it ripens. The annual weed management of almond in Israel costs $ 250 per hectare. However, squirting cucumber is the major problem. The distribution of squirting cucumber in Israel increased in the past years as a result of banning the use of key herbicides i.e. simazine and trifluraline. Distribution of weeds in field crop, vegetables and orchards is often in a patchy pattern, meaning that some regions infested with high density of plants are next to areas infested with low weed density. This patchiness might be spatially and temporally stable as a result of small scale dispersal of seeds, seed bank, vegetative reproduction and soil conditions heterogeneity which is also patchy. Understanding the spatiotemporal dynamic of weed patches can help to develop weed maps to be used in site-specific weed management aiming precise herbicides application. The aim of this study was to understand the biology of seed dispersal of squirting cucumber, the distribution pattern and the interaction between them. We mapped the location of all squirting cucumber in seven different orchards in north of Israel, using GPS (ArcPad, ESRI) and GIS (ArcMap, ESRI). Spatial pattern was analyzed using an Average Nearest Neighbor analysis. Results revealed that in all seven fields squirting cucumber displayed spatial clustering pattern. However, the patch size and density varied between plots. This was further supported by the visualization of the spatial point patterns using heatmaps (density raster) (QGIS). Squirting cucumber distribution pattern in almonds orchards is not random. The knowledge on the spatial pattern of this species will help in developing maps that will serve for herbicides application.

Keywords: *Ecballium elaterium*, GIS, Spatial distribution, Weed mapping

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Opportunistic farming of road verges reduces plant diversity and promotes weeds in intensively managed farmlands mosaics (558)

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Agricultural intensification has promoted the loss of semi-natural habitats, which primarily resulted from cropland increase at the expense of rangeland areas, fencerow removal, and the extension of cropped areas closer to road margins. Habitat loss resulting from the rapid inception of herbicide tolerant transgenic crops has not been studied as thoroughly as introgression of engineered genes into wild relatives and development of glyphosate resistant weeds. In the Rolling Pampa, the corn belt of Argentina, semi-natural habitat loss associated with road verges has been promoted by the rapid adoption of no-tillage and soybean varieties genetically modified to tolerate glyphosate. Here, I present preliminary results from surveys of weeds and the spontaneous vegetation along road verges, whether cropped with soybean or uncropped. Surveys of road verges are also compared with others of crop fields and along fences in the same region. Results indicate that uncropped road verges retain a substantial share of plant diversity, particularly native species from the pampa grassland. Total richness decreased from 233 species in uncropped road verges to 60 species when these habitats were opportunistically cropped with transgenic soybean. Consequently, many native species reduced their occurrence, or even became locally extinct, especially perennial grasses and subshrubs. Wind-dispersed species, both native and exotic, were notably more frequent along uncropped road verges and fencerows, suggesting that these habitats may function as seed traps. Occurrence of conspicuous weed species in warm-season crops increased when road verges were cropped with soybean (*Anoda cristata*, *Digitaria sanguinalis*, *Echinochloa crusgalli, Portulaca oleraceae*). These findings highlight the critical role of uncropped road verges and fence row networks for conserving habitat heterogeneity and biodiversity in intensively managed farmland mosaics. Results presented here stress the urgent need for both discontinuing the cultivation of road verges and implementing initiatives to restore and conserve semi-natural vegetation across these patch types.

Keywords: Biodiversity, Corridor, Habitat loss, Landscape homogenisation, Native flora

Sowing selected flowering plants in a processing tomato field margin to conserve biodiversity (377)

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Field margins in annual crops have lost the floral components and structural elements that offer food and shelter to pollinating insects, as a result of continuous soil tillage and use of herbicides. In this study, we enhanced the floral biodiversity in the margin of a processing tomato field using Greek biotypes of selected flowering plants and compared their capacity to support populations of pollinators in relation to that of conventional field margins. Plants were selected from a diverse range of families to increase attractiveness for pollinators, excluding potential weeds, alien species or pest hosts. The seeds were provided by the Greek Gene Bank and were sown in a 70m long x 2m wide area along one side of a 2ha processing tomato field in Boeotia, Greece in early December 2014. A similar size area of conventional field margin was allocated as the control. Flowering per species (% cover of surface) and numbers of attracted Hymenoptera pollinators based on counts of insect-visits per flower were measured biweekly for ten weeks. Sown species flowered from April to July and reached a peak in consecutive order: *Lathyrus sativus* L. ≥ *Vicia* sp. > *Chrysanthemum coronarium* L. ≥ *Coriandrum sativum* L. > *Anethum graveolens* L. The control field margins had limited flowering period and consisted mainly of grasses and small numbers of *Anthemis arvensis* L., *Matricaria chamomila* L., *Rapistrum rugosum* L. and *Convolvulus arvensis* L. Flower cover and number of attracted Hymenoptera pollinators (Apidae, mining bees) were significantly higher in the sown field margin compared to the control at all measurements. The results show that sowing field margins with selected plant species can be a practice to reverse the degradation of biodiversity in intensively cultivated areas, regardng flowering plants and Hymenoptera pollinators.
This work was funded under the biodiversity project Operation Pollinator of Syngenta.

Keywords: Field margin, Processing tomato, Flowering plant mixture, Hymenoptera pollinators

The poster in a PDF version is available here.

Effects of *Flaveria bidentis* invasion on the diversity of functional bacteria in the soil (777)

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Flaveria bidentis is an invasive plant found in large areas of northern China. This study conducted a separation and screening of the main functional bacteria in the soil of *F. bidentis* and investigated the changes in the community structure. A variety of functional microbes were isolated using selective media and rep-PCR clustering, and a diversity analysis was carried out. In addition, the dominant populations of various functional bacteria were identified using 16S rRNA sequence alignment. *Flaveria bidentis* increased the contents of the major available nutrients in the soil, and the levels of azotobacteria, organic phosphorus-solubilizing bacteria, inorganic phosphorus-degrading bacteria, and silicate bacteria in the soil of *F. bidentis* were significantly higher than those of the native plant *Tagetes erecta* and the control. rep-PCR analysis indicated that the structure of the four functional bacterial microfloras in the soil of *F. bidentis* was significantly different from those of the native plant and control. The diversity analysis demonstrated that the diversity of functional microorganisms in the soil of *F. bidentis* was richer, the community structure was more complex, the predominant microflora comprised a greater proportion of the total population, and the ecological diversity was higher. This was further evidenced by identification of the main functional isolates from three soil samples. Our findings indicated a mechanism of invasion by *F. bidentis.*

Keywords: Flaveria bidentis, invasive plant, functional bacteria, diversity

Session 13
CROP-WEED INTERACTIONS

Comparison of the allelopathic capacity of *Parthenium* weed leaf litter with a range of other allelopathic plants leaf materials (526)

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Parthenium weed (*Parthenium hysterophorus* L.) is an herbaceous plant that has now invaded over 44 countries worldwide. It is a significant weed due to its impact on crop and pasture production, natural community biodiversity and human and animal health. Allelopathy is a well-defined physiological trail that is possessed by some crops and native plant species, especially by invasive weeds. Allelopathy is a biological phenomenon involving the release of chemicals that may cause a stimulatory, but more often an inhibitory effect on another plant's growth, reproduction and survival. A large number of studies have associated the invasive success of parthenium weed with a proficient allelopathic attribute, causing an inhibitory effect on germination, seedling growth, dry matter production and phenological development and/or flowering in a range of agriculturally important and native species. The presumed allelochemicals are produced by a number of plant parts including the stem, leaves, roots, pollen and other floral parts. In order to elucidate the strength of the allelopathic attribute, parthenium weed leaf litter was tested on the seedling growth of lettuce in the sandwich test. When compared to the leaf litters from other well-known allelopathic species (*Melia azedarch* L., *Litchi chinensis* Sonnerat., *Tamarindus indica* L., *Amhersita nobilis* Wall. and *Citharexylum spinosum* L.), parthenium weed leaf litter was found to be moderately allelopathic. The greatest suppression of lettuce seedling growth was obtained with *Tamarindus indica* L. followed by *Parthenium hysterophorus* L. producing 82 and 52% growth inhibition, respectively.

Keywords: Allelopathy, *Parthenium* weed, invasive weed

The poster in a PDF version is available here.

Allelopathic potential of mugwort (*Artemisia vulgaris* L.) to control *Amaranthus retroflexus* L. in maize and green bean crops (202)

Euro Pannacci *(University of Perugia, Perugia, Italy)*

A study was conducted to evaluate the allelopathic potential of mugwort to control *A. retroflexus* in maize and green bean, using bioassays in Petri dishes and pots. Above-ground biomass of mugwort was collected (at flowering) in central Italy, dried, ground to a fine powder, soaked in distilled water for 24 h and then filtered to obtain aqueous extract (25% w/v). Fifty seeds of *A. retroflexus* and thirty seeds each of maize and green bean were treated separately in Petri dishes with 6-extract concentrations (from 0 to 25 % w/v) of mugwort. The Petri dishes were placed in a growth chamber and treatments were arranged in a completely randomised design with three replications. For the pot bioassay, plastic pots (5.5 cm dia_{max}, 3.7 cm dia_{min}, 5 cm depth) were filled with 65 ml of quartz sand, sowed individually with 4 seeds of maize and 30 seeds of *A. retroflexus* and treated with 6-extract concentrations (from 0 to 12.5% w/v) of mugwort. The pots were placed in a glasshouse in a completely randomised design with three replications. Germination percentage and the lengths of radicle and hypocotyl were determined in Petri dishes, whereas seedling emergence percentage and fresh and dry weights of plants were recorded in pots. Dose-response analysis was performed using a non-linear regression. Results showed that mugwort extract did not affect germination or the lengths of radicle and hypocotyl produced by maize and green bean, but strongly inhibited (up to 100% inhibition compared to control, with extract concentration starting from 10% w/v) seed germination and the lengths of radicle and hypocotyl produced by *A. retroflexus*; these results were confirmed by pot bioassays on emergence and weight of plants. This study supports practical use of mugwort extract to control *A. retroflexus* in maize and green bean.

Keywords: Allelopathy, seed germination, weeds, bioassays, Integrated weed management

The poster in a PDF version is available here.

Developing selection criteria for the identification of rice germplasm with superior weed-suppressive capacity (827)

Hanwen Ni *(China Agricultural University, Beijing, China),* ***Xiangrui Meng*** *(China Agricultural University, Beijing, China)*

Utilization of genetic variation in weed suppressiveness is one of the proposed weed control measures in rice. This genetic trait to suppress weeds may include an allelopathic capacity and a competitive ability. However, identifying suitable and effective germplasm that can be used for breeding for these traits requires effective selection criteria. In this paper, we proposed a standard for evaluating rice germplasm on the presence of a weed-suppressive ability based on allelopathy and weed competitiveness. Experimental results showed that there was a highly negative correlation between weed infestation intensity and weed-suppressive index composed of an allelopathy index and the growth rate of rice at an early stage. This result will be useful for breeding rice varieties with weed-suppressive capacities.

Keywords: Suppressive ability, competition, allelopathy, weed, rice

An allelopathic substance of *Aglaia odorata* Lour. leaf extracts (601)

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Aglaia odorata Lour. is a shrub species belonging to the family Meliaceae and distributed from Southern China to the Indochinese peninsula. Allelopathic potential of *A. odorata* has been studied for its potential use as a natural herbicide. Odorine isolated from ethyl acetate extracts of *A. odorata* leaves was reported as a putative allelopathic substance. However, the growth inhibitory activity of odorine was much weaker than that of ethyl acetate extracts of *A. odorata* leaves, suggesting possible presence of other putative allelopathic substances in *A. odorata* leaves. Thus, the current study was undertaken to evaluate allelopathic potential of *A. odorata* leaf extracts and to isolate and identify putative allelopathic substances. Results showed that the ethanol extracts of *A. odorata* leaves inhibited the coleoptile/hypocotyl and root growth of Italian ryegrass, timothy, barnyardgrass, cress, lettuce and alfalfa, wherein the level of inhibitions increased with increase in extract concentrations. The extracts were then partitioned with water and ethyl acetate. The ethyl acetate fraction was sequentially separated by several chromatographic runs, while the inhibitory activities of all fractions in each separation step were monitored and the active fractions were subjected to further separations. An active substance was finally purified by HPLC analysis and identified as 'rocaglaol' by mass spectrometry and nuclear magnetic resonance spectroscopy. Rocaglaol inhibited the coleoptile/hypocotyl and root growth of barnyardgrass and cress at concentrations greater than 0.03 μM. The concentrations of rocaglaol required for 50% growth inhibition on barnyardgrass coleoptiles and roots were 0.70 and 0.11 μM, respectively, and those on cress hypocotyls and roots were 0.057 and 0.64 μM, respectively. In conclusion, the ethanol extracts of *A. odorata* leaves possess allelopathic property. Rocaglaol isolated from *A. odorata* leaf extracts showed the potential to act as an allelopathic substance and may contribute to the growth inhibition properties of *A. odorata* leaf extracts.

Keywords: Allelopathy, *Aglaia odorata*, Rocaglaol

Allelopathic activity and growth inhibitory substances in *Cyathea lepifera* leaves (603)

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Cyathea lepifera Copel. is a tall tree fern belonging to the family of *Cyatheaceae* and distributed in the subtropical and tropical areas of East and Southeast Asia. The species is one of the dominant forest species in those areas. Allelopathic interaction of this fern with other species may explain this domination. However, there is no report on the study of allelopathic property of *C. lepifera*. The objectives of this study were the elucidation of the allelopathic activities of *C. lepifera* and the isolation of potential growth inhibitory substances causing this allelopathic activity. Aqueous methanol extracts of *C. lepifera* leaves inhibited the seedling growth of shoots and roots of cress (*Lepidium sativum* L.), lettuce (*Lactuca sativa* L.), alfalfa (*Medicago sativa* L.), Italian ryegrass (*Lolium multiflorum* Lam.), timothy (*Phleum pratense* L.) and barnyard grass (*Echinochloa crus-galli* (L.) Beauv.), and the increasing extract concentration increased the inhibition. This result suggests that *C. lepifera* leaves may have allelopathic activities and may possess growth inhibitory substances. The extracts were then separated by silica gel and Sephadex LH-20 columns, and C_{18} cartridges with monitoring inhibitory activity with cress bioassay, which is one of the most sensitive test plants. Two growth inhibitory substances were purified by HPLC. Both substances completely inhibited the seedling growth of cress hypocotyls and roots at the concentration of 2.0 g dry weight equivalent extract/mL, which concentration indicates that the extract obtained from 2.0 g *C. lepifera* leaves were contained in 1 mL of the assay solutions. The results suggest that leaves of *C. lepifera* may contain at least two growth inhibitory substances, and these growth inhibitory substances may play an important role in the contribution of the domination of the fern in those forests. These substances may work as allelopathic agents that can be used in weed control.

Keywords: Allelopathic activity, growth inhibitory substance, tree fern, *Cyathea lepifera*

Adaptive value biotypes of *Lolium multiflorum* L. susceptible and resistant to herbicide glyphosate (97)

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The ability for survival and reproduction determines a plant's adaptability, which depends primarily on its biological characteristics. Knowledge of these characteristics and the plant's bioecological behavior is vital to establish appropriate management strategies, especially towards the prevention and management of herbicide resistance. Glyphosate resistance in Italian ryegrass has become a serious problem in wheat production in the Rio Grande do Sul State, Brazil and the resistant biotypes appear to be as vigorous as the susceptible biotypes. This study hypothesizes that the resistant biotypes have an adaptive potential equal to that of a susceptible biotype. Adaptive potential was determined as a function of growth rate. The experiment was conducted in a greenhouse, following a factorial completely randomized design with four replications. The first factor included resistant (SVA 4 and PFU 5) and susceptible (SVA 2) biotypes, whereas the second factor consisted of different timings of sampling (20, 40, 60, 80, 100, 120, 140 and 160 days after emergence). The variables measured at each sampling were: plant height (HEI); number of tillers (NT); leaf area (LA), measured using a leaf-area meter; and, shoot dry matter (SDM), determined after drying the tissues in an oven at 60°C until constant weight. There was a significant biotype by sampling period interaction for HEI and NT. There was single effect biotypes and single effect periods for the variable LA and, single effect periods for SDM. The resistant and susceptible biotypes used in this study showed similar adaptive potential.

Keywords: Ryegrass, Glyphosate, Resistance, Adaptive value

Allelopathic activity and allelopathic active substances in the needles of dawn redwood (602)

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Hisashi Kato-Noguchi *(Faculty of Agriculture, Kagawa University, Miki, Kagawa, Japan)*

Dawn redwood (*Metasequoia glyptostroboides* Hu et Cheng) is one of the living fossil plants, which has not changed its characteristics for a long time since the Cretaceous period. The plant species may have some advantages to survival for long time, such as allelopathy which may improve the plant's ability to compete with neighboring plants. The objectives of this study were to evaluate the allelopathic activity of dawn redwood and to isolate allelopathically active substances in this species. Aqueous methanol extract of the needles of dawn redwood inhibited the growth of hypocotyls/coleoptiles and roots of cress (*Lepidium sativum* L.), lettuce (*Lactuca sativa* L.), alfalfa (*Medicago sativa* L.), Italian ryegrass (*Lolium multiflorum* Lam.), timothy (*Phleum pratense* L.) and barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.) to less than 25% that of controls at a concentration of 0.3 g dry weight equivalent extract/mL. The level of inhibition was dependent on the concentration of the extract and plant species tested. Results suggest that the extract may contain allelopathically active substances because the extract was subsequently partitioned using an equal volume of ethyl acetate. The ethyl acetate fraction was separated by columns of silica gel, Sephadex LH-20 and cartridges, and finally purified by reverse phase HPLC. Allelopathically active substances were eluted by HPLC at the retention times of 91, 98, 105, 106, 113, 122 and 132 min. Those substances inhibited hypocotyl and root growth of cress by less than 30% that of control. Results suggest that the needles of dawn redwood may contain at least seven allelopathically active substances, which may contribute to the allelopathic potential of dawn redwood.

Keywords: Allelopathy, growth inhibitory substances, *Metasequoia glyptostroboides*, dawn redwood

Allelopathic activities of *Actinidia deliciosa* root and leaf extracts (589)

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Kiwifruit (*Actinidia deliciosa* (A. Chev.) C.F. Liang *et* A.R. Ferguson) is a widely cultivated fruit tree in the world. The productivity of kiwifruit orchards gradually decline year-by-year after reaching the high productive age. Those aged trees are then replaced by young plants, but the growth of the young plants is typically poor when planted in the same land. It has been suspected that allelopathic substances of kiwifruit plants may accumulate in the soil and inhibit the growth of the new plantings. However, there is limited information concerning the allelopathic potential of kiwifruit plants. In this research, allelopathic activities of the aqueous methanol extracts of kiwifruit roots and leaves were evaluated using cress, lettuce, alfalfa, timothy, barnyardgrass and italian ryegrass as test species, using extract-concentrations of 1-300 mg dry weight equivalent extract/mL. At the concentration of 100 mg dry weight equivalent extract/mL, both root and leaf extracts inhibited the growth of hypocotyls/coleoptiles and roots of all test plants by less than 50% and 10% that of controls, respectively. Lettuce and alfalfa roots showed the highest sensitivity against the extracts. The level of inhibition was species-specific and increased with the concentration of the extract. In addition, it was found that the extracts also inhibited the growth of kiwifruit seedlings. Results suggest that kiwifruits may contain allelopathic substances, which may affect the growth of the replanted new young plants of kiwifruits.

Keywords: Allelopathy, kiwifruit, replant problem

Session 14
HERBICIDES AND APPLICATION TECHNOLOGY

REAPED – APPLY: Innovative technology for pre-emergence herbicide application to ratoon sugar cane (536)

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In the 2013-2014 harvest as a result of an innovative idea proposed by the company ADAMA and developed by the Research Institute of Sugarcane (INICA) and the Research Institute of Agricultural Engineering (IAgric) began to work on a new system application whose concept is based on timely and different from the usual time; The Reaped – Applied system consisting of an innovative methodology that takes advantage of the combine step for simultaneously applying pre-emergent herbicides in areas of sugarcane shoot. Thus, two operations are performed in a single pass, reducing the passage of machinery within the field, avoiding the increased risk of compaction. In addition, use of crop trash to cover and help herbicide soil moisture allows immediate action on the seeds of weeds. The fact that the harvest is in green and leave waste on the surface could be considered an ally to the action of the herbicide provided they remain covering the application. While the best opportunity to apply the pre-emergent herbicide during harvesting combine, there was not such technology, so that, was necessary to adapt an applicator to perform the operation without it being detrimental to the operation of harvesting equipment. This technology is implemented in actual field conditions from december 2014 on a squad of four harvesters KTP-2 in areas of „Uruguay“ sugar factory in Sancti Spiritus, Cuba, where they harvested and applied more than 490 hectares, yielding satisfactory results on weed control, coupled with high selectivity to sugarcane cultivars C90-317, C86-12, Co997, C86-56, CP52-43, B80250 and SP71-1406 as well as significant savings in inputs (herbicides, fuel and lubricants) and time.

Keywords: Technology, chemical control, weeds, sugarcane

Role of salicylic acid in regulating antioxidant defense system and related genes expression in *Oryza sativa* against quinclorac toxicity (225)

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The quinolinecarboxylic acid, a new class of highly selective auxin herbicide, is widely used in paddy rice. Quinclorac toxicity can cause severe damage to rice plants. Salicylic acid (SA), a phenolic compound, plays a critical role in plant defense responses against abiotic stress. A study investigated the effect of different concentrations (0, 0.1 and 0.5 g l^{-1}) of quinclorac on the physiological and biochemical changes of two rice cultivars (XS 134 and ZJ 88), and further analyzed the ameliorating role of SA in rice plants under quinclorac toxicity. Quinclorac toxicity induced inhibition in plant growth in both rice cultivars. Herbicide application increased the antioxidant activities (POD, APX, SOD and GSTs) while CAT activity was decreased. Moreover, GSH content was reduced while GSSG content was increased under herbicide toxicity. The accumulation of malondialdehyde (MDA) and reactive oxygen species (ROS) content were enhanced as we increased levels of quinclorac in solution media. Exogenously pretreated SA increased the plant biomass, enhanced the activities of antioxidant enzymes and reduced the MDA and ROS contents under quinclorac toxicity. Histochemical staining (NBT and DAB) and ultrastructural analysis further showed that higher concentration of quinclorac (0.5 g l^{-1}) damaged different plant organelles. Pretreatment of exogenous SA recovered the negative effects of quinclorac and further strengthen the plant organelles. This study also revealed that expression level of ethylene (*OsACSs*, *OsACOs*) and ABA (*OsABA8oxs*, *OsNCEDs*) pathway genes was enhanced under quinclorac stress. The transcript level of genes related to ethylene and ABA pathway were down regulated with pretreatment of SA under quinclorac stress conditions. Findings of the present study suggested that rice cultivar XS 134 was more resistant to quinclorac toxicity than ZJ 88 with respect to observed parameters.

Keywords: Salicylic acid, quinclorac stress, oxidative stress, OsACS genes, OsABA8ox genes

The poster in a PDF version is available here.

MCPA as ionic liquids with increased efficacy (693)

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MCPA (4-chloro-2-methylphenoxyacetic acid) is a well-known auxin-like herbicide for control of annual and perennial broadleaf weeds. It is still widely used in modern agriculture due to cost-effective and anti-resistant weed management strategies, mainly in cereal crops. The recommended doses range is from 0.6 to 1.2 kg ha^{-1} depending on the formulation. We synthesized ultra-low volatile herbicidal ionic liquids (HILs) based on MCPA: hexadecyltrimethylammonium 4-chloro-2-methylphenoxyacetate and trimethyloctadycylo-ammonium 4-chloro-2-methylphenoxyacetate. HILs are novel ionic liquids defined as organic compounds with a melting point below 100 C with some of the ions manifesting herbicidal activity [1]. Synthesized new HILs were characterized by ^{1}H and ^{13}C NMR spectroscopy and their efficacy was investigated under greenhouse and field conditions. The field experiments were conducted in spring barley using a randomized block design with four replications. The size of individual plot was 16.5 m^2. The applications were made at the end of tillering (BBCH 30) using a knapsack sprayer equipped with XR11003 flat-fan nozzle delivering 200 L ha^{-1} of spray solution. The HILs were applied at rates corresponding to 400 g ha^{-1} of MCPA. The results showed excellent efficacy for the new formulations of MCPA against many weed species including *Chenopodium album*, *Thlaspi arvense, Descurainia sophia and Cirsium arvense*. The efficacy of HILs were 20 – 88 % greater compared to the commercial formulation based on sodium and potassium salts. HIls with MCPA anion were selective to the spring barley plants.

[1] Pernak, J., Syguda, A., Janiszewska, D., Materna, K., Praczyk, T.: Ionic liquids with herbicidal anions. (2011) *Tetrahedron*, 67 (26), pp. 4838-4844

Keywords: Herbicidal ionic liquids, MCPA, efficacy, dicot weeds, spring barley

The poster in a PDF version is available here.

Broomrape (*Orobanche* spp.) control with some organic herbicides in sunflower (162)

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Broomrape (*Orobanche* spp.) is a major problem in sunflower fields in Turkey. Chemical control possibilities are very limited with Broomrape. In this study, the effect of some organic herbicides were evaluated to manage to Broomrapes. This research was conducted in the Research and Experimentation Fields of Plant Protection Department at Cukurova University, Adana-Turkey. The trial was conducted using a randomized plot design with four replications in the greenhouse previously infested by Broomrape. Clearfield sunflower was sown in pots. These plots were treated with one of ten different herbicide applications. The first application was imazamox (registered chemical for Broomrape control). Other replicated herbicide treatments were; acetic acid, citric acid, d-Limone, azadirachtin, parts of wild mustard, amino acid salt, isothiocyanate, corn gluten, clove and cinnamon oil. When Broomrape emerged on the soil surface, it was counted and recorded. Herbicides were applied as pre-sowing and post-emergence using recommended doses. Before and after the application of organic herbicides, Broomrape was counted and control was recorded at 1, 3, 5, 7, 14, and 28 d after application. Amino acid salt, which was applied both to the soil and on Broomrape was the most effective active ingredient in terms of density and dry weight of Broomrape. It could be recommended for organic sunflower farming where the broomrape is problematic.

Keywords: Broomrape, Sunflower, Organic Herbicides

Does microencapsulated caraway essential oil reduce weeds in maize? (209)

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The primary restriction in broader application of essential oils in agriculture is their volatilization, which reduces their biological potential. A way to potentially overcome this problem is through microencapsulation of essential oils, which consists of coating a micro-drop of essential oil with different solid compounds.
This experiment evaluated the effect of microencapsulation on inhibition of weeds in field conditions. For encapsulation, the essential oil of caraway (*Carum carvi* L.) was chosen as it exhibited strong inhibition of weed germination in series of laboratory experiments. A field research experiment was conducted to determine the effect of microencapsulated essential oil of caraway, applied to the soil in the form of maltodextrine or silica microcapsules on a weed infestation in maize. Weed infestation was evaluated at three terms including initial growth of maize (BBCH13-15), full vegetation (BBCH51-53) and maturity (at maize harvest) during 2014 and 2015. As a control treatments consisting of the microencapsulated carrier (with no herbicide) as well as herbicide treatment were included.
The effect of microencapsulated caraway oil was the most visible during the first month after application. Application of microencapsulated caraway oil resulted in a decreased number of selected weed species including *Cirsium arvense*, *Galinsoga parviflora*, *Agropyron repens*. At full vegetation of maize (BBCH51-53), weed control was diminished due to secondary weed infestation. By harvest, all microencapsulated treatments, including those with carrier only had significantly greater levels of overall weed infestation compared to the weed-free herbicide control. In summary, the application of microencapsulated essential oil of caraway provided weed control early in the season and may have potential for use as a natural herbicide.

Keywords: Natural herbicide, weed infestation, non-chemical weed protection

The poster in a PDF version is available here.

Control of volunteer corn (*Zea mays*) as influenced by nozzle type and adjuvants (538)

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Clethodim is an Acetyl CoA Carboxylase (ACCase) inhibitor and is primarily used for postemergence grass control in broadleaf crops and can be used in mixtures with different adjuvants. Non-ionic surfactants (NIS), crop oils concentrates (COC) or ammonium sulfate are recommended for use with clethodim. The objective of this study was to determine the influence of adjuvants, spray nozzles and carrier volumes with clethodim on the control of volunteer corn (Zea mays). Treatments were in a factorial arrangement with five tank solutions, three nozzles and two carrier volumes with a randomized complete block design with eight replications in two experimental runs. Clethodim was applied at 25 ae ha^{-1} alone or with one of the following adjuvants: COC at 3.33% v v^{-1}, NIS at 0.25% v v^{-1}, methylated seed oil (MSO) at 3.33% v v^{-1} or high surfactant oil concentrate (HSOC) at 1.67% v v^{-1}. The spray solutions were applied using an XR110015, AIXR110015 or TTI110015 spray nozzle at 276 kPa. The applications were made using single nozzle track sprayer at speeds 4.1 km h^{-1} and 8.2 km h^{-1} to achieve carrier volumes of 66 L ha^{-1} and 132 L ha^{-1}, respectively. Visual estimations of injury were collected at 28 days after treatment. Plants were severed at the base and dried for 72 hours at 65°C prior to recording dry weights. Results indicate control of the volunteer corn was greatest at 66 L ha^{-1} and nozzle selection did not influence control at this carrier volume. At 132 L ha^{-1}, control was highest using the AIXR nozzle. Control was highest with COC at 66 L ha^{-1} while MSO or HSOC provided the highest level of control at 132 L ha^{-1}. The data from this study will be useful to guide applicators attempting to control grass weeds in a broadleaf cropping systems.

Keywords: Clethodim, Herbicide applications, Carrier volume

The poster in a PDF version is available here.

Mineralization of mesotrione alone and mixed with S-metolachlor + terbuthylazine in Brazilian soils (104)

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Literature on herbicide behavior in soils is limited to individual studies on specific molecules. However, application of herbicide mixtures is a common with soil being the destination for a number of different herbicides. Bioaccessibility of a given herbicide is understood as the proportion of herbicide available immediately and potentially over time to organisms for further processes. Therefore, the objective of this study was to evaluate the mineralization of mesotrione alone and mixed with S-metolachlor + terbuthylazine applied to the Brazilian soils [Alfisol – Paleudult, sandy clay texture (sand: 46.6%, clay: 37.6% and silt: 15.8%) and Ultisol – Typic Hapludalf, sandy loam texture (sand: 81.6%, clay: 15.1% and silt: 3.3%)]. Soil treatments consisted of ^{14}C-mesotrione (150 g ai ha^{-1}) alone and combined with S-metolachlor (1,250 g ai ha^{-1}) and terbuthylazine (750 g ai ha^{-1}). 50 g soil (dry weight) was placed in each Bartha flask, and spiked with a mixture of mesotrione, water, and trace amounts of ^{14}C-mesotrione yielding a final concentration of 0.125 mg mesotrione kg^{-1} soil and a soil moisture content of ~75% of the water holding capacity and a radioactivity of ~1,000,000 dpm ^{14}C-mesotrione. Flasks were kept in an incubator at 20 ± 2°C for a period of 49 days. Mineralization was measured by placing a glass vial containing 1 mL 0.2 mol L^{-1} NaOH in each flask to collect the $^{14}CO_2$ produced at 7, 14, 21, 28, 35, 42 and 49 days after application, and measured by Liquid Scintillation Spectrometry. The highest half-life (DT50) values were observed in sandy loam soil at 28 and 32 d for mesotrione applied alone and mixed, respectively. In sandy clay soil, the DT50 was 17 and 18 d, respectively. The mineralization of mesotrione was influenced by soil texture but not by application with or without S-metolachlor + terbuthylazine.
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Keywords: Aerobic degradation, contrasting texture, half-life, weak acid

The poster in a PDF version is available here.

Abutilon theophrasti Med. sensitivity to topramezone and adjuvants combination (339)

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Maize is the most important crop in Croatia with production occurring on 400,000 ha (i.e. 35% of total arable land) in Croatia. Herbicide use totals 1,015,000 kg a.i. in Croatia with maize accounting for 370,000 kg a.i. In last two decades *Abutilon theophrasti* (ABUTH) become a very important weed in maize. Although ABUTH is relatively sensitive to topramezone, in some cases its absorption can be reduced due to leaf morphology (hair and epicuticular wax. The goal of this research was to determine the application rate of topramezone that results in 90% ABUTH growth reduction (GR_{90}). Topramezone was applied at 8.25; 16.5; 33, and 66 g a.i. ha^{-1} in combination with the following adjuvants: nonionic surfactant (NIS), crop oil concentrate (COC), methylated seed oil (MSO), urea ammonium nitrate (UAN), ammonium sulfate (AMS) and combinations thereof (NIS+UAN; NIS+AMS; COC+UAN; COC+AMS; MSO+UAN; MSO+AMS; UAN and AMS). A non-treated check was included for comparison purposes.
Abutilon theophrasti plants were grown under controlled conditions at the constant temperature of 25^0C:20^0C (day:night) with a photoperiod of 16:8 h (light:dark) and a relative humidity of 75%. All herbicide/adjuvant combinations were applied to ABUTH with four to six leaves. Plant shoots were harvested three weeks after treatment to determine biomass weight per pot.
An interaction between adjuvant system x topramezone application rate was present for ABUTH biomass. *Abutilon theophrasti* was sensitive to topramezone even at 33 g a.i. ha^{-1} applied alone. However, the addition of adjuvants to topramezone increased ABUTH control particularly when combinations of adjuvants were applied (COC+UAN; COC+AMS; MSO+AMS; NIS+UAN and NIS+AMS). The calculated topramezone application rate when applied with selected adjuvants required for 90% ABUTH dry matter reduction was lower than the half the normal topramezone application rate (33 g a.i. ha^{-1}) and ranged from 2.5 g a.i. ha^{-1} (MSO+AMS) to 21.5 g a.i. ha^{-1} (NIS).

Keywords: Topramezone, adjuvants, *Abutilon theophrasti*, maize

Influence of UAN as a carrier for herbicide application in corn (420)

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Carrier options are one of the most important factors to consider when addressing weed control with residual herbicides applied before maize emergence. Water is the main carrier for herbicide applications but applying herbicides and UAN (solution of urea and ammonium nitrate in water used as a fertiliser) at the same time as a tank mix for maize could be an optimal way to save time and ride across the field.
The aim of this research was to determine the influence of different carrier options (water and UAN) on the efficacy of herbicides contains dimethenamid-P, pendimethalin, S-metolachlor; terbuthylazine, mesotrione; isoxaflutol and thiencarbazon-methyl applied pre-emergence. Visual assessment and reduction of bioassay of weeds was determined as herbicide efficacy. Field trials were conducted using maize grown at the Brody Research and Education Station of Poznań University of Life Sciences. The soil type was luvisoil. Fertilisers and agronomic practices were applied according to State Soil Testing Laboratory recommendations. The trials were set up as complete, randomised block design with four replications.
There was no phytotoxicity observed on maize after herbicide treatments. The main weeds present in the untreated plots in all trials included Echinochloa cruss-galli, Chenopodium album, Viola arvensis, Geranium pusillum, Polygonum aviculare and Polygonum convolvulus. Results indicated similar weed control in all carrier options in wet year. However in dry year herbicide which contains dimethenamid-P, pendimethalin was more effective than others.

Keywords: Corn, uan, herbicide, herbicide carrier

The poster in a PDF version is available here.

Evaluation of herbicides and their mixture on weed control in maize in irrigated vertisols of Tamil Nadu (729)

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Maize is a versatile crop, having the highest yield potential among cereals, and is cultivated over a wide range of agro-climatic zones. Weeds can cause considerable yield loss due to competition for resources with maize in irrigated ecosystems of Tamil Nadu. Season long competition reduced the grain yield of maize by 70%. Presently, pre-emergence herbicides are used in larger area. However, subsequent flushes of weeds are not controlled as effectively as at the emergence stage. The objective of this research was to evaluate and identify suitable herbicide mixtures for early post-emergence weed management. A field experiment was conducted during *rabi*season of 2015-2016 at TNAU, Coimbatore, India, to evaluate tembotrione (420 SC) with and without surfactant against grassy and broadleaf weeds. The experiment was laid out in a randomized block design with three replications. Treatments comprised of herbicides *viz*., tembotrione, atrazine and 2,4-D dimethylamine salt evaluated alone at different doses and in combination with surfactants and other herbicides. Weed flora predominantly consisted of *Setariaverticillata*, *Dinebraretroflexa*, *Panicumjavanicum, Dactylocteniumaegyptium*and*Cynodondactylon, Trianthemaportulacastrum*, *Cleome gynandra*, *Digeraarvensis* and*Partheniumhysterophorus*among broad-leaved weeds and *Cyperusrotundus*the only sedge. At 30 DAS, total weed density and weed dry weight were significantly lower in early post-emergence application of tembotrione (420 SC) at 120 g a.i./ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i./ha with higher weed control efficiency of 82.5%, which was on par with pre-emergence application of atrazine at 500 g a.i./ha. It is concluded that the early post-emergence application of tembotrione (420 SC) at 120 g a.i./ha + surfactant at 1000 ml/ha + atrazine at 500 g a.i./ha at 2-4 leaf stages of weeds for higher weed control efficiency in irrigated maize.

Keywords: Irrigated Maize, Tembotrione, Herbicide Mixtures, Weed Density and Dry weight, Weed control efficiency

The poster in a PDF version is available here.

Efficacy of herbicides applied at reduced doses together with liquid fertilizer DAM 390 (264)

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The competitive effect of weeds is one of the most important factors affecting yield and quality parameters of winter wheat grain. The good strategy of herbicide protection is based on the optimization of application term and method of weed control.
The small-plot trial experiment with winter wheat was carried out to test effectiveness of reduced doses of herbicides (tribenuron-methyl+fluroxypyr; aminopyralid+florasulam; 2.4/D+aminopyralid+florasulam; iodosulfuron-methyl+2.4-D+mefenpyr-diethyl) applied in liquid nitrogenous fertilizer DAM 390 in years 2012-2013. The dose of herbicides applied in nitrogenous fertilizer DAM 390 was reduced to 80% of the recommended registration dose. Weed control was done at crop growth stage BBCH 29 (end of tillering). In the experiment, the assessment of the efficacy of herbicides, weed and crop aboveground biomass, yield and quality parameters of winter wheat grain were done. The intensity of nitrogen fertilization was chosen as another factor. Influence of nitrogen level on biomass of weeds was analysed. The reduction of herbicides dose rate applied in liquid fertilizer DAM 390 did not lead to the decrease of herbicides efficacy. Efficacy on weed control was excellent for all treatment for 28 days after application and fluctuated in the range 99-100%. Aboveground biomass of winter wheat was in both experimental years significantly higher in herbicide-treated variants in tank-mix with liquid fertilizer DAM 390. The increase of yield and improving the quality parameters of winter wheat was found for all herbicide treatments. Slightly higher yield and quality parameters always showed herbicidal treatment in tank-mix with liquid fertilizer DAM 390.
Application of herbicides in the basic mode of fertilization had a significant effect on increasing yield and grain quality parameters. Nitrogen fertilizer application secondary ensured a positive impact on further increasing yield and grain quality parameters of winter wheat. To ensure these results must be carry out appropriate agronomic measures.

Keywords: Herbicide, reduced doses, liquid nitrogen fertilizer, efficiency, biomass

The poster in a PDF version is available here.

Optimising efficacy of herbicides with multifunctional adjuvant formulations (371)

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Activator and utility adjuvants incorporated in the herbicide formulations or added to the spray mixture are used to overcome unfavorable factors responsible for herbicide retention, deposit formation, absorption and efficacy. However, a single-component adjuvant is not able to overcome all important factors responsible for herbicide efficacy and will not optimise herbicide performance under a wide range of environmental, application, and biological conditions. The aim of laboratory and field experiments was to search for surfactants, oils, fertilisers, humectants, and pH modifiers that act additively and/or synergistically in mixtures and incorporate the most effective compounds in multi-component adjuvant formulations. Several thermostable, homogenous, and convenient-to-use multi-component liquid adjuvant for tank-mix and herbicide-build-in formulations were invented. These formulations were tested in greenhouse and field experiments for efficacy of postemergence and/or preemergence herbicides.
AS 500 SL adjuvant formulation was developed for herbicides containing glyphosate, 2,4-D, MCPA, dicamba and bentazon. This adjuvant formulation includes ammonium sulphate, cationic surfactant, and pH buffer. Glyphosate efficacy applied in hard water with this adjuvant was higher than the solid ammonium sulphate fertiliser and was significantly more efficacious than the commercial fatty amine ethoxylate surfactant. A new BGT® glyphosate formulation with incorporated multifunctional adjuvant system showed high and consistent efficacy in various environment even when was applied at significantly reduced rates. Atpolan BIO 80 EC was developed for herbicides that require an oil-based adjuvant. It contains modified oil blend with anionic and cationic surfactants and a basic-pH adjuster that has superior herbicide-solubilizing properties responsible for increased efficacy of sulfonylurea herbicides. To optimize soil applied herbicides Atpolan Soil Maxx was developed. It is based on various oil and surfactant mixture that provided uniform spreading of spray droplets on the soil surface, accurate distribution of herbicide in the upper layer of soil, decreased leaching by rain and enhanced efficacy of metazachlor and clomazone.

Keywords: Herbicide, adjuvant, formulation

The poster in a PDF version is available here.

Quinate as a potential glyphosate-enhancer in the control of *Amaranthus palmeri* (576)

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Quinate is a secondary compound synthesized in a lateral branch of the shikimate pathway, which is accumulated in plants after treatment with glyphosate. Glyphosate functions by inhibiting the enzyme 5-enolpyruvylshikimate-3-phosphate synthase in the biosynthetic pathway of aromatic amino acids (AAA) (the shikimate pathway). *Amaranthus palmeri* is an important weed in many crops and usually controlled by glyphosate in glyphosate-resistant crops. The objective of this study was to ascertain if glyphosate efficacy on *A. palmeri* could be enhanced with quinate spray, thus leading to a lower rate of herbicide use. *Amaranthus palmeri* seed from North Carolina (U.S) were planted in aerated hydroponic culture under controlled conditions and sprayed with glyphosate (0.25 times recommended field rate) and/or quinate at two different times including: quinate application two days before glyphosate application or simultaneous application of both compounds. *Amaranthus palmeri* plants were harvested 3 days after the last treatment. Shikimate accumulation in leaves was used as the marker of the herbicide toxicity. When quinate was applied before glyphosate, an alleviation glyphosate toxicity was observed as shikimate accumulation was less evident in plants treated with both compounds than in plants treated with glyphosate alone. The higher content of AAA observed at the time glyphosate application (two days after the application of quinate), could be the reason for the alleviation of glyphosate toxicity. When quinate and glyphosate were applied simultaneously, no attenuation was detected. Shikimate accumulation was higher when both quinate and glyphosate were applied together than when glyphosate was applied alone. These results suggest that application of quinate with glyphosate may be used to enhance glyphosate efficacy.

Keywords: Quinate, Glyphosate, Amaranthus palmeri, herbicide enhancer

The poster in a PDF version is available here.

Interference of ACCase-inhibitor herbicides used to burndown of glyphosate-resistant ryegrass (*Lolium multiflorum* L.) on irrigated rice cultivated in succession (256)

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Minimum tillage is used in 70% of irrigated rice fields in the southern Brazil. Ryegrass (*Lolium multiflorum* L.) is the main cover crop in this system, predominant in more than 50% of the fields. This cover crop is normally desiccated with glyphosate, but with the appearing of glyphosate-resistant biotypes, farmers have used herbicides with other mechanisms-of-action, such as the ACCase-inhibitors. The objective of this research was to identify the time required between the application of ACCase-inhibitors and the rice sowing, in order to avoid toxicity to the crop by herbicide carryover. The experiment (designed as a randomized block with five replicates per treatment) was conducted in the Experimental Station Lowlands of Embrapa, Capão do Leão, Brazil, in the 2014 crop season. The soil is an Albaqualf with 17% of clay, 1.2% of organic matter and pH H_2O 5.6. Herbicides were applied at -14, -6, -1 and +6 days in relation to rice seeding (DRS) with haloxyfop-methyl and -14 and -6 DRS with clethodim or -14 DRS with sethoxydim plus glyphosate. At 30 days after rice emergence (DAE), penoxsulam was applied to control the escaped weeds. The cultivar BRS Pampa was dry-seeded at 350 seeds m^2 in rows spaced 17 cm apart and surface-irrigated at 35 DAE. Data collected were phytotoxicity at 10 DAE, biomass and number of culms at 23, 51 and 120 DAE, spikelet sterility, plant height and grain yield at harvest. The ACCase herbicides tested reduced the number of culms up to 52% and the rice biomass rice by 62%, even with applications 14 days before rice sowing. This study suggests that there is a minimum 14 d interval needed between the application of ACCase-inhibitors in glyphosate-resistant ryegrass and the sowing of rice in minimum tillage, to prevent phytotoxicity of herbicides to the crop.

Keywords: Carryover, herbicide resistance, minimum tillage, phytotoxicity

Progression of injury development following tomato (*Solanum lycopersicum*) exposure to simulated drift rates of 2,4-D and glyphosate (442)

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Farmers in the USA corn-belt increasingly use 2,4-D to control an explosion of glyphosate-resistant weeds. To date increased use has been pre-plant application to emerged weeds and some post-emergence use in corn. Adoption of genetically engineered crops with tolerance to 2,4-D will result in further increased use and major geographic shifts in where the herbicide is used. These trends are resulting in more sensitive crop injury because of 2,4-D drift. Our goal is to improve knowledge of disease progression following sensitive crop exposure to 2,4-D and glyphosate drift so that professionals can better advise farmers. 'Early Girl' (tomato) *Solanum lycopersicum* plants were treated with 0.3, 1 and 3% of the field dose (520 g ae/ha) of 2,4-D plus/ or identical proportions of the field dose of glyphosate (1260 g ae/ha) in water (200 L/ha), using TTJ60-11002 nozzles (267 kPa) on a moving track (10 kph) laboratory sprayer. Plants were greenhouse reared. Crop injury was assessed visually; plant height and dry weight, number of racemes, fruit number, fruit shape and yield were measured. Data were analyzed in SAS using PROC GLM. A common effect of both herbicides was reduction in growth/ or necrosis of the main stem followed by increased growth of low-dry-matter axillary shoots. Response to 2,4-D or 2,4-D plus glyphosate varied considerably between experiments, ranging from epinasty and adventitious root formation along the stem (2 experiments), to nearly complete foliar necrosis and plant death in a third. Variable response to glyphosate ranged from basal chlorotic bands in newly expanding leaf tissue (2 experiments) to effects that mostly mimicked 2,4-D in the third. 2,4-D was more injurious that glyphosate; visual assessment generated mean rankings ranging from a low of 15% with 0.3% field dose to 90% with 3% field dose. Glyphosate applied with 2,4-D generally enhanced injury expression of 2,4-D-typical symptoms.

Keywords: 2,4-D, glyphosate, drift, tomato, crop injury

The poster in a PDF version is available here.

Response of common lambsquarters (*Chenopodium album*) to various glyphosate formulations (495)

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Common lambsquarters (*Chenopodium album L.*) is a summer annual weed native to Europe and Asia and is recognized worldwide as one of the most problematic weeds in agriculture. The main challenges for postemergence herbicide efficacy on common lambsquarters is wettability and foliar uptake because of the epicuticular wax on the plant leaves. The cuticle has chemical substances called aldehydes that represent a barrier for water-soluble herbicides. Surfactants may improve herbicide efficacy by reducing surface tension, therefore increasing the wettability and subsequent herbicide uptake. The objective of this study was to evaluate the efficacy of different glyphosate formulations or different concentrations of nonionic surfactant (NIS) with a glyphosate formulation that does not contain surfactants on common lambsquarters control. Potassium and isopropylamine salt glyphosate formulations along with different rates of NIS were applied to 30 cm tall common lambsquarters plants at 420 g ae ha^{-1}. Applications were made using a single nozzle track sprayer calibrated to deliver 94 L ha^{-1} with a Teejet AI95015EVS nozzle at 414 kPa. Visual estimations of injury and above ground biomass were recorded 28 days after treatment. The experiment was conducted twice in a randomized complete block design with 11 different glyphosate based treatments: untreated control, potassium salt 1 (no adjuvants in the formulation) +NIS at different rates (0, 0.125, 0. 25, 0.5 and 1 % v v^{-1}), two potassium salt formulations with surfactants, and three isopropylamine salt formulations with surfactants. Each treatment had 10 replications (individual plants) and data were analyzed using analysis of variance. Results indicate that the addition of NIS is necessary for glyphosate efficacy on common lambsquarters. Glyphosate formulations that had NIS in the formulations provided satisfactory control of common lambsquarters. Interactions between the herbicide formulation, adjuvants and the leaf surface are key factors for a successful weed control.

Keywords: Integrated weed management, Adjuvants, Nonionic surfactant, Efficacy

The poster in a PDF version is available here.

Efficacy of glyphosate and glufosinate-ammonium on *Lolium multiflorum* as affected by temperature (410)

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Contrasting evidence exists in published literature regarding optimum temperatures for efficient action of glyphosate and glufosinate-ammonium. Based on data from previous research, optimum temperature for maximum efficacy of both herbicides may be species dependent.Therefore, the objective of this study was to determine the optimal temperature for maximum efficacy of glyphosate and glufosinate-ammonium on *Lolium multiflorum,* a major problem weed in the Mediterranean area of South Africa.

Lolium multiflorum seedlings were grown in four greenhouses with night/day temperatures of 10/15, 15/20, 20/25 and 25/30 ºC respectively. Six dosage levels of glyphosate (0, 400, 800, 1200, 1600 and 2000 ml ha^{-1} of 360 g ai L^{-1} formulation) and six dosage levels of glufosinate-ammonium (0, 1500, 3000, 4500, 6000 and 7500 ml ha^{-1}) was applied to *Lolium multiflorum* seedlings in two separate experiments at the 6-10 leaf stage. Herbicides were applied using a pneumatic pot spraying apparatus with an operating pressure of 2 bar and application volume of 100 and 200 L ha^{-1} of water for the glyphosate and glufosinate-ammonium, respectively. Evaluations were carried out 6 weeks after application and the percentage control was calculated. Analysis of variance (two-way) was conducted using the Statistica 12 statistical package.

The two herbicides exhibited quite similar results. In both cases, a significant ($P < 0.01$) interaction between dosage rate and temperature was present. For both herbicides, the lower dosage rates of each herbicide performed worse when *Lolium multiflorum* was grown at the lowest temperature of 10/15 ºC compared to *Lolium multiflorum* grown at 15/20 and 20/25 ºC. Efficacy of glyphosate and glufosinate-ammonium on *Lolium multiflorum* declined significantly when grown at 25/30 ºC.

It therefore appears as if both herbicides performs optimally on *L. multiflorum* at temperatures ranging from 15 to 25 ºC whilst they performed poorer at the lowest and the highest temperatures.

Keywords: *Lolium multiflorum*, glyphosate, glufosinate ammonium, efficacy, temperature

The poster in a PDF version is available here.

Trifloxysulsuron sodium GD 75, enhancer of glyphosate LS 48 for problem weed control in sugarcane (547)

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The objective of this research was to identify new options to reduce the time of Glifosato's application and control of the weeds. Glifosato LS 48's effect was evaluated to 3 L ha^{-1} in mixture with trifloxysulfuron-sodium GD 75 (Envoke**)** to 0.02 kg ha^{-1} as compared with the traditional treatment of Glifosato at 5 L ha^{-1} and Regulux to 0.30 L ha^{-1}. The studies were done in commercial sugar cane plantations units Andrés Cueva and Cartagena, belonging to the sugarcane company Arquímedes Colina on September 5. The treatments were established in strips with 64 m^2 sampling stations. Glifosato LS 48's treatment at 3 L ha^{-1} with trifloxysulfuron-sodium GD 75 at 0.02 kg ha^{-1} in area without sugarcane resulted in superior control compared to the Glifosato's standard treatment for control of *Cynodon dactylon, Sorghum halepense, Ipomoea trífida, Echinochloa colona, Digitaria adscendens, Dichanthium annulatum* and *Rhynchosia minima* and other annual weeds like *Rottboellia conchinchinensis* that were completely controlled, with a reduction of d of control, cost and dose. The evaluated treatment had higher control of dicotyledonous and monocotyledonous plants, that escape the Glifosato treatment.

Keywords: Weedses, herbicides, sugar cane

Results of the use of Break-Thru LS 100 as an adjuvant in the effectiveness of weed control in sugarcane in Cuba (533)

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The objective of this work was to evaluate the effectiveness of adjuvant Break-Thru LS 100, at doses between 0.5 and 0.8 L ha^{-1}, postemergence treatments with herbicides *Glufosinate ammonium* (Finale LS 15) to 2.0 L ha^{-1} and *Paraquat* standard LS 20 to 2 L ha^{-1} in controlling *Dichanthium annulatum, Sorghum halepense, Ipomoea trifida, Rottboellia cochinchinensis, Desmodium canum, Cynodon dactylon, Euphorbia heterophyll*a and *Echinochloa colona*. The work was conducted in several provinces of Cuba. Every 15 days the emerging post effect and phytotoxicity to sugar cane was evaluated. The data were processed statistically using analysis of variance, after processing, and multiple range test of Duncan when there were significant differences at 0.05 probability of error. The results showed that the mixture of *Glufosinate ammonium* LS 15 to 2 L ha^{-1} + Break-Thru LS 100 to 0.08 L ha^{-1} has performed better control over weeds evaluated at 15 and 30 days after application. *Paraquat* mixed with Break Thru makes control of weeds present between slightly higher to similar to standards of *Paraquat* mixed with Agrotin surfactant to 0.25 L ha^{-1} and final solution between 250 and 200 L ha^{-1}, was observed, thus replacing a dose of Agrotin of 4 to 5 times higher than with a lower end solution in 50 L ha^{-1}.

Keywords: Adjuvant, effectiveness, weed control, sugarcane

Response of fall panicum (*Panicum dichotomiflorum*) populations to asulam (796)

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Fall panicum (*Panicum dichotomiflorum*) is a troublesome annual grass weed associated with sugarcane production in Florida. Sugarcane growers in Florida rely on asulam for postemergence control of annual grasses including fall panicum. However, many sugarcane growers have recently observed reduced control of fall panicum with asulam. Greenhouse studies were conducted at the University of Florida in Gainesville in 2015 to determine the sensitivity of fall panicum populations to asulam using a dose response bioassay. Fall panicum seeds from four populations from sugarcane fields in Florida (EREC, PPI, Okeelanta, and Tecan) and a population from Azlin, Mississippi were planted and treated with asulam 46 days after planting in the greenhouse under natural light conditions. Seeds from Azlin were from a population that had never been treated with or exposed to asulam. Asulam was applied at 0, 0.231, 0.463, 0.925, 1.85, 3.7, 7.4, and 14.8 kg ha^{-1} which represent 1/16X to 4X sugarcane labeled use rates. Overall, fall panicum aboveground dry weight decreased as asulam rates increased 28 days after treatment for all populations. A four-parameter log-logistic model was used to determine the rate of asulam required to cause 50% fall panicum growth reduction (GR_{50}) based on aboveground dry biomass at 28 days after treatment. Sensitivity of EREC, PPI, Okeelanta, and Tecan populations to asulam was 1.1, 1.2, 1.5, and 1.4 fold more, respectively when compared to the Azlin population using GR_{50} values for the populations. The probability of fall panicum resprouting 14 days after harvesting aboveground biomass at the 1X use rate of asulam (3.7 kg ha^{-1}) was predicted to be 0, 2, 0, 1, and 7% for Azlin, EREC, PPI, Okeelanta, and Tecan populations, respectively. These results indicate that there was differential sensitivity of fall panicum populations to asulam.

Keywords: Postemergence, Control, Asulam, Sugarcane

The poster in a PDF version is available here.

Controlling broomrape in tomato with rimsulfuron (699)

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Tomato is one of the main crops in the Canakkale Province of Turkey. Broomrape (*Pheliphance ramosa*) infests almost all production areas in the province. Farmers in this region typically use rimsulfuron to control broomrape. A field experiment conducted in 2015 to determine the most effective application method of rimsulfuron. Rimsulfuron was sprayed on tomato plants at 15 or 15 and 25 days after planting. Chemigation applications were applied once (15 DAP), twice (15 and 25 or 15 and 30 DAP), or three times (15 DAP, 25 and 35 DAP or 15, 30, and 45 DAP). Experiments were conducted using a RCBD with five replications which included a no application check plot. The effect of rimsulfuron on broomrape was determined by counting the number of infested tomato plants per plot, which had 10 tomatoes each, and the number of broomrape shoots per plant. Broomrape emergence occurred following all treatments; however, significant differences in broomrape emergence due to treatment were observed. Rimsulfuron applied three times at 15, 25, and 35 DAP resulted in reduced number of infested tomato plants followed by three rimsulfuron applications which were made at 15, 30, and 45 DAP and one application of rimsulfuron at 15 DAP. The lowest number of broomrape shoots were observed following three application of rimsulfuron via chemigation at 15, 30, and 45 DAP. Tomato yield and yield component data as well as tomato quality data are currently being analyzed.

Keywords: Tomato, *Pheliphance ramosa*, chemigation, rimsulfuron

An *in vitro* system for predicting herbicide subcellular partitioning (818)

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A complete understanding of herbicide chemical properties is essential to predict their behavior in plants. Herbicides must pass one or more membranes to reach their target enzyme, and therefore the process by which a herbicide crosses a membrane will partially determine its effectiveness. Small molecule diffusion and subcellular partitioning is extremely difficult to study *in vivo*. In an attempt to increase the tools to study passive herbicide movement, we have modified a three-phase partitioning system that mimics biological semipermeable membranes, allowing us to study and measure compartment partitioning. Additionally, we are able to empirically measure important chemical phenomena such as acid trapping, concentration based diffusion, and hydrophobicity. This system is also able to predict the effectiveness of additional apoplast acidification for any given herbicide and whether minor changes in pH will affect herbicide diffusion. To test our apparatus, we studied clopyralid, sulfentrazone, 2,4-D, and glyphosate. These four herbicides vary substantially for pKa and K_{ow} and therefore are a robust test of our apparatus and its capabilities. For the most part, our four herbicides partition predictably based on their pKa and K_{ow}; however, we were able to detect a higher affinity for the organic layer for 2,4-D when it is protonated then initially predicted. Our findings illustrate the value of our system to provide useful and novel information about herbicide subcellular behavior.

Keywords: Herbicide Diffusion, Acid Trapping, Clopyralid, 2,4 D, Glyphosate

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Control of blackgrass (*Alopecurus myosuroides*) according to an increasing occurrence of resistance – Evaluation of field trials in the states Brandenburg, Hessen, Saxony, Saxony-Anhalt and Thuringia in the years 2000–2014 (786)

Ewa Meinlschmidt *(Saxon state office for environment, agriculture and geology, Nossen, Germany),* ***Christine Tümmler*** *(Brandenburg state office for agriculture, Zossen, Germany),* ***Heiko Schmalstieg*** *(State office for plant protection, Berlin, Germany)*

An increasing occurence of blackgrass at high densities has been reported for the Brandenburg, Hessen, Saxony-Anhalt, Saxony and Thuringia. In recent years, an increasing resistance to *Alopecurus myosuroides* especially to ALS-inhibiting herbicides resistance and partial to ACCase inhibiting herbicides has been reported for some eastern federal states and Hessen. The locations with confirmed ALS and ACCase resistance from 2010 to 2014 for four federal states are shown and the reasons for the resistance (crop rotation, non-ploughing soil tillage) are discussed. It was determined to what extent dicotyledonous and monocotyledonus weeds are associated with *A. myosuroides*. The efficacy of different herbicide applications was tested in field trials between 2000 and 2014. Using the HRAC-classification of herbicides tested, combinations of herbicides were formed which might help solve problems specifically linked to the detected resistances. The study investigated the right timing of the herbicide applications as well as applications in single or sequential treatments. In the autumn, single applications of soil active herbicides (flufenacet, pendimethalin, prosulfocarb, chloroluron) were not effective, especially at high densities (more than 500 heads of *A. myosuroides* per m²). The mixtures of soil active herbicides with foliar applied herbicides (flupyrsulfuron, mesosulfuron, pyroxsulam, pinoxaden, clodinafop) applied on the autumn achieved control. The herbicide sequences (flufenacet in autumn / mesosulfuron or fenoxaprop or pinoxaden in spring) were more effective than single applications. They achieved an efficacy of 97% or more. In this case the density of *A. myosuroides* (seed heads/m²) has no impact on efficacy. In order to counter further spread of herbicide resistance, the right choice of mode-of-action and highly efficacious herbicide treatments are the methods of choice, and non-chemical control measures such as delayed autumn drilling, ploughing and crop rotation.

Keywords: Anti-resistance management, frequency of weeds, herbicide efficacy, herbicide resistance, field trials

The poster in a PDF version is available here.

Absorption and translocation of diuron in sugarcane (810)

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Studies on absorption and translocation of herbicide in plants may be performed by analyzing their radiolabeled molecule accumulation in different parts of the plant. In the traditional sugarcane cultivation, one of the most widely used herbicide is diuron which is effective in controlling weeds and presents low potential to leach into the soil. The objective of this study was to determine the effect of diuron applied pre-emergence in the early development of three cultivars (RB867515, RB975157 and RB985476), and its absorption and translocation (radiolabeled diuron). The minicuttings were planted in pots filled with Dusky Red Latosol soil. The design of the experiment was completely randomized with three repetitions. The first assay was conducted at the Center for Agricultural Sciences (CCA) of Federal University of São Carlos (UFSCar), in Araras/São Paulo/Brazil. The commercial diuron was applied at doses of 0, 1.6, 3.2 and 6.4 kg ai ha^{-1}, and the pots were kept in the greenhouse. Phytotoxicity assessments at 7, 15, 30, 45, 60 and 90 d after emergence (DAE). The results demonstrated that the herbicide caused no negative effects on plants through 90 DAE. The second assay was conducted in Ecotoxicology Laboratory of the Center for Nuclear Energy in Agriculture (CENA/USP), in Piracicaba/São Paulo/Brazil. The surface layer of the soil received ^{14}C-diuron, and evaluated the absorption and translocation of the herbicide by plants through quantification of herbicide in the wash water, soil and plant (shoots, roots and stem). The evaluation periods were 5, 10, 15, 20 and 25 DAE. The results showed that the absorption and translocation among cultivars was very low and the product was retained on the ground. However, cultivating RB975157 showed comparatively higher amounts of herbicide translocates the minicuttings.

Keywords: Sensitivity, phytotoxicity, radiolabeled

The poster in a PDF version is available here.

Response of two maize lines to foramsulfuron (207)

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Stress tolerance lies in high activity of defence systems, including antioxidative systems. The role of antioxidants is one of the most important in detoxication systems. They scavenge free radicals produced by xenobiotics or other stress produced compounds. Alteration in their content could be an important tool for better understanding of herbicide detoxication. The aim of this study was to examine changes in fresh biomass and dry biomass accumulation in two maize lines and their correlation with changes in antioxidants. Based on previous research, the reaction of sensitive- and tolerant-maize lines to increased doses of foramsulfuron was followed in controlled conditions. Two maize lines were grown in germination room in pots. Foramsulfuron was applied in cabinet sprayer on four leaves plants, in following doses: 0, 23, 45 (recommend field dose), 90, 135, and 180 g ai ha^{-1}. After application plants were returned to the germination room. After 7 d, fresh biomass and dry biomass accumulation were measured. The content of soluble proteins, phenolics, thiolic groups and phitic acid were determined from dry leaves. Dose response analysis was performed using R statistics, while contents of biochemical parameters were analysed with regression analyses. According to changes in fresh and dry matter content, the tolerant maize line was 2.3 times more tolerant than sensitive line. Increasing the herbicide dose increased soluble proteins, thiolic groups and phytic, as well as decrease insoluble phenolics in the sensitive line, while in tolerant line no correlations were observed. Also, the tolerant line had twice as much phytic acid. Results indicated that tolerant maize line is able to maintain antioxidative capacity present in slight variation of analysed antioxidants compared to the sensitive one.

Keywords: Maize lines, foramsulfuron

The poster in a PDF version is available here.

Diagnosis and causes of sunflower injury by herbicides (507)

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Sunflower is very sensitive to most of herbicides. Selectivity of most of pre-emergent soil active herbicides to sunflower is achieved by different herbicide placement. Intensive precipitation after application of this herbicides lead to leaching and injury of young plants sunflower. Intensity of herbicide leaching depends on soil structure and sorption capacity, physical and chemical characteristics of herbicide and weather conditions. Phytotoxicity caused by oxyfluorfen is affected also by size of raindrops bouncing from the soil surface, which contaminated leaves and caused necrosis and leaf deformation. Symptoms of sunflower phytotoxicity caused by acetamide herbicides are growth retardation and abbreviation of firsts node distance. Leaf bleaching of sunflower is typical for flurochloridone and leaf necroses is common after application of oxyfluorfen and PS II inhibitors (mainly used linuron). Callus at base of stem is common after application of pendimethalin, especially on skeleton or non structural soil.
In herbicide tolerant (HT) sunflower hybrids (Clearfield or ExpressSun technology), some ALS inhibitors are recommended for post-emergent weed control. Sensitivity of some HT hybrids may be lower, especially at rain-cold weather. Stems or flower-heads deformations and leaves pucker are typical symptoms of this sunflower phytotoxicity. Same symptoms may occur at conventional hybrids, which were affected by run off herbicide from neighbouring crop or by residua of ALS inhibitors at sprayer or at soil.
Growth regulator herbicides, especially phenoxyacids formulated as esters are relatively very volatile and there are very often damages of neighbouring crops. Sunflower is very sensitive to these herbicides. The main symptoms of phytotoxicity are leaf and stem twisting, leaf deformations, elongations, abnormal growth, production of calluses or tumours at stem tops. Consequently, meristem chloroses occur together with willing and necroses.
Also, glyphosate can injure sunflower at relative low rates. The symptoms of phytotoxicity are similar as at ALS inhibitors, only effect of glyphosate is usually faster.

Keywords: Herbicides, sunflower, phytotoxicity, environmental conditions

The poster in a PDF version is available here.

Barren brome (*Bromus sterilis* L.) control with herbicides in winter wheat in Poland (491)

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In Poland winter wheat are cultivated with an average amount of sown area about 1.8 million hectares for the years 2003-2013, it is above 17% the total sown area of agricultural land. The aim of the study was to evaluate *Bromus sterilis* control with different herbicides in winter wheat.
The study was divided into two different experiments: field and glasshouse. The field experiment was conducted in a winter wheat plantation established in Experimental Station in Baborówko (2012-2014). Herbicide treatments in the field experiment were applied in spring, after the beginning of winter wheat vegetation. The glasshouse experiment was carried out at the Institute of Plant Protection (2013-2015). In the glasshouse experiment herbicides were used in both – pre-emergence and post-emergence *Bromus* plants. In the post-emergence *Bromus* plants herbicides were applied in two different growth stages of *Bromus* plants: in 1-2 leaf stage (BBCH 11-12) and the initial tillering growth stage (BBCH 22-24). The herbicides were applied on their own or in tank-mixtures. Fresh and dry mass of *Bromus sterilis* in all trials was investigated 6 weeks after the herbicide treatment. In the field experiment seed yield of winter wheat was taken each year from one square meter of each plot.
In the field experiment the yields reduction on the wheat monoculture plots infestation by *Bromus* was significantly lower than the crop-rotation plots about 80%. In the field experiment result showed the highest efficiency of *Bromus* control and winter wheat yield was the highest when used propoxycarbazone-sodium + sulfosulfuron. In the glasshouse experiment highest reduction mass of *Bromus* plants was obtained after the application: propoxycarbazone-sodium, pyroxsulam, and mixture propoxycarbazone-sodium + sulfosulfuron, iodosulfuron-methyl-sodium + mesosulfuron-methyl and diflufenican + mesosulfuron-methyl + iodosulfuron-methyl-sodium. Other herbicides were less effective or not effective for brome grass control.

Keywords: Bromus sterilis, Barren brome, weed management, herbicides, winter wheat

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Session 15
NON-CHEMICAL WEED CONTROL TOOLS

Response of weed flora to different crop management practices in long-term period (573)

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Crop management practices are being developed all the time. An understanding of changes in the weed flora can provide new knowledge and help to evaluate and improve the associated cropping practices. The objective of our study was to determine the influence of crop rotation and fertilizer system on weed density and weed species diversity. The long-term trial was located at State Priekuli Plant Breeding Institute in Latvia (57°19′ N, 25°20′ E). Crop rotations: 1) spring cereals-potatoes-spring cereals; 2) spring cereals-forage-winter cereals-potatoes; 3) spring cereals-forage-spring cereals-winter cereals-spring cereals-potatoes; 4) spring cereals-forage-potatoes; 5) spring cereals-forage-forage-winter cereals-spring cereals-potatoes. Fertilizer systems: 1) unfertilized; 2) animal manure; 3) N66P90K135; 4) animal manure + N66P90K135; 5) N132P180K270; 6) straw + N66P90K135. Early summer arable weed data were collected in 22 years between 1973 and 2009. Data were analyzed using descriptive statistics and general linear model (GLM). GLM analysis included weed density and species diversity as dependent variables and crop rotation, fertilization system, weather conditions and soil chemical characteristics (pH, organic matter, P2O5, K2O) as factors. Crop rotation had a significant impact on weed density, as well as on annual and perennial weed species diversity. The explained variation by crop rotation was 13.1%, for the weed density, and 4.8 and 7.6% for annual and perennial weed species diversity. The explained variation by fertilizer system was 12.1%, 14.6% and 6.7% for total, annual and perennial weed density, and 23.6%, 32.9% and 4.4% for total, annual and perennial species diversity. Impact of interaction of crop rotation and fertilizer system on weed flora was not significant. Precipitation and air temperature had greater impact on weed density than on weed species structure; higher explanation of variation was found for the perennial weed flora. The results are applicable to areas that have similar environmental conditions as they were at the investigation site.

Keywords: Weed density, weed diversity, crop rotation, fertilizer, long-term

The poster in a PDF version is available here.

Common oat (*Avena sativa*) as a cover crop in potato production (323)

Hadar Kuzikaro *(Faculty of Agriculture, Food & Environment, The Hebrew University of Jerusalem, Rehovot, Israel),* ***Yaakov Goldwasser*** *(Faculty of Agriculture, Food & Environment, The Hebrew University of Jerusalem, Rehovot, Israel),* ***Gil Eshel*** *(Ministry of Agriculture and Rural Development, Bet-Dagan, Israel),* ***Rubin Baruch*** *(Faculty of Agriculture, Food & Environment, The Hebrew University of Jerusalem, Rehovot, Israel)*

Cover crops (CCs) are used as a management practice in orchards, vegetables and field crops due to their multiple agronomic beneficial aspects. CCs suppress weeds through competition for light, water and nutrients and by the exudation of allelopathic toxins. CCs reduce soil erosion and water runoff, by shielding the soil from the raindrops impact. The aims of this study were to examine the effect of common oat CC on soil temperatures, weed infestation and potato yields. The experiment was conducted in 2014-2015 on four Hamra soils (Typic Rhodoxeralfs): sandy to sandy loam soil adjacent plots, 7 ha in total, in the central Mediterraneancoastal plain of Israel. Common oat CC was seeded on beds on half of each plot and the second half was managed according to the common conventional practice on ridges (CR) without CCs. CCs were terminated before potato seeding (var. Sifra) using glyphosate. Weed and CC counts and determination of foliage weight were performed periodically. Soil temperatures and soil moisture were recorded continuously with “Phytech” sensors. Final potato yields were determined manually in each plot. The conventional (no CC) plots were heavily damaged by rains before and after potato seeding, requiring rebuilding of the ridges while the CC plots were not damaged. CCs reduced the daily amplitude of the soil temperatures compared to the conventional bare ridges treatment, stabilize the soil temperatures on optimal range for potato development. Potato yields in the CC treatment were equal to the no CC ridges treatment. Further studies are required to test the possibility of reducing herbicide application and reducing irrigation in the oat CC regime compared to the no CC commercial ridges regime.

Keywords: Temperatures, weed management, mosture

Effect of tillage practices combined with residues management on weeds (216)

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Different tillage practices often lead to diversification of the weed flora. The objective of this study was to evaluate the effect of different tillage systems in combination with and without residues management on weed species composition. Tillage systems were – conventional tillage (CT) – stubble cultivation (10-12 cm) + ploughing (23-25 cm + presowing S-tine cultivation (4-5 cm); reduced tillage (RT) – stubble cultivation (10-12 cm) + glyphosate (3 l ha^{-1}) + presowing S-tine cultivation (4-5 cm) and no-tillage (NT) – glyphosate (3 l ha^{-1}) + direct drilling. Post-harvest residues of preceding crop have been removed from half of the field. On the other half the residues were chopped and spread on the soil surface. A 5-course crop rotation winter wheat – spring oil-seed rape – spring wheat– spring barley– peas was implemented in the trial. The weed flora in all tillage systems was dominated by annual broadleaf species compared to the perennial weeds. Seven annual broadleaf (*Chenopodium album, Thlaspi arvense*, *Lamium purpureum*, *Galium aparine, Viola arvensis, Veronica arvensis*, *Tripleurospermum perforatum* and three perennial (*Cirsium arvense*, *Convolvulus arvensis* and *Trifolium pratense*) species dominated the weed flora in all systems. Density of *C. album*, *T. arvense* and *T. perforatum* was higher after NT, compared to CT systems. Reduced tillage increased *L. purpureum* and *T. perforatum.* Tillage systems had no influence on the density of *G. aparine, V. arvensis* and *V. arvensis.* The residues of the preceding crop increased the density of *G. aparine compared to straw removal.* The dry mass of *C. album*, *T. arvense* and *L. purpureum* were higher in NT than in CT and RT systems. NT system increased the total dry mass of weeds as compared with other systems. Residues of the preceding crop did not have an effect on the total dry mass of weeds.

Keywords: Tillage systems, plant residues, crop, weeds

The poster in a PDF version is available here.

Effect of different planting methods on weeds population, corn grain yield and yield components (454)

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To evaluate the effect of different planting methods on reduction of nicosulfuron dose and weed populations in corn, an experiment was carried out at Iranian Research Institute of Plant Protection field, Karaj, Iran during 2012-2013. Ten treatments were arranged as a randomized complete block design with four replications. Treatments were different corn planting methods including: on row bed (ridge) with band spraying, on row bed with a cultivation, on row bed with twice cultivation, on row bed with weeding, on row bed without weeding and herbicide use, on furrow bed with broad spraying, on furrow bed with band spraying, on furrow bed and then displacement of furrow to row by a soft cultivation, on furrow bed with weeding, on furrow bed without weeding and herbicide use. Results showed that the lowest and the highest weeds density and dry weight was observed in the corn planting on furrow bed and then displacement of furrow to row, and the planting on furrow bed without weeding and herbicide application treatments, respectively. The highest yield was observed in the corn planting on furrow bed and then displacement of furrow to row. Also, growth analysis results indicated that total dry matter, crop growth rate and leaf area index was greater in corn planted on furrow bed and displacement of furrow to row compare to other treatments. This method can be a suitable tool to reduce herbicide in maize.

Keywords: Planting on row, reduced dosage, weeding, cultivation

The poster in a PDF version is available here.

Possible cover crop plants for managing weeds in corn fields (160)

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Chemical weed control is the preferred way by producers in the corn fields of the Cukurova region/Turkey. Continuous herbicide use brings many negative effects such as herbicide resistance and environmental health. So use and improvement of alternative methods such as cover crop is needed.
This study was conducted to two aims. The first was to determine convenient cover crop species to Cukurova region, the second to reveal the competition between corn and cover crop plants. During the experiments, maize and 16 different cover crop species were used.
Between April-July 2015, 16 cover crop species were sown in plots with 4 replicates. Half of each plot (both cover crop plants and weeds) was harvested when cover crops were in blooming time. At the end of cover crop vegetation, all plants were mowed separately and dry weight was measured. The data show that the most competitive cover crop plant with the weed was Egyptian clover (*Trifolium alexandrinum* L.).
In the second experiment, competition between maize and cover crops in pots with five replications was compared. Ten cover crop species were tested against maize. The experiment was completed after two months and, dry weight and height of maize was compared. According to the pot experiments, the least competitive cover crop against maize was red clover (*Trifolium incarnatum* L.).
Based on the results, in Cukurova Region, *Trifolium* species could be used as a cover crop, also because of the low competition with maize.

Keywords: Weed, Cover crop, Maize

Mulch weed control from intercropped cover and cash crops in no-till soybean (543)

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Alternative weed control has been studied not only in organic farming but also as a tool for integrated weed management. In Brazil the majority of grain crops are no-till cultivated, so increasing weed suppression efficiency by winter cover crops may be an option to be adopted by farmers. Intercropping cover crops with cash ones could give both soil cover and economic return, and also could possibly be enough to pay crops costs. The aim of this study was to evaluate the effect of intercropping cover crops to cash crops on mulch weed suppression in no-till soybean without herbicide. In this paper only soybean results will be analysed because of the amount of data. The experiment was carried out in Paraná State, southern Brazil, in the 2014/15 crop season. The experiment was arranged in a randomized complete blocks design with three replications. The main plots were the cover and cash crops sowed in April: oat (*Avena sativa*), wheat (*Triticum aestivum*), sunflower (*Helianthus annuus*), rapeseed (*Brassica napus)* and intercropping combinations: oat + wheat, oat + sunflower, and rapessed + oat. The sub-plots were weed control on soybean: weeded and unweeded. Cover crops were managed with knife roller just before soybean sowing in October. Mulch didn't suppres weed cover, as weeding treatment. But all treatments with oat and single sunflower produced more soybean. Oat is the main cover crop used in Brazil in no tillage systems, and it continues to be the best choice. In conclusion oat either as single crop or in intercroping is the most efficient mulch for unweeded soybean.

Keywords: Organic farming, mulching, cover crop, no-till, soybean

Effects of tillage and crop rotation on weed infestation (310)

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In Lithuania, the land area under reduced tillage *has been steadily increasing* over the recent years. Crop rotation is an effective tool for weed management by changing weed community. The objectives of this research were to determine the influence of crop rotations and conventional (CT) and reduced tillage (RT) systems on weed infestation. The experiment was composed of two tillage treatments: mouldboard ploughing and stuble cultivation, and two short crop rotations: spring oilseed rape → spring barley → winter wheat, winter wheat → winter oilseed rape and winter wheat monoculture. Prior to the experiments, annual dicotyledonous weeds predominated (96.1-99.2%). 16-22 weed species were registered, while only few on them dominated: *Chenopodium album* L., *Sinapis arvensis* L., *Galium aparine* L., *Tripleurospermum perforatum* (Merat) M. Lainz, *Capsella bursa-pastoris* (L.) Medik. and *Fallopia convolvulus* (L.) Löve. The population of perennial weeds *Sonchus arvensis* L. (32.6-40.1%) and *Cirsium arvense* (L.) Scop. (41.8-58.1%) prevailed. Conventional tillage decreased the abundance of annual weeds on average by 5% and perennial weeds by 91 % in all crop rotations as compared with reduced tillage. In the stubble-cultivated soils, the density of *C. album* and *S. arvensis* was higher than in the ploughed soils. The density of weeds in winter wheat was 1.5-fold lower when grown in a rotation compared to monoculture. Spring barley had the best suppressing ability compared to all crops investigated. The spring and winter oilseed rape exhibited weak weed suppression ability: the number of weeds was 179% higher compared to spring barley.

Keywords: Reduced tillage, crop rotation, monoculture, weed

The poster in a PDF version is available here.

Introduction of Agro-ecological Service Crops (ASCs) in organic orange orchard: effect on weed community and dynamics in Mediterranean environment (291)

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The overall objective of this study was to evaluate the use of cover crops to reduce weed populations in a subsequent soybean crop as an alternative to traditional weed management in production systems in the south east of Cordoba (Argentina). Furthermore, we have studied the water consumption and economic costs comparing this cover crop system with both a traditional fallow system and traditional chemical management. The weed control treatments used were cover crops of rye (*Secale cereale* (L.) M. Bieb.) and oat (*Avena sativa* L.) at a density of 200 seeds/m^2, and fallow as traditional control.The experimental units consisted in plots of 30 x 100 m arranged in a completely randomized blocks design, with three replicates. Drying of cover crops and weed control in the control treatment was carried out with glyphosate (1120 g ai ha^{-1}) + 2-4D Amine (800 g ai ha^{-1}) + silicone oil (0.1 g ai ha^{-1}). Dominant weeds in the test area were *Parietaria debilis*, *Ipomoea* spp, *Conyza bonariensis* and *Setaria viridis*. Control evaluations were performed at 36 days after drying. Soybean (*Glycine max* (L.) Merr.), Nidera 500 variety was used as successor crop.According to the results obtained and the conditions under which the trials were conducted, we can conclude that the use of rye or oat cover crops have a beneficial effect on reducing weed populations in a subsequent culture. However, oats as a cover crop has greater efficiency in reducing weed populations compared to the use of rye. The economic costs and water consumption were significantly higher compared to a traditional fallow. In low precipitation years the cover crops adversely affect both the subsequent crop yields and the final economic balance of the production system.

Keywords: Cover crop, roller crimper, green manure, biodiversity indices, weed phenology

The poster in a PDF version is available here.

A long-term experiment testing feasibility, efficiency and durability of crop systems using less herbicide in a non-irrigated zone (764)

Fanny Vuillemin *(Terres Inovia, Thiverval-Grignon, France),* ***Alain Rodriguez*** *(Acta, Baziege, France),* ***Jean-Luc Verdier*** *(Arvalis – Institut du végétal, Baziege, France)*

The weed control practices which have a lower level of dependence on herbicides need to be tested system-wide and for a long time to see cumulative effects on weed infestation. So, French technical institutes decided to establish a long term experiment to evaluate 6 different crop systems. These systems combine different practices of weed management such as: long rotation cropping, ploughing every 2 years, cover crops during certain inter-crop periods, late sowing period, superficial soil tillage to favor the emergence of weeds with the intention to destroy them before sowing, and mechanical weed control (hoeing machine or harrow comb). The aim is to know which system is the most interesting for weed control, the most economic, the most ecologic and the less time-consuming... on the assumption that it will not be the same system which will be the best for these different aspects. Obviously, the results are dependent on the context (region, soil, climate...).
We followed the evolution of weed infestation in these systems (before weeding and before cropping). With a short-term rotation (wheat – sunflower), we observed an infestation of *Lolium multiflorum* increasing with time. Clearly, the infestation increased less in ploughed systems than in no-ploughed systems. In the first years of the trial, the usually weeded systems were less infested with *Lolium multiflorum* than systems using alternative techniques (late sowing, stale seedbed technique, mechanical weed control) but with time it started to become the contrary in the no-ploughed systems.
With both long-term rotation systems (sorghum – sunflower – wheat – pea – rape – wheat), we observed a higher diversity of species and a lower infestation with *Lolium multiflorum* compared to the short-term rotation systems. It is too early to conclude about the effect of cover-crop in the rotation between both systems.

Keywords: Long-term experiment, evaluation of crop systems, alternative practices of weed management, *Lolium multiflorum*

The poster in a PDF version is available here.

Natural mulching: an option for sustainable weed management in young citrus orchards (478)

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In Brazil, lime orchards are concentrated on small farms; have great economic, environmental and social appeal; and require sustainable management techniques. The aim of this study was to evaluate the use of *Urochloa* as a natural soil cover and of side mowers and glyphosate on weed control and development of the Tahiti acid lime. The experiment was set up in 2010 as a split-split-plot with a randomized block design and four replications. Plots included two species of *Urochloa* (A): *U. ruziziensis* and *U. decumbens*. The subplots included two types of lateral mowers (B): "ecological mower" (EM), with six knives and a 2.60 m cutting width, which launches the mowed biomass around the the base of the trees; and "conventional mower" (CM), with four knives and a 2.60 m cutting width, which launches the mowed biomass in the row middles. And the sub subplot contained herbicide application in the line (C): no application of glyphosate and glyphosate application. Between 2011 and 2014, the following aspects of production were evaluated: the dry matter of the aerial part (DM) of these cover crops between the lines and canopy projection (row); density of weeds in the citrus planting line (weeds m^{-2}); vegetative development of Tahiti acid lime through measurements of height and crown diameter; and production in the lime with direct weighing of the fruit. *Urochloa decumbens* produces higher DM values, whereas EM provides greater deposition of the *Urochloa* DM in the row and CM in the inter-row. *Urochloa decumbens* promotes weed control; the ecological mowing and the use of glyphosate are effective for controlling weeds and promote greater vegetative and productive development in the Tahiti acid lime; and *U. ruziziensis* with EM promotes weed control and increased productivity. The ecological mower is established as a good option for sustainable management in citrus orchards.

Keywords: Citrus latifolia, *Urochloa*, Inter-row management, herbicide, glyphosate

The poster in a PDF version is available here.

Integrating cover crops into no-till grain systems to diversify herbicide resistance management in the Mid-Atlantic United States (226)

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In order to combat a rapid increase in glyphosate-resistant *Conyza canadensis* and *Amaranthus spp. in the Mid-Atlantic United States,* we are assessing the integration of cover crops to diversify weed management in no-till grain crop production. This region is comprised of dairy farms, where conservation-tillage practices are being promoted to preserve soil health and reduce erosion. The main objectives of this study are to (1) test the effects of cover crop functional traits on weed population dynamics; (2) quantify the relationship between cover crop and herbicide integration on weed control efficacy; and (3) evaluate trade-offs of cover crop strategies related to herbicide resistance management, ecosystem services, and grower priorities. To address these objectives, we have initiated three field experiments in Pennsylvania and Delaware that are based on a preliminary experiment. At both sites, the preliminary experiment indicated that fall-planted cover crop treatments that included cereal rye (*Secale cereale*) alone or in a two-species mixture significantly suppressed *C. canadensis* density (0.5 m^2) by over 75% prior to burndown herbicide applications. *C. canadensis* plant height and average rosette diameter also showed significant reductions in cereal rye cover crop mixtures, thus reducing herbicide resistance selection pressure. Our additional experiments are designed to determine how cover crop strategies with different functional traits affect (1) winter- and summer-annual weed dynamics within various growing season windows, (2) herbicide resistance selection pressure and weed control efficacy when integrated with herbicide programs, and (3) other grower priorities and ecosystem services. Selected cover crop strategies include one- or two-species cover crop mixtures of cereal rye, spring oats (*Avena sativa*), hairy vetch (*Vicia villosa*), forage radish (*Raphanus sativus*), and crimson clover (*Trifolium incarnatum*).

Keywords: Herbicide-resistant, integrated weed management, cover crops, no-till, cropping systems

Cover crops in cereals – better companions than weeds? (481)

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Cover crops have gained popularity in cereal cropping now that they are one of the subsidized options in agri-environmental schemes of the EU. Several studies on cover/catch crops affecting nutrient leaching have been published but less information is available concerning their applicability for weed management. In our opinion, combinations of crop and cover crop types as well as crop sequencing conform IPM principles and optimize weed management. The PRODIVA project (ERA-Net Core Organic Plus Action, www.coreorganicplus.org) aims at identifying weed community associations with most common crop types in organic crop production systems. We will clarify the characteristics and relative competitiveness of cover crops providing strong weed suppression without severely compromising weed species diversity and crop yields. Long-term cropping system experiments in Denmark, Finland and Latvia provide information on weed dynamics both in terms of weed biomass production and weed community associations with cropping factors such as crop type, crop sequencing and mechanical weed control. We aim at understanding the main factors driving weed pressure and weed community assemblies under northern European circumstances. Perennial weed species (e.g. *Cirsium arvense*, *Elymus repens*, *Sonchus arvensis*) are particular important in organic cropping systems because they heavily constrain crop productivity. Cover crop establishment and early growth are key factors for the suppression of weeds. Poorly developed cover crops can cause extensive proliferation of rhizomatous perennials. Clover species (*Trifolium* spp.) are one of the most applicable cover crops thriving in the Nordic/Baltic agroclimate. Clovers supply nitrogen to the crops to improve both yield and crop competitiveness against weeds and they suppress *C. arvense* in cropping systems where clover together with grasses acts as a green manure that is repeatedly mown.

Keywords: Cover crops, organic cropping, perennial weeds, weed management

The poster in a PDF version is available here.

Weed management and community evaluation in a diverse cropping system (430)

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William S Curran *(Pennsylvania State University, University Park, United States),*
Heather Karsten *(Pennsylvania State University, University Park, United States)*

A diverse, no-till dairy cropping systems study was established in 2010 seeking to produce enough feed, forage, and fuel to supply a 65-cow, 97 hectare dairy farm in Pennsylvania while minimizing off farm inputs. A 6-year diverse crop rotation, the Pest Management rotation, evaluated strategies that attempted to reduce herbicide inputs and the risk of herbicide resistant weeds. The rotation was composed of a sequence of annual crops, cover crops, and a perennial hay crop. A Reduced Herbicide (RH) treatment was compared to a Standard Herbicide (SH) treatment that was more reliant on chemical weed control. Both treatments utilized Integrated Weed Management where the RH treatment incorporated more cultural and mechanical methods of control. In 2015, the full six year rotation was completed, allowing for the comparison weed and crop response to the both the rotation and treatment. The RH and SH treatments were compared based on crop yield, weed biomass, and weed seedbank across the rotation. The seedbank was compared to above ground weed biomass to determine the cumulative effect of management on the weed community. Resulting weed communities varied between crops and treatments. However, both the RH and SH treatments generally maintained adequate weed control over the six years. Crop yield varied between the treatments in several years, but these differences were not attributed to weed competition.

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Better utilization of crop diversification for weed management in north European organic arable cropping systems. Introduction to the study of international research-network on diversification and weed management: PRODIVA (317)

Merel AJ Hofmeijer *(University Rostock, Rostock, Germany),* ***Bärbel Gerowitt*** *(University Rostock, Rostock, Germany),* ***Bo Melander*** *(Aarhus University, Aarhus, Denmark),*
Roman Krawczyk *(Institute of Plant Protection, Poznan, Poland),* ***Jukka Salonen*** *(Natural Resources Institute Finland, Jokioinen, Finland),* ***Theo Verwijst*** *(Swedish University of Agricultural Sciences, Uppsala, Sweden),* ***Livija Zarina*** *(State Priekuli Plant Breeding Institute, Priekuli, Latvia)*

The international research network PRODIVA aims to improved utilization of crop diversification for weed management in northern European organic arable cropping systems. The over-all aim is to support organic agriculture for the exploitation of crop diversification methods to improve weed management and still maintain a diverse weed flora. Hypothesized is that crop diversification can improve weed management while ensuring a diverse weed flora by the employment of: (I) pertinent crop sequencing that mitigates noxious weed species (II) improved cover crop establishment with selected competitive cover crop species (III) crop mixtures utilizing the resources better than sole crop species resulting in more weed suppression (IV) variety mixtures exerting a stronger pressure on weed development than the sole varieties. Objectives are: (I) to strengthen the scientific foundation for the employment of crop diversification, (II) to survey the weed situation in practice region-wise and link it to the agronomic measures applied (III) to bridge the information from the surveys with the scientific groundwork (IV) to disseminate important results and recommendation to extension services and growers. PRODIVA focuses on terminated and ongoing European research on crop rotation experiments with the inclusion of work packages on crop sequencing and cover crops (Finland, Latvia, Denmark), crop mixtures (Sweden, Poland), variety mixtures (Denmark, Poland, Latvia) and current crop diversity applications and their effect on weeds on farms (Germany, Denmark, Sweden, Finland, Latvia). This project has the duration of three years: 2015-2018.

Keywords: Crop diversity, Weed diversity, Organic cereals

The poster in a PDF version is available here.

Winter cereal cover crops as the preplanting treatment of weed management in sugar beet (81)

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Hossein Najafi *(Iranian Research Institute of Plant Protection, Tehran, Iran),*
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Winter cover crops are one of the main tools to manage weeds with non-chemical approaches. They can particularly be used as a preplanting treatment in crops like sugar beet that have a weak competitive ability against weeds. In order to study cover crops effects on weed suppression in sugar beet, an experiment was performed in the Iranian Research Institute of Plant Protection, Karaj station. The experiment was arranged as a completely randomized blocks design with four replications and seven treatments. The weed management treatments consisted of four different cover crops (including: wheat, barley, triticale and rye) that were planted between rows, and two traditional weed management treatments (chemical weed control, manual control (weed free)) and an untreated weedy control. Cover crops were removed by herbicide application (paraquat at 400 g a.i. ha^{-1}). Phenmedipham+desmedipham+ethofumesat was also used in the four-leaf stage of sugar beet to control weeds. Results indicated that cover crop treatments suppressed major weeds (*Amaranthus retroflexus* L. and *Chenopodium album* L.) and gave similar results as recommended chemical control (application of herbicide). In addition, the total weed biomass was decreased in barley, rye and control treatments. The minimum biomass of total weeds belonged to the barley+herbicide treatment. Because of synergism effects, barley+herbicide treatments resulted in the highest root and sugar yield (29.83 and 4.47 t ha^{-1}, respectively), that was significantly different from other treatments. Overall, barley cover crop had the most beneficial effects on sugar content. Therefore, sowing winter cover crops between rows for seedbed prepared in autumn (barley, rye, wheat and triticale, respectively) will suppress the dominant weeds and increase the quality and yield of sugar beet.

Keywords: Non-chemical approaches, seedbed, paraquat, barley

The poster in a PDF version is available here.

Effects of mowing and glyphosate on weeds under different soil tillage regimes in fig orchards (470)

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Weed control is required in fig orchards after fruit ripening to ensure clean soil surface where dried figs drop and are collected for processing. Conventional weed control includes plough and disc harrow in March followed by disc harrow, harrow and slide in June. Although conventional weed control is effective in controlling weeds, intensive soil tillage has negative effects on soil properties and cause an increase in the population of perennial weeds. Therefore different weed control strategies have been investigated in which glyphosate use and mowing has been evaluated in combination with reduced and no tillage systems. Experiments are being carried out since 2012 and are still going on. The efficacies of 5 treatments are being evaluated on total summer weeds as well as on bermudagrass. Treatments include Conventional tillage; reduced tillage + mowing; reduced tillage + glyphosate; no tillage + moving and no tillage + glyphosate. Reduced tillage treatments include cultivator, disc harrow and chisel in October and March followed by mowing or glyphosate treatment in May. Mowing or glyphosate treatments were replicated two times, in March and June to control winter and summer weeds, respectively. Evaluations were done as visual cover estimation in June and July and data was subjected to ANOVA. Cover of total weeds and *bermudagrass* were highest on plots on no till + mowing and reduced tillage + mowing plots. The covers of other treatments were significantly lower. These results showed that glyphosate can effectively be combined with no-till and reduced tillage system to provide efficient, cheaper weed control with less soil disturbance.
Acknowledgement: Information given here is a part of the project “The effects of alternative soil tillage methods on the growth, yield and fruit qualities in dried fig production”, Project Code: TAGEM/BBAD/12/A08/P07/1 supported by General Administration of Agricultural Research and Politics Affair (TAGEM)

Keywords: Glyphosate, mowing, fig orchard, reduced tillage, no tillage

The poster in a PDF version is available here.

Weed management in organic rice (41)

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Gnanasoundari P *(Tamil Nadu Agricultural University, Coimbatore, India)*

Field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, India during Rabi 2012-13 (October-February) to identify the suitable weed management technique in organic rice production in randomized block design with three replications. The weed management techniques evaluated are paired row planting of rice with daincha as intercrop and incorporation on 35 days after transplanting (DAT), Azolla as dual crop and rotary weeder incorporation on 20 and 40 DAT. Azolla as dual crop and cono weeder incorporation on 20 & 40 DAT. Rotary weeder four times on 10, 20, 30 and 40 DAT and cono weeder four time on 10, 20, 30 and 40 DAT, rice hill solution (50%) spray on 3 DAT + hand weeding (Hw) on 35 DAT, Rice hill solution (50%) spray on 15 DAT + Hw on 35 DAT. Sunflower dried stalk solution (1:10 w/v) spray on 3 DAT & 5 Hw on 35 DAT, sunflower dried stalk solution (1:10 W/v) spray on 15 DAT + Hw on 35 DAT, Rice straw @ 3t ha^{-1} on 3 DAT + Hw on 35 DAT; Rice bran @ 2 t ha^{-1} on 3 DAT & Hw on 35 DAT, Hw on 15 & 35 DAT and unweeded control. Medium duration (135 days) rice variety Co (R) 48 was used as test cultivar sown at 30 x 10 cm. Weed flora, density and dry was taken at 20, 30 and 50 DAT. Rice growth, yield parameters and yield of rice was calculated and statistically analyzed. Results revealed that application of rice bran @ 2 t ha^{-1} on 3 DAT followed by hand weeding on 35 DAT kept the weed density (15 no/m^2) and dry weight (3.38 g m^{-2}) below the economic threshold level which increased the grain yield of organic rice (4816 kg ha^{-1}) besides increased the nutrient reserve.

Keywords: Days after transplanting (DAT), organic rice, nutrient reserve, iincorporation, decomposition

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Non-chemical weed management in organic rice (40)

Somasundaram Eagan *(Tamil Nadu Agricultural University, Coimbatore, India),*
Shobha Rathod Bavaji Gudi *(Tamil Nadu Agricultural University, Coimbatore, India)*

Field experiment was conducted during October 2014 to February 2015 at Tamil Nadu Agricultural University, Coimbatore to identify the effective non-chemical weed management technique for organic rice production. Experiment was laid out in randomized block design with three replications. Weed management practices viz., Application of paddy straw @ 3 t ha-1 on 3 DAT + Hand weeding on 35 DAT, Azolla as dual crop with rice and incorporation on 35 DAT using powerweeder, Hand weeding on 15 DAT and 35 DAT, Conoweeder 3 times on 20, 30, 40 DAT, Mulching with biodegradable polyethelene sheet, Intercropping mesta (Hibiscus cannabinus) with rice as paired row and harvested greens, Intercropping daincha (Sesbania aculeata) with rice as paired row cropping and incorporation on 35 DAT, Application of rice bran @ 2 t ha-1 on 3 DAT + Hand weeding on 35 DAT, Hand weeding on 15 DAT followed by azolla inoculation and Unweeded check were evaluated. Observations on weed flora, density and dry weight and rice growth, quality and yield parameters, grain and straw yield of organic rice were recorded. Nutrient uptake by crop and removal by weeds and economic parameters were estimated. Results revealed that application of rice bran @ 2 t ha-1 on 3 DAT followed by hand weeding on 35 DAT recorded reduced weed density, dry weight and higher weed control efficiency. Mulching with biodegradable polyethelene sheet enhanced the growth and yield of organic rice by suppressing the weed growth, increased microbial population and nutrient uptake of rice. Net returns and Benefit/Cost ratio were higher under hand weeding on 15 DAT and azolla inoculation on the same day.

Keywords: Days after transplanting (DAT), rice bran, biodegradable polythene sheet, non-chemical weed management

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The effect of different organic mulches on weed control in experimental cultivation of *Mentha* x *piperita* (309)

Ana Matković *(Institute for Medicinal Plant Research „dr Josif Pančić" Belgrade, Belgrade, Serbia),* ***Dragana Božić*** *(University of Belgrade, Faculty of Agriculture, Belgrade, Serbia, Belgrade, Serbia),* ***Sava Vrbničanin*** *(University of Belgrade, Faculty of Agriculture, Belgrade, Serbia, Belgrade, Serbia),* ***Dragoja Radanović*** *(Institute for Medicinal Plant Research „dr Josif Pančić" Belgrade, Belgrade, Serbia),* ***Tatjana Marković*** *(Institute for Medicinal Plant Research „dr Josif Pančić" Belgrade, Belgrade, Serbia)*

Mentha piperita is an aromatic, perennial plant of *Lamiaceae* family. Due to its wide use for pharmaceutical, food and cosmetic purposes, it is considered as one of the most important aromatic plants in the world. Although it has been widely cultivated in many regions of the world for decades, the estimated losses caused by the weeds still accounts for nearly half of all the losses encountered during its cultivation. In our field experiment conducted in Serbia, following organic mulches were tested for their efficacy in weed control of *M. piperita* cultivation: straw, chopped pieces of the pine bark, sawdust of acacia, dry pine needles, chopped maize sedge, chopped pieces of the acacia bark, herbal composts 1 and 2. *M. piperita* plantation was established in the fall of 2014, by planting stolons in the rows (spacing 0.7 m) and the mulches were spread over 0,5 m between them in the early spring of 2015. In all treatments the weeds were left intact till the first *M. piperita* harvest (in 3 replicates) while the control treatment was the *M. piperita* row and the space between it without any weed removal. The positive effects of applied mulches were estimated on the basis of weed biomass reduction (%) in the spaces between the rows, compared to the control treatment. Results show that all mulches proved efficiency in controlling weeds, with average reduction of weed biomass of 54.9% compared to control treatment, ranging from 83.4% achieved by chopped maize sedge mulch, to 15.3% in herbal compost 1. According to obtained results in our study it can be concluded that all organic mulches might be used in control of inter-row spaces in cultivation of *M. piperita*, with more or less success.

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Keywords: Organic mulches, weed control, weed biomass reduction, medicinal plant, cultivation

The poster in a PDF version is available here.

Selective cutting of *Cirsium arvense* in spring cereals (354)

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Theo Verwijst *(Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden)*

In organic farming, weed control of *Cirsium arvense* (L.) Scop. is a great challenge. A balanced crop rotation is very important but mechanical control is usually necessary. A selective weed cutter (CombCut), which cuts *C. arvense* in growing cereals without damaging the crop, has been developed in Sweden, and was evaluated in research project. The hypotheses were that selective weed mowing (i) decreases the ability of the weeds to compete and reproduce in a crop, (ii) decreases the long term development of the weed populations, and (iii) increases the crop yields. Two field experiments and two outdoor pot experiments have been performed in Sweden. In the field experiments, the effects of selective mowing on *C. arvense* and spring wheat were determined by mowing at two different development stages of *C. arvense*. In pot experiment 1, effects of mowing two years in a row on *C. arvense* and spring barley were studied. In pot experiment 2, effects of different machine settings on spring barley were evaluated. Results from the first pot experiment showed that growth of *C. arvense* was significantly reduced after mowing two years in a row compared with the control. When competition from spring barley was added, the reduction was even higher. Also crop yields were significantly higher after mowing compared with the control. Machine settings had strong effects on the crop. A more aggressive setting caused stronger damage on the crop at later development stages. In the field experiments, no significant effects were obtained on the crop yield due to large amounts of *C. arvense*. We conclude that selective mowing combined with crop competition decreases the abundance of *C. arvense.*

Keywords: Creeping thistle, mechanical control, organic farming, Sweden

The poster in a PDF version is available here.

Utilization of domesticated swine for nutsedge (*Cyperus* spp.) management in annual cropping systems (32)

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Yellow and purple nutsedges (*Cyperus esculentus and Cyperus rontundus*) are some of the most ubiquitous and troublesome weeds in annual cropping systems. Pigs (*Sus domesticus*) have been known to rogue out and consume nutsedge tubers, so studies were conducted to determine if pigs would provide a viable means of nutsedge control. Studies were initiated in the spring of 2014 and repeated in the spring of 2015. Three conjoining fenced pens in heavily purple nutsedge infested areas were constructed with same number of pigs per pen, providing a density of 50 and 25 m^2 per pig in 2014 and 2015, respectively. Recently weaned piglets (6-9 kg) were utilized and raised according to University recommendations. Pigs were allowed to forage/root in the pens for 2 weeks, and then rotated to the next pen for a total of 2 full cycles (12 weeks). Prior to introducing the pigs, soil core samples (7.6 cm diameter x 30.5 cm deep) were pulled from each pen using a grid sampling design, resulting in 7.3 and 3.0 m^2 per core in 2014 and 2015, respectively. The soil was sifted and the number of nutsedge tubers was determined from each core sample. This procedure was repeated immediately following removal of the pigs after 12 weeks, and samples were taken using the same sampling pattern. The pigs began rooting immediately after being placed in the pens, disturbing the top 30-45 cm of soil and completely removing all above ground vegetation. Compared to tuber numbers collected initially, pigs caused a 48% and 47% reduction in nutsedge tuber density across the three pens in 2014 and 2015, respectively. This method may provide a viable alternative to chemical weed control, or could be used as part of an integrated weed management system for smallholder farmers.

Keywords: *Sus domesticus*, nutsedge, herbicide resistance, tuber

The poster in a PDF version is available here.

Cinnamon and clove essential oils in weed control (427)

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Essential oils as herbal products, with special aroma and flavor, have herbicidal activity not only on the weed species but also an allelopathic effect on the germination of their seeds. They would be eligible for weed control in organic production, because of fast break down in the environment. The experiment was set up under semi-controlled conditions in order to investigate the herbicide effects of essential oils. Eight different weed species were used: *Amaranthus retroflexus, Chenopodium album, Datura stramonium, Lamium purpureum, Poa annua, Stellaria media, Taraxacum officinale* and *Veronica hederifolia*. Weeds were treated with three different dilutions of cinnamon (*Cinnamomum verum*) and clove (*Syzygium aromaticumm*) oils, 1% v/v, 5% v/v and 10% v/v, all with 0.2% concentrations of different adjuvants. Weeds were also treated with hot water 80-90 ^oC, glyphosate 2.88 g a.i.ha^{-1} and tap water as a control. All treatments were conducted in four repetitions. Weed species were in the 3-6 leaf stage. The effects of the treated variants were evaluated after 1, 24, 48 and 72 h of treatment (Tworkoski, 2002). Phytotoxicity of essential oils was visible as leaf drying and stem disruption, 1 hour after applying concentrations of 5% v/v and 10% v/v,. Concentration of 1% v/v did not show satisfactory effect with the exception of cinnamon oil in *Taraxacum officinale* with 75% damage. Essential oils of cinnamon (*Cinnamomum verum*) and clove (*Syzygium aromaticum*) at applications of concentrations of 5% v / v and 10% v / v showed high herbicide efficacy on the tested weed species *Amaranthus retroflexus, Chenopodium album, Datura stramonium, Lamium purpureum* and *Stellaria media*, in comparison with the hot water (80-90^{0}C) application as a standard.

Keywords: Essential oils, cinnamon oil, clove oil, phytotoxicity, weed control

Dose-response curves of various weeds in selected orchards in Central Turkey (501)

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The objective of this study was to obtain the dose-response curves of the weed species found in three different orchards in Central Turkey. A research weed flamer with 2 meter swath width was used to apply six propane doses (15, 30, 45, 60, 75, 90 kg/ha) in a walnut, apricot, and mixed fruit orchard. The gas pressure was set to 0.2 MPa and the ground speed of the tractor was varied from 1.83 to 8.3 km h^{-1} to apply the desired propane doses. Weed control rate was determined by visual observations and log-logistic model was used to obtain the dose-response curves for each weed specie after treatment (1, 7, and 14 DAT) at growth stages of 2-4, 6-8, and 10-12 L. The narrow leaf weeds in the experimental orchards were *Cynodon dactylon, Phragmites australis, Sorghum halepense* and the broadleaf weeds were *Chrozophora tinctoria, Convolvulus arvensis, Sophora alopecuroides, Xanthium strumarium, Lactuca serriola, Anthemis nobilis, Papaver rhoeas,* and *Echinophora* spp. Two of the weed species (*Lactuca serriola* and *Echinophora* spp) could not be found at 2-4 L growth stage and two of the weed species (*Anthemis nobilis* and *Papaver rhoeas*) were found only at the flowering stage. Narrow leaf weeds at 14 DAT could be controlled with propane doses from 128 to 177 kg ha^{-1} and 150 to 220 kg ha^{-1}, respectively for 2-4 L and 10-12 L stage. Broad leaf weeds could be controlled at 90% with propane dose ranges of 35-63 kg ha^{-1} at 2-4 L stage, and 75 to 144 kg ha^{-1} at 10-12 L stage, respectively. At 80% control, broad leaf weeds generally could be controlled by applying propane doses less than 90 kg ha^{-1} at 14 DAT.

Keywords: Flame cultivation, broadcast flaming, weed control, orchard, dose-response

The poster in a PDF version is available here.

Manual for propane-fueled flame weeding in corn, soybean and sunflower (170)

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Flame weeding is an approved method for weed control in organic cropping systems, with the potential for use in conventional agriculture. From 2006-2012 we have conducted a series of over 40 studies, which were funded by Propane Education and Research Council PERC and other sources (eg. USDA). This extensive work resulted in over 20 journal and proceeding articles about crop tolerance to heat and weed control with flame weeding in field corn, popcorn, sweet corn, sunflower, soybean, sorghum and winter wheat. We compiled the above research information into a training manual that describes the proper use of propane fueled flaming as a weed control tool in six agronomic crops (field corn, popcorn, sweet corn, soybean, sorghum, and sunflower). The flame weeding manual contains 32 pages of text and color pictures. The pictures provide visuals of crop growth stages when flaming can be conducted safely without having side-effects on crop yield. Pictures of weeds provide visuals of appropriate growth stages when weeds need to be flamed to achieve good weed control. There are six chapters in the manual: (1) The need for alternative weed control methods; (2) Propane fueled-flame weeding; (3) How flame weeding works; (4) Equipment and configurations; (5) Propane dosage at different weed growth stages, and (6) Crop Tolerance to post-emergent flame weeding. We believe that our manual provides a recipe on how to use flaming procedures and it is written in a user friendly manner that can be understood by the general public. The manual is free, it can be downloaded in a pdf format from the following website:
http://www.agpropane.com/ContentPageWithLeftNav.aspx?id=1916

Keywords: Maize, soybean, flaming, heat, cultivation

The poster in a PDF version is available here.

Influence of non chemical weed management in organic brinjal (*Solanum melongena*.L) (270)

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Dr.P.Murali Arthanari *(Tamil Nadu Agricultural University, Coimbatore, India)*

Brinjal(*Solanum melongena*.L) is one of the most commonly grown vegetable crop of the country. India produces about 5 MT of brinjal from an area of 3.2 lakh ha. Application of higher level of fertilizer input and plant protection chemical leads to more toxic residues in fruits and vegetable compared to grains as they are consumed at horticulture maturity. Beside this it has been reported that continuous use of inorganic input causes soil degradation in long term which latter on result in reducing the soil health. Organic farming is one of the ways to bring stability and sustainability to agriculture. Hence in recent year the trend founds organic farming is increasing and each produce is getting attractive rate in the market. Increasing concerns about effect of usage of herbicides in cultivation and steadily increasing conversion to organic farming are major factors which are driving research in non chemical weed control methods. A field experiment was carried out to investigate the best non chemical weed management practice that will be suitable for organic brinjal cultivation. The experiment was conducted at Annur during *Kharif* 2015 using Randomized block design (RBD) with three replications. The treatments comprised of ten different weed management practices. The variety chosen was CO 2 and was planted with the spacing of 60 x 60 cm. The plant growth parameters and weed observations are taken accordingly. The result revealed that application of Corn Meal Gluten @1 t/ha on 3 DAT followed by one hand weeding on 30 DAT kept the total weed density and weed dry weight below the economic threshold level followed by application of sunflower dried stalk solution 1:10 w/v basis 3DAT followed by one hand weeding on 30 DAT and also there is increase in yield of organic brinjal.

Keywords: Non chemical weed management, pre emergence application of corn flour, sunflower dried stalk solution, weed control, *Solanum melongena*.L

Session 16
AGRICULTURAL, ECONOMIC AND SOCIETAL ASPECTS OF WEED MANAGEMENT

Progresses on esenias-tools project on plant introductions (787)

Ahmet Uludag *(Duzce University, duzce, Turkey),* ***Teodora Trichkova*** *(Bulgarian Academy of Science, Sofia, Bulgaria),* ***Vladimir Vladimirov*** *(Bulgarian Academy of Science, sofia, Bulgaria),* ***Milica Rat*** *(Novisad University, Novisad, Serbia),* ***Rumen Tomov*** *(University of Forestry, sofia, Bulgaria),* ***Giuseppe Brundu*** *(University of Sassari, Sardinia, Italy),* ***Necmi Aksoy*** *(Duzce University, duzce, Turkey)*

ESENIAS-TOOLS project “East and South European Network for Invasive Alien Species – a tool to support the management of alien species in Bulgaria” has been just launched in 2015. The project focuses all ESENIAS region, which is a network mainly in the Balkan area (East and South European Network for Invasive Alien Species). This initiative, funded under the Programme BG03 “Biodiversity and Ecosystem Services” within the EEA FM (2009-2014), will result in networking and development of IAS tools within the framework of ESENIAS to support the management of alien species in Bulgaria and in the overall region. New introductions of plants and other organism have been recorded in Europe and worldwide. These introductions, along with climate change and unsustainable farming practices will cause the appearance of new weeds in managed and unmanaged areas. Currently lists of alien plant species as well as other organisms are under preparation. Data related to the region has been searched through internet and a few field studies have been conducted to support findings. Priority species will be identified and fact sheets will be distributed. Internet connections are also a goal of this project.

Keywords: Invasive alien plants, introduction, ESENIAS, networking, project

Vineyards farmer's views on weed management and environmental issues in the Sarigol district, Turkey (694)

Ahmet Uludag *(Duzce University, Duzce, Turkey),* ***Yakup Erdal Erturk*** *(Igdir University, Igdir, Turkey),* ***Mustafa Cinkilic*** *(Duzce University, Duzce, Turkey)*

Grape production is a foremost activity in some parts of Turkey such as the Sarıgöl District of the Manisa Province, Turkey. Surveys with farmers help to understand situation and define problems, activities and solutions. Weed control practices and environmental views of farmers were determined face to face discussions with 373 producers. Farmers mentioned 20 weed species for the most problematic weeds. *Sorghum halepense* and *Chenopodium album* were mentioned by all producers. Almost all producers (95 %) apply weed control methods. Over half of them practices chemical control and glyphosate is unique herbicide. Two third of farmers aware of environmental effect of pesticides while 15 % believes pesticides do not have effect on environment. But, awareness negative effect on human is higher. One third of farmers give pesticide packaging to recycling. More detailed questions revealed problematic points related to environment which shows extension services focus on environmental issues.

Keywords: Weed control, vineyard, farmers'view, environment, herbicide application

Sexual preference of tarnished plant bug on Palmer amaranth in the Mississippi delta (816)

Angus Catchot *(Mississippi State University, Mississippi State, United States),* ***Darrin Dodds*** *(Mississippi State University, Mississippi State, United States),* ***Andrew Denton*** *(Mississippi State University, Mississippi State, United States),* ***Chase Samples*** *(Mississippi State University, Mississippi State, United States),* ***Michael Plumblee*** *(Mississippi State University, Mississippi State, United States)*

The tarnished plant bug [Lygus lineolaris (Palisot de Beauvois)] is the primary insect pest of cotton (*Gossypium hirsutum* L.) in Mississippi, as well as most of the Mid-Southern growing region of the U.S. In 2012, 99% of the cotton acres planted in the Delta region of Mississippi were infested with tarnished plant bugs (Williams 2013).
Palmer amaranth [*Amaranthus palmeri* (S. Wats.)], is a fast growing, broadleaf weed that is very problematic in agriculture throughout the Mid-South and Southeastern U.S. With the proliferation of glyphosate-resistant Palmer amaranth in Mississippi, along with the increasing yield loss and cost to control tarnished plant bugs, this experiment was conducted to determine whether or not dioecism in Palmer amaranth had an effect on densities of tarnished plant bugs. Sex of Palmer amaranth had a significant effect on number of tarnished plant bugs observed when pooled over locations with significantly greater numbers of tarnished plant bugs observed on male plants. Tarnished plant bug counts visually sampled from the heaviest weed pressure area (Dundee, MS) on male Palmer amaranth plants were significantly higher in number compared to female plants and locations. Although male Palmer amaranth plants had significantly greater tarnished plant bug counts, all Palmer amaranth should be destroyed, regardless of sex, to prevent buildup of tarnished plant bug populations that could later become a problem. Non-crop areas such as ditch banks or areas where gin trash is dispersed where Palmer amaranth thrives should be of concern due to the potential threat of high populations of tarnished plant bugs.

Keywords: Cotton, tarnished plant bug, Palmer amaranth

The poster in a PDF version is available here.

Impact analysis of chemical weed management in banana cultivation in the western zone of Tamil Nadu, India (402)

Chinnusamy Chinnagounder *(Tamil Nadu Agricultural University, Directorate of Crop Management, Coimbatore, India)*

Banana has its origin in tropical region of South East Asia and is a nutritious gold mine. In Tamil Nadu Banana is cultivated in nearly 1.11 lakh hectares with a production of 51.48 lakh tonnes. Hence, a study was carried out to know the existing weed management practices adopted by the banana growers in the Western Zone of Tamil Nadu, to identify the constraints in adoption and to evaluate the adoption level of IWM technologies. Survey was conducted in four randomly selected villages in the Western zone of Tamil Nadu. In each village 50 farmers cultivating banana were selected randomly and the pretested questionnaire was applied to them to get information on the impact of integrated weed management in banana. Data were post stratified into users and non-users of herbicide for weed control in banana. Broad leaved weeds have dominated the weed flora while the grasses followed them in terms of infestation intensity. Farmers generally apply herbicides once or twice during the initial stages of crop cultivation followed by three or four manual weedings. The results of the study have revealed that adoption of integrated weed management practices has increased the yield of banana and thereby increasing the farm income of farmers, which was proved by the partial budgeting analysis revealing a positive change in the income level of the farmers due to the adoption chemical means of controlling the weeds. The probability of farmers adopting the herbicide application for the control of weeds was mainly attributed to the factors like educational level, source of information and awareness levels of the farmers about the benefits of the technology. Hence by educating the farmers on the beneficial effects of herbicides would go a long way in making an impact on chemical method of weed control in harnessing the yield potential.

Keywords: Bannana, Chemical Weed Managment, Survey, Impact analysis, Productivity

The poster in a PDF version is available here.

An ecosystem services approach to pesticide risk assessment and risk management of non-target terrestrial plants: recommendations from two SETAC Europe workshops (353)

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The registration of Plant Protection Products (PPPs) in the EU is under Regulation 1107/2009, which requires that PPPs are efficiently protecting the crops, that they have no immediate or delayed harmful effects on human health and that they have no unacceptable effects on the environment. Failure in any of these conditions will lead to non-authorization of the PPP. In the area of ecotoxicology a tiered approach to assessing the risk to non-target terrestrial plants (NTTPs) is recommended. However, little information is provided on how to perform and implement higher tier studies or how to use them to refine the risk assessments. Therefore, two SETAC endorsed workshops (April 2014, Sept 2015) were organized with the aim of:

- developing a framework for a higher-tier approach for assessing the risk of plant protection products to non-target terrestrial plants (NTTP) in off-crop areas
- providing expert opinion and advice as input for the ongoing revision of the terrestrial ecotoxicology guidance document and NTTP risk assessment procedures.

The participants of the workshops adopted the European Food Safety Authority (EFSA) approach of using an ecosystem services framework for identifying specific protection goals. A number of concerns were raised during the 1st workshop and three literature reviews were performed and data collected in order to reduce uncertainty concerning higher tier methodologies, protectiveness of standard test species for wild species, and protectiveness of regulatory endpoints for reproductive endpoints. The second workshop built upon the results of these literature reviews, the recommendations of the first workshop and the EFSA opinion on risk assessment of plant protection products for non-target terrestrial plants. The main charge questions identified for the second workshop were: how to address reproductive endpoints; how to mitigate risks; how to conduct higher tier tests. Recommendations from both workshops will be presented.

Mitigating on agrochemical uses impact on infectious disease resurgence, emerging outbreaks and insecticide resistance in developing countries (522)

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The global epidemiologic transition has been challenged by unprecedented resurgence and emerging diseases outbreaks public health burden resulting from climatic and environmental changes. Setting uncertainties in the global community due to instability in weather conditions and increasing usage of agrochemicals and pest control programs such as herbicides, fungicides and insecticides products throughout the globe. Pest control programs accounts for a larger part of the health expenditures and economic importance in recent years. This paper analyzes the factors and bottlenecks that are crucial in strengthening evidence-based, effective and sustainable approaches and choices in weed and vectors control programs in these countries. Our findings showed that tropics geographical landscape, globalization and climate changes offer favorable conditions to the rising vectors density and resurgence, transmission patterns and dynamics of Middle East respiratory syndrome coronavirus (MERS-CoV), Ebola virus fever (EBoV), dengue hemorrhagic fever (DENV), Malaria, Influenza (Avian Flu) and related vector-associated diseases. The trend was significantly associated with weak health systems, lack of environmental protection and poor safe choices, and requires urgent investment in research and development to validate innovative systems of pest management capability and opportunities to overcome vector resurgence and emerging diseases outbreaks. Conclusively, there is need to develop effective community-based non-chemical insecticide methods and careful pest monitoring to anticipate and prevent the development of resistance, sharing best practices of environmental health risk mitigation and services delivery and enhancing multicounty collaboration in environmental health good practices, and implementing environment friendly, cost-effective and sustainable evidence-based integrated vectors and diseases early indicators, surveillance and response interventions.

Keywords: Pest, agrochemical, outbreak, insecticide, resistance

Which decision-support systems for sustainable weed management: why, how and when to use it? (614)

Floriane Colas *(INRA, Dijon, France),* ***Sylvie Granger*** *(AgroSup Dijon, Dijon, France),* ***Jean Villerd*** *(INRA, Vandœuvre-lès-Nancy, France),* ***Henri Darmency*** *(INRA, Dijon, France),* ***Nathalie Colbach*** *(INRA, Dijon, France)*

Weeds are both harmful for crop production and important for biodiversity. Predicting the impacts of agricultural practices, and their interactions, on weeds is critical to help farmers developing cropping systems that reconcile crop production and biodiversity. Mechanistic weed dynamics models (such as FlorSys) are useful to identify candidate cropping systems but are too complex to be used by non-modellers. Our objective is to develop a decision support system (DSS) from FlorSys for designing and evaluating weed management strategies. The purpose of the present study was to understand why and how future users would use such a tool, based on semi-structured questionnaires for advisors and farmers, via web surveys and group meetings.

We identified different needs for DSS depending on the aim: (1) users confronted with a dead-end (herbicide resistance, high weed infestations etc) would be ready to radically change their cropping system (e.g. diversify crop successions) but would provide only meta decision rules (e.g. plough every two years) to be tested with the DSS; (2) users ready to understand and modify their practices before reaching a dead-end would be prepared to provide a detailed description of the practices (e.g. tillage tools, depths and timing, sowing dates and patterns) in order to finely tune their system in terms of options and timings of operations. The same goes with possible outputs of the DSS, either regression trees predicting weed impact for contrasting combinations of cultural practices, or detailed proposals of operations and decision rules to reach combinations of weed impact objectives (e.g. reduced crop yield loss and high functional biodiversity). Helping farmer to better understand weeds and how these react to all cultural practices is a step forward more sustainable weed management.

The present work was financed by INRA (EA and MIA divisions), the French project CoSAC (ANR-14-CE18-0007) and the Burgundy Region.

Keywords: Survey, decision-support system, model, cropping system, farm counselor

The poster in a PDF version is available here.

NTTPs – vegetative vs. reproductive endpoints in context of proposed changes in data requirements and risk assessment – Literature review and analysis for SETAC AG Plants (359)

Heino Christl *(tier3 solutions GmbH, Leverkusen, Germany),* ***x on behalf of the 1st SETAC workshop on "Non-target terrestrial plants"*** *(SETAC, Saint-Gilles, Belgium)*

Following recommendations of the first SETAC workshop on "Non-target terrestrial plants" (NTTPs) literature reviews were performed to compare the sensitivity of endpoint groups, i.e. vegetative vigour endpoints and reproductive endpoints of terrestrial plant species. Also an EFSA expert group recently worked on a Scientific Opinion regarding risk assessment for NTTPs (EFSA 2014); considerable changes are proposed, most prominently a change from an ER50 to an ER10 and from a vegetative to a reproductive endpoint. Formal literature searches were performed, using published literature and confidential GLP data (provided by industry), and all endpoints and potential explanatory variables were compiled in a data base, testing the hypothesis if reproductive endpoints are more sensitive than standard vegetative vigour endpoints (from tier1/tier2 tests), and by which margin. Secondly the impact of the changes proposed by EFSA on regulatory acceptable rates (RARs, i.e. the drift rates considered acceptable) was assessed, differentiating between the changes due to a) the proposed requirement for reproductive endpoints, b) the proposed move from ER50 to ER10 endpoints. In addition the assessment was repeated using solely the EFSA-data set that had been basis for the conclusions of the opinion paper. Both assessments revealed that overall the difference in sensitivity between vegetative and reproductive endpoints was minor (ca factor 1.5, although prominent exceptions are reported), whereas the proposed change from ER50 to ER10 would increase conservatism by ca. factor 6. Both changes combined would reduce the RARs by a factor of ca. 10. In combination with other proposed changes, the conservatism of the tier-1 risk assessment would increase dramatically. Ecological relevance and increased uncertainty of the proposed new regulatory endpoints, practical problems with testing reproductive endpoints, and effects on the notification of herbicides will have to be discussed.

Acknowledgement – This review is sponsored by members of the CLI NTP group and ECPA

Keywords: Risk assessment, Herbicide, Non-target plants, Reproduction, Sensitivity

The poster in a PDF version is available here.

The influence of organic system management on weed infestation in Lithuania (212)

Lina Sarunaite *(Institute of Agriculture, Lithuanian Research Center for Agriculture and Forestry, Kedainiai, Lithuania),* ***Irena Deveikyte*** *(Institute of Agriculture, Lithuanian Research Center for Agriculture and Forestry, Kedainiai, Lithuania),* ***Zydre Kadziuliene*** *(Institute of Agriculture, Lithuanian Research Center for Agriculture and Forestry, Kedainiai, Lithuania),* ***Ausra Arlauskiene*** *(Joniskelis Experimental Station of the Lithuanian Research Center for Agriculture and Forestry, Pasvalys, Lithuania)*

In Lithuania, the land area under organic management *has been steadily increasing* over the recent years. In 2012–2013, a research and development project was implemented in Lithuania with the aim of ascertaining plant diversity, agricultural load, phytosanitary state of agrocenoses in organically-managed mixed farms. Monitoring of organic production farms was carried out. Organic farms were divided into groups according to regions – West, Central and East Lithuania. The weed suppressive ability of different cereals depends on crop density, height, soil cover earliness and intensity. All investigated farm crops were dominated by perennial weeds, except winter wheat, spring triticale, soybeans and clover. Weeds ranged from 4.0 to 840.0 weeds m^{-2}. Perennial weeds were found 1.0 to 7.8 times more compared with annual weeds. Lower weed numbers were found in winter wheat compared with other winter cereals. Rye and triticale had 7% and 30% more weeds than wheat. Spring oats and barley weed infestations were similar (164.7 to 173.9 weeds m^{-2}) but weeds in spring rye and triticale crops were 2 times more than the other spring cereals. The highest weed infestations were found in bean and lupine crops compared with the other legumes. Averaged data indicate that weed dry matter was highest in triticale, while the lowest dry matter was in rye. Total crop weed infestations were similar in the western and eastern regions of Lithuania. The highest suppression of annual weeds were observed in crops grown in eastern Lithuania, while perennial weed suppression was greatest in the west region.

The study has been supported by the Ministry of Agriculture of the Republic of Lithuania.

Keywords: Annual and perennial weeds, cereal, legume

The poster in a PDF version is available here.

Weed seedbank communities of organic farms: A comparison of New England, the Midwestern United States, California, and the Netherlands (587)

Marleen M Riemens *(Wageningen University and Research Centre, Wageningen, the Netherlands),* ***Randa Jabbour*** *(University of Wyoming, Laramie, United States),* ***Eric Gallandt*** *(University of Maine, Orono, United States),* ***Kevin Gibson*** *(Purdue University, West Lafayette, United States),* ***Richard Smith*** *(University of California, Salinas, United States)*

Weed communities on organic farms vary widely in density and diversity from their conventionally managed counterparts, but only a handful of studies report weed seedbank data from organic farms. We will present a detailed comparison of weed seedbanks on 91 organic farms from four distinct regions: northern New England, the Midwestern United States, California, and the Netherlands. Soil samples were collected to a depth of 10 cm from 3-5 fields at each farm in 2010 or 2011, and then germinated, identified, and counted in the greenhouse. Germinable weed seedbank density, diversity measures including richness and evenness, and community composition were measured. Seedbank density significantly differed between regions with highest mean weed seed density in the Indiana (12,212 seeds per m-sq), followed by New England (8,739 seeds per m-sq), the Netherlands (8,739 seeds per m-sq), and California (1,756 seeds per m-sq). Notably, each region included high seedbank density farms with densities greater than 20,000 seeds per m-sq. The lowest seedbank density farms in each region varied from 13 seeds per m-sq in California to 2,774 seeds per m-sq in New England. Weed species community composition revealed shared and unique weeds of concern in each region. The weed species communities of the Dutch and Californian seed banks were similar, whereas the New England and Indiana seed banks were distinct from any other group. There were associations between community composition and farmer perceptions of their most problematic weeds. For example, on New England farms, hairy galinsoga *Galinsoga ciliata* and crabgrass *Digitaria spp.* were most often reported as the most problematic weeds. These two species were also the most abundant in New England seedbanks. We will highlight distinctive management strategies and philosophies in each region, and the implications for education and outreach.

Keywords: Germinable weed seed bank, organic agriculture, management strategies

The poster in a PDF version is available here.

Using Lightroom® to manage weed photographs (403)

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Lightroom® is widely used by professional photographers to manage photographic files and to perform routine file manipulation. When appropriately configured, Lightroom® has the ability to search for, and locate, photographs of plants. The location of the files does not have to be known. Using a personal database with over 80,000 photographic files the author can locate any tagged photograph within a few seconds. A combination of appropriate metadata tagging and a specifically designed keywording system permits searching for plant photographs by family, genus, Latin binomial or by common name. Searches by plant attributes can also be made, such as whether or not the plant is a weed, or whether the photograph is of seeds, seedlings, leaves, or fruits. Photographs can also be filtered by habitat/ecosystem. Camera metadata allows for searching by time of acquisition, camera and/or lens used, and by location and altitude when using global positioning system enabled cameras. The key to plant searches is setting up the metadata fields of ‚title' for the common name, ‚caption' for the Latin binomial, and ‚label' for the genus. The keywording system described here, which is hierarchical, uses main keyword categories that include location, habitat/ecosystem, altitude, and plants. The main keyword ‚plants' is divided into sub-categories including dicotyledon families, monocotyledon families, gymnosperm families, non-flowering plants, growth stages/forms, and type of plant. Each sub-category is sub-divided further to permit retrieval of individual plant families, genera, growth forms, or plant types (e.g. weeds).

Keywords: Weed photography

Weed management and soil function – What's the connection? (362)

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The contribution of weeds to below-ground function in agricultural systems is not well understood. In this study, we used a mesocosm approach with soils collected from a long-term rotation study to compare legacy effects of previous flax (*Linum usitatissimum* L.) or canola (*Brassica napus* L.) and different levels of weediness established over a decade by different herbicide-use patterns. In these soils, denitrification and the *nirK* denitrifier community were evaluated in planted (durum wheat – *Triticum durum* L.) and unplanted mesocosms. The impact of level of weediness superseded that of the preceding crop and altered the temporal dynamics of denitrification and the *nirK* denitrifier communities. The presence of durum plants did modify the legacy effects of preceding crop and weediness on the denitrifier community although this effect was relatively small. Our findings suggested that increasing weediness contributes to priming effects and that degree of weediness also may contribute to unexplained variation associated with these soil processes in field studies. Therefore, weed management history should be taken into consideration when determining soil function and soil microbial community dynamics in agricultural systems.

Keywords: Denitrification, long-term field experiment, nirK community, weed management

The poster in a PDF version is available here.

Developing an early warning system against alien weeds for crop protection in Japan (582)

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Many types of alien weeds have invaded arable land and caused severe damages to several crops since the late 1980s in Japan. Most weeds have been accidentally introduced into Japan via imported feed grains amounting to 26 million ton per year. Global warming could aggravate the serious problems caused by tropical weeds such as *Ipomoea hederacea*, *Physalis angulata*, and *Anoda cristata* in soybean production, in the temperate region of Japan. To effectively manage alien weeds, early detection and rapid response are important. For this, we developed an early warning system against alien weeds to ensure crop protection. Three different ranking systems were adopted depending on the invasion stages. For the pre-entry stage, a weed risk assessment (WRA) targeting specific crop was developed. The WRA consists of three elements: possibility of entry, weediness, and difficulty of control. We examined the validity of WRA score for use in soybean cultivation and compared it with the average weediness values evaluated by three weed scientists. The result showed a positive correlation between WRA score and weediness. Further, a method to determine management priority for the early establishment stage was developed using a formula for calculating priority score based on the principle that weed species with high risk and in a small infested area should be managed with priority. We ranked 10 weed species in soybean plantations by using the priority score. From the result, oneseed bur cumber (*Sicyos angulatus*) ranked the highest. For the widespread stage, weed species were simply ranked using the area infested. The early warning system developed in this study is presently not rigorous, but the ranking could help local governments decide on the weed species that should be monitored or managed.

Keywords: Alien weeds, Early warning system, Soybean, Weed risk assessment, Global warming

The poster in a PDF version is available here.

Agronomic and economic evaluation of integrated weed management in maize (73)

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A long-term experiment was set up in 2011 in north-eastern Italy, within the European Project PURE (Pesticide Use-and-Risk reduction in European farming systems with Integrated Pest Management, http://www.pure-ipm.eu), to evaluate two IPM levels against the conventional in four-year maize-based cropping systems. Since all crops per system were not present every year, the final effect of the crop protection levels on maize was evaluated at the beginning of the second cycle (in 2014) when maize was present again in all systems.
For maize, the conventional management (CON) involved pre- and post-emergence herbicide applications, whereas the integrated weed management (IWM) strategies involved pre- and post-emergence band application (30 cm band, 60% reduction) of herbicides (IWM1) and only post-emergence in band application (IWM2). After the post-emergence herbicide application, hoeing was also practiced in all strategies to incorporate the urea applied. For the pre-emergence application (CON, IWM1) a mixture of mesotrione (3.75%), S-metolachlor (31.25%) and terbuthylazine (18.7%) was used at 4.5 l/ha, while for the post-emergence application in all strategies a tank mix of rimsulfuron (25%, 60 g/ha), dicamba (21%, 1 l/ha) and paraffin oil (1.25 l/ha) was applied.
Results showed that overall (2011 and 2014 years) CON had significantly lower final weed density and higher grain yield compared to IWM strategies. However, in 2014 maize (i.e. 2nd cycle), CON and IWM1 had no significant difference in final weed density, whereas IWM2 had higher densities. Grain yield did not differ between IWM strategies in both years. Total weed control costs were 70€ and 120€/ha less under IWM1 and IWM2, respectively, thus the risk of yield reduction could be partly compensated for by the lower costs from reduced herbicide use. Evaluation of the long-term effects of IWM strategies and of crop rotations involved will be done after the end of the 2nd crop rotation cycle.

Keywords: Maize, Integrated Weed Management, Pesticide risk reduction, Economic sustainability

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To find all contributions by an author:

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Azevedo, Eduardo
Azevedo, Fernando
Babaei, Sirwan
Babec, Ivana
Babineau, Marielle
Baez Buchanan, Marcos
Bagavathiannan, Muthukumar
Bagheri, Abdolreza
Baghestani, Mohammad Ali
Bah, Boni
Bai, Lianyang
Bailey, Karen
Bailly, Geraldine
Bajwa, Ali
Bakar, Baki
Bakayoko, Anatole
Baker, Claire
Baležentienė, Ligita
Balkcom, Kip
Balogh, Ákos
Balusamy, M.
Balzergue, Sandrine
Banniza, Sabine
Bàrberi, Paolo
Baric, Klara
Barlow, Kathryn
Barreto, Robert
Barroso, Arthur
Baruch, Rubin
Başaran, Selcuk
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Bastiaans, Lammert
Bastiani, Marlon
Bastida, Fernando
Baum, Christel
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Becker, Rafael
Beckie, Hugh
Beffa, Roland
Begcy, Kevin
Begum, Mahfuza
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Bell, Carl
Bell, Jared
Bell, Richard
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Belz, Regina
Ben Haj Jilani, Imtinen
Bendavid, Oz
Benemann, Daiane
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Bhowmik, Prasanta
Bhullar, Makhan
Bianchi, Mario
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Birger, Nitzan
Bishnoi, Dalip
Bitomský, Martin
Blackshaw, Robert
Blagojević, Milan
Blakeslee, Joshua
Blank, Lior
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Boari, Angela
Bolfrey-Arku, Grace
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Bon, Marie
Boote, Ken
Boraud, Maxime
Borger, Catherine
Bošiaková, Dominika
Boström, Ullalena
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Botta-Dukát, Zoltán
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Bourdot, Graeme
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Božić, Dragana
Brabetz, Veronika
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Braga, Raildo
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Brandsæter, Lars
Brankov, Milan
Brant, Václav
Brants, Ivo
Bravo-Hoyos, Washington
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Brecke, Barry
Breeden, Gregory
Breeden, Shane
Brighenti, Alexandre
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Bruening, Chris
Brundu, Giuseppe
Brunetto, Felipe
Brunharo, Caio
Brurberg, May Bente
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Bunchek, Jess
Burgos, Nilda
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Büyükkurt, Nurcan
Cahoon, Charles
Calderon, Diego
Calha, Isabel
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Campanelli, Gabriele
Campbell, Joan
Canali, Stefano
Canella Vieira, Bruno
Cantoro, Renata
Cao, Aocheng
Çapkan, Deniz
Caramia, Domenico
Caratti, Fernanda
Carbonari, Ciao
Cardina, John
Cardoso, Rafael
Carlesi, Stefano
Carreira, Analía
Carrijo, Daniela
Casella, Francesca
Castilho, Alexandre
Caswell, Katherine
Catchot, Angus
Celepci, Ezgi
Chamanabad, Hamidreza
Champagne, Rebecca
Chandi, Aman
Chandler, Michael
Chantre, Guillermo R.
Chao Trujillo, Roberto
Charudattan, Raghavan
Chaudhari, Sushila
Chauhan, Bhagirath
Chauvel, Bruno
Chebil, Samir
Chen, Guo-Qi
Chen, Jie
Chen, Yin
Chen, Yong
Childs, Dylan
Chinnagounder, Chinnusamy
Chinnamuthu, C. R.
Chinnasamy, Nithya
Chinnusamy, Chinnagounder
Chivasa, Stephen
Choakongjak, Supattra
Choe, Eunsoo
Choe, MunMyong
Choi, Jung Sub
Chovancova, Svetlana
Christl, Heino
Christoffoleti, Pedro
Chrtek, Jindřich
Chytrý, Milan

Ciaccia, Corrado
Ciasca, Biancamaria
Cimalová, Šárka
Cimmino, Alessio
Cinkilic, Mustafa
Civit, Jordi
Claerhout, Sofie
Clark, Andrew
Claussen, Steve
Clemente, Borja
Cochavi, Amnon
Colas, Floriane
Colbach, Nathalie
Collavo, Alberto
Collegari, Stella
Collet, Lutz
Colvin, Daniel
Comont, David
Compant, Stéphane
Conceição, Patricia
Concenço, Germani
Constantin, Jamil
Cook, Sarah
Cordovez, Gabriela
Costa, Gabriel
Costa, Jaime
Costa, Saulo Italo
Costa, Yanna
Costanzo, Ambrogio
Cougnon, Mathias
Coutinho, Anselmo
Coutts, Shaun
Cripps, Michael
Crook, Laura
Crow, Whitney
Cruz Velázquez, Mauricio
Cuadras Isaac, Francisco
Cui, Hailan
Culman, Steven
Culpepper, Alford
Culpepper, Stanley
Cummings, Daniel
Cunha, João Paulo
Curran, William
Cygan, Magdalena
Czúcz, Bálint
Čerevková, Andrea
Čūrišķe, Jolanta
da Silva, Jessica
Dagan, Mali
Dai, Weimin
Dalazen, Giliardi
Dalinova, Anna
Dalla Valle, Natalino
Dancza, István
Daniell, Tim
Danihelka, Jiří
Danmaigoro, Olanrewaju
Daoud-Bouattour, Amina
Darmency, Henri
Datta, Avishek
David, Diego
Davies, Jo
Davis, Adam
Dayan, Franck
de Avila, Luis
de Castro, Ana Isabel
De Cauwer, Benny
De Costa, Emanuel
de Gaujac, Xavier
de la Fuente, Elba
de Mol, Friederike
De Palo, Fernando
De Ryck, Sander
Dehmer, Klaus
del Monte, Juan Pablo
Délye, Christophe
Demİr, Ibrahim
Demirci, Mehmet
Denton, Andrew
Denysenko, Magdalena
dePamphilis, Claude
DePrado, Rafael
Derakhshan, Abolfazl
Derby, Jo-Anne
Deru, Joachim
Deveikyte, Irena
Díaz Díaz, José
Dick, Warren
Dicke, Dominik

Diehji, Ahmad
Dimou, Paraskevi
Dinda, Nirmal
Dionisis, Kalivas
DiTommaso, Antonio
Dittmar, Peter
Dixon, Andrea
Djalovic, Ivica
Djeddour, Djamila
Dobešová, Tereza
Dodds, Darrin
Dogan, Isik
Dogan, Mehmet
Doğan, Mehmet Nedim
Doğan, Özlem
Dollinger, Margit
Domonkos, Zsolt
Donayre, Dindo King
Dong, Li-Yao
Dong, Zhaoxia
Doohan, Douglas
Dorner, Zita
Dostatny, Denise
Dourado Jr, Sidney
Downer, Roger
Dragičević, Vesna
Drekic, Milan
Drinkwater, Laurie
Drobny, Hans
Du, Long
Duarte, Thiago
Duarte Silveira, Erica
Dudele, Ieva
Duhan, Anil
Duhoux, Arnaud
Duke, Stephen
Dukes, Jeff
Dumonceaux, Tim
Duraisamy, Ravishankar
Dutertre, Alain
Dutta, Writuparna
Duus, Joachim
Dzomeku, Israel
Đaković, Nikola
Eagan, Somasundaram
Economou, Garifalia
Economou, Leonidas
Economou-Antonaka, Garifalia
Edwards, Joan
Eizenberg, Hanan
Ekkatin, Pruchaya
El-Hossary, Shabaan
Elahifard, Elham
Elameen, Abdelhameed
Eleftherohorinos, Ilias
Ellis, Jeffery
Ellison, Carol
Elpida, Fanouriou
Elsner, Viviane
Engländer, Judith
Entling, Martin
Eom, Min Yong
Ephrath, Jhonathan
Eppler, Lisa
Erener, Güray
Erken, Songül
Erturk, Yakup
Eshel, Gil
Esitmez, Bilal
Espinosa García, Francisco
Esteve, Joan
Evans, Harry
Everman, Wesley
Evidente, Antonio
Evidente, Marco
Fadaeishahri, Mohammad Reza
Faisal, Islam
Fan, Longjiang
Fang, Feng
Fanouriou, Elpida
Farhoudi, Rouzbeh
Faria, Daniela
Farkas, Anikó
Farooq, Muhammad
Feiza, Virginijus
Feiziene, Dalia
Felitti, Silvina
Fendrychová, Veronika
Fennimore, Steven
Feola, Martín

7th International Weed Science Congress June 19–25, 2016 Prague, Czech Republic

Ferlito, Filippo
Fernandez, Jose
Fernández Duvivier, María
Fernández Martínez, Ciro
Fernández-Escalada, Manuel
Fernando, Ramírez-Muñoz
Ferreira, Amanda
Ferrell, Jason
Ferrero, Aldo
Ferus, Peter
Figueroa, Rodrigo
Fikrová, Martina
Files, Maurício
Filin, Sagi
Fillols, Emilie
Finstrom, Brian
Fischer, Albert
Fleuridor, Louceline
Florianová, Anna
Fløistad, Inger
Fogliatto, Silvia
Foloni, Luiz
Fomsgaard, Inge
Fontanetti, Anastacia
Forcella, Frank
Foster, Trae
Fouad, Ahmed
Fracchiolla, Mariano
Fraga, Diego
Fraidman, Eyal
Francisco Blanco, Vidal
Freckleton, Robert
Frene, Raphael
Friebe, Bernd
Fritz, María
Fu, Fei
Fu, Jian
Fu, Weidong
Furlan, Lorenzo
Furtado, Joelson
Furuya, Naruto
Gabriel, José Luis
Gaines, Todd
Gajic Umiljendic, Jelena
Gallandt, Eric
Gallart, Montserrat
Gallego Domínguez, René
Galon, Leandro
Gammar-Ghrabi, Zeineb
Gao, Xingxiang
García Perú, Andrian
García Ruiz, Inoel
Gasich, Elena
Gasparini, Valentina
Gast, Roger
Gavriil, Elissavet
Gbehounou, Gualbert
Geddes, Charles
Gehrke, Vinicios
Geiger, Michael
Geng, Heli
Geng, Shan
Gerhards, Roland
Gerowitt, Bärbel
Gesch, Russell
Gfeller, Aurélie
Ghadiri, Hossein
Ghanizadeh, Hossein
Ghantous, Katherine
Ghosh, Dibakar
Ghosh, Sayan
Gibot-Leclerc, Stéphanie
Gibson, Kevin
Giffard, Brice
Gil, Mercedes
Gil González, Duvier
Gilbertsson, Mikael
Gill, Bikram
Gill, Gurjeet
Gill, Rafaqat
Gill, Rishi
Gioria, Margherita
Giszter, Rafał
Gnanasoundari, P.
Gogos, George
Goldwasser, Yaakov
Gomes, Giovanna
Gomez, Robin
Gonçalez, Amanda
Gonzalez, Ignacio
Gonzalez, Susana
Gonzalez Torralva, Fidel
Gonzalez-Andujar, Jose
Goodhue, Rachael
Góralski, Grzegorz
Gossler, Gabriel
Gotz, Ana
Goulart, Michael
Goyal, Neha
Granger, Sylvie
Gressel, Jonathan
Grey, Timothy
Grichar, James
Grubbs, Rebecca
Grujić, Mica
Gu, Xing-You
Gulab, Rangani
Gülce, Mehmet
Gulden, Robert
Gulec, Duran
Guo, Wenlei
Guo, Yiqing
Gurgel, Ely
Guse, Jan
Güzel, Nuran Pınar
Güzel, Okan
Haghnama, Kianoosh
Hahn, Juliane
Hain, Ruediger
Haley, Scott
Hall, Linda
Hall, Tilghman
Hamouz, Pavel
Hamouzová, Kateřina
Han, Heping
Han, Jun
Han, Qingxiang
Hançerli, Levent
Hancock, Jillian
Hanif, Zahid
Hanson, Bradley
Hansson, David
Haque, Md. Shahidul
Harabiš, Filip
Hare, Flemming Frederik
Harker, K.
Harlow, Christopher
Harries, Martin
Harrington, Kerry
Hashem, Abul
Hashim, Saima
Haug, Erika
Hauvermale, Amber
Havlickova, Vendula
Hayes, Robert
Heiermann, Monika
Heijne, Bart
Heini, Julia
Heiniger, Ron
Hejda, Martin
Helsen, Herman
Hemerik, Lia
Henry, Gerald
Henry, Ryan
Henschke, Christian
Hereward, James
Herms, Catherine
Hernández, Dante
Hernández Hernández, Fidel
Hernández Hernández, Oddonell
Hernandez Plaza, Eva
Herrmann, Johannes
Hess, Martin
Hicks, Helen
Hoffmann, Andrea
Hoffmann, Mark
Hofmeijer, Merel
Holec, Josef
Holland, John
Holm, Anne-Kari
Holst, Niels
Honaas, Loren
Honěk, Alois
Hoová, Thien Thanh
Hosek, Petr
Hoťka, Peter
Hotz, Simon
Hoyerova, Klara
Hu, Guanfang
Hu, Luyang

7th International Weed Science Congress June 19–25, 2016 Prague, Czech Republic

Huang, Hongjuan
Huang, Yao
Huang, Zhaofeng
Hugo, Elbé
Huiting, Hilfred
Hull, Richard
Hulting, Andrew
Hupka, Daniel
Hurrell, Geoff
Hutchings, Sarah-Jane
Hynes, Russell
Ibrahim, Usman
Ida, Noriyuki
Ikeda, Fernanda
Im, Ji-Hoon
Imaizumi, Toshiyuki
Inácio, João
Inci, Deniz
Inman, Matthew
Inoue, Miriam
Ipou Joseph, Ipou
Irfan, Mohammad
Irmak, Suat
Isik, Dogan
Islam, Faisal
Islam, Md.
Itano, Ai
Itaya, Tomotaka
Iwakami, Satoshi
Iwasaki, Arihiro
Iwata, Rie
Izquierdo, Jordi
Jabbour, Randa
Jabran, Khawar
Jackman, Sarah
Jackson, Lucy
James, Trevor
Jamjod, Sansanee
Jan, Asad
Janků, Jaromír
Janovský, Zdeněk
Janusauskaite, Daiva
Jeanneret, Philippe
Jennings, Katie
Jensen, Peter
Jessop, Robin
Jhala, Amit
Jhonny, Rabefiraisana
Ji-Soo, Lim
Jia, Chunhong
Jiang, Linjian
Jibrin, Dahiru
Joachimiak, Andrzej
Joel, Daniel
John, Wallace
Johnson, Eric
Jokar, Leila
Jones, Brittany
Jordan, David
Jowkar, Ladan
Jugulam, Mithila
Juntwait, Kelsey
Jursik, Miroslav
Kaasik, Riina
Kabiri, Stella
Kaczmarek, Sylwia
Kaczmarek-Derda, Wiktoria
Kadziene, Grazina
Kadziuliene, Zydre
Kaiser, Yasmin
Kakhki, Seiied Hosien
Kalivas, Dionissios
Kamboj, Baldev
Kambou, Georges
Kanellou, Ilektra
Kang, Hunchol
Kannan, Sivagamy
Kar, Sudeshna
Karabacak, Selvinaz
Karaca, Fatih
Karácsony, Péter
Karam, Decio
Karamaouna, Filitsa
Karhikeyan, R.
Karmollachaab, Aziz
Karnieli, Arnon
Karsten, Heather
Kashefi, Javid
Kaspary, Tiago
Kassis Carvalho, Fernando
Kataoka, Ikuo
Kathir, Kathiresan
Kati, Vaya
Kato-Noguchi, Hisashi
Kaundun, Deepak
Kaundun, Shiv
Kaur, Maninder
Kaur, Navneet
Kaya, Ilhan
Kaya Altop, Emine
Kaydan, Mehmet
Kazerooni Monfared, Ebrahim
Keenan, Michelle
Keene, Clair
Keller, Martina
Kena, Alexandra
Kerekes, Gabor
Keshtkar, Eshagh
Keskin, Fatma
Khadi, Basavaraj
Khalaf, Husam
Khan, Muhammad
Khater, Emad
Kheirkhah, Mir Masood
Khiari, Ramla
Khiavi, Hossein
Kierzek, Roman
Kikugawa, Hiroshi
Kim, Da-Som
Kim, Dong-Gil
Kim, Do-Soon
Kim, Chang-Seog
Kim, Inchul
Kim, Jae Deok
Kim, Jin-Won
Kim, Su-Hwan
Kim, Young Sook
Kioleoglou, Vasilis
Kleemann, Samuel
Kleinhenz, Matthew
Kleinman, Ziv
Klem, Karel
Kliper, Tom
Knezevic, Stevan
Ko, Young Kwan
Kobayashi, Hiroyuki
Kochnev, Yury
Koçtürk, Barış
Koecher, Cornelia
Kohlschmid, Eva
Kolarova, Michaela
Kolodii, Sergii
Kongsangdow, Sermsiri
Koning, Laurie
Konôpková, Jana
Konstantinović, Bojan
Konstantopoulos, Konstantinos
Koo, Dal-Hoe
Korenko, Stanislav
Kósa, Géza
Kosnarova, Pavlina
Kots, Sergiy
Kouanda, Nongamanégré
Kouchakpour, Sepideh
Kovács, Károly
Kraehmer, Hans Joerg
Krawczyk, Roman
Kristensen, Michael
Kristiansen, Paul
Kroulík, Milan
Kruger, Greg
Kubes, Martin
Kubsik, Krzysztof
Kucharski, Mariusz
Kudsk, Per
Kuklina, Alla
Kulakov, Vitaly
Kulakova, Yuliana
Kumar, Bhumesh
Kumar, Sunny
Kumarappan, Subbu
Kumsueb, Benjamas
Kundu, Abhishek
Kunz, Christoph
Küpper, Anita
Kurokawa, Shunji
Kurose, Daisuke
Kuzikaro, Hadar
Kwolek, Dagmara
Kysilková, Kristýna

Labrada Romero, Ricardo
Ladha, J.
Lagopodi, Anastasia
Lamb, Alyssa
Lamego, Fabiane
Langarica Fuentes, Adrian
Laoken, Anucha
Laor, Yael
Lapiņš, Dainis
Larose, Hailey
Lasorella, Cesare
Lati, Ran
Lattanzio, Veronica
Lawrence, Nevin
Lawton-Rauh, Amy
Le Corre, Valérie
Le Goupil, Gael
Le Roux, Johannes
Lee, DoKyoung
Lee, Dong J
Lee, Imshik
Lee, In-Yong
Lee, Jeongran
Lee, Keon
Leiva, Andrea
Lemerle, Deirdre
Lenart-Boroń, Anna
Leon, Ramon
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7th International Weed Science Congress
June 19–25, 2016
Prague, Czech Republic

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7th International Weed Science Congress June 19–25, 2016 Prague, Czech Republic

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7th International Weed Science Congress
June 19–25, 2016
Prague, Czech Republic

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