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1. Spread, monitoring and management of fall armyworm (FAW)

Organizer: R Muniappan

Lead

O1-1. The role of USAID in management of the fall armyworm

John Bowman[1] and R Muniappan[2]

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Since the fall armyworm (FAW) (*Spodoptera frugiperda*) reached Nigeria in early 2016, USAID has been setting up a task force to tackle the pest. The IPM Innovation Lab, funded by USAID, became involved in addressing this pest once it spread to Ethiopia in May 2017, one of the program's host countries. Even though several options were proposed by different international organizations for management of FAW, the IPM Innovation Lab strongly believes in adopting biological control of FAW not only on its preferred host, maize, but also on all other crops attacked by it. The program has identified several egg and larval parasitoids of FAW in East and West Africa and has been promoting augmentative release of egg parasitoids, *Trichogramma* spp. and *Telenomus remus*, and the larval parasitoid *Habrobracon hebetor*. In addition, the IPM Innovation Lab has conducted awareness and management workshops for FAW in Ethiopia and Nepal as well as training on mass rearing and release of parasitoids of FAW in Kenya and Niger for about 20 different countries in Africa and Asia.

Invited

O1-2. The fall armyworm, *Spodoptera frugiperda* (J.E. Smith): Status and management options in Nepal

Lalit Prasad Sah[1], Ditya Lamichhaney[1], Luke A Colavito[1], George Norton[2] and R Muniappan[2]

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Fall Armyworm (FAW) *Spodoptera frugiferda* (J.E. Smith), is a voracious pest of agricultural crops with native origins in the Americas. FAW is likely to create a high risk of food insecurity especially in the hills of Nepal where maize has been established as the principal food crop. A national level task force has been formed with chairmanship of the Secretary of Ministry of Agriculture and Livestock Development (MoALD) and involving representatives from Government of Nepal (GON), International Projects, Research Centers, and freelance experts under which a technical committee has been formed for FAW surveillance and protocol development and quarantine alerts. Detection surveys and regular monitoring of FAW, orientations on FAW identification tips, distribution of FAW identification kits, IEC materials development, and awareness are considered joint efforts of all the stakeholders involved. In addition, a national level stakeholders' workshop on the preparedness and rapid response of the threats of FAW in Nepal and an international workshop on Fall

Armyworm Preparedness and Management involving different national and international experts and stakeholders has been conducted to produce synergy in effectively fighting against the pest. The FAW effort is building on the successful approaches and last mile supply chains developed to address the invasive pest by the USAID-funded IPM Innovation Lab program. A key aspect is rapid mobilization of the private sector through identification of IPM based approaches and products and training.

O1-3. Push-Pull farming system controls *Spodoptera frugiperda* in Africa: A lesson from Africa

Zeyaur Khan, Charles Midega and Jimmy Pittchar

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Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), a pest native to tropical and sub-tropical America, invaded Africa in early 2016, and now affects at least 40 African countries, causing total crop loss amounting to over $6.2 billion per year. *S. furgiperda* has recently been reported to invade the Indian sub-continent and other Asian countries. Integrated pest management (IPM) packages like the Push-Pull technology (*www.push-pull.net*) which eliminate pesticide use, and deploys natural processes are more suitable and cost-effective. Push-pull is a farming system intensification approach that involves attracting insect pests with trap plants (pull) such as Napier grass (*Pennisetum purpureum*) or *Brachiaria* grass, while driving them away from the main crop using a repellent intercrop (push), *Desmodium* spp., commonly known as desmodium, and attracting natural parasitoids and predators to the field. In the rhizosphere, chemicals secreted by desmodium roots inhibit attachment of germinated parasitic striga weeds to corn or sorghum roots and abort germination of striga seeds which are rapidly depleted in the soil. Moreover, it improves soil fertility by fixing nitrogen, improving carbon sequestration, organic matter, moisture retention, and soil biota, and prevents further degradation of soil. The climate-adapted push-pull technology significantly reduces plant damage by *S. furgiperda* and is the first IPM management tool for the pest in Africa and is well suited to agro-ecosystem intensification needs of smallholder mixed farming systems in Africa and beyond. A lesson can be learned from the Push-Pull farming system developed in Africa for control *S. furgiperda* in Asia and Latin America.

O1-4. Management of fall armyworm, *Spodoptera frugiperda* with semiochemicals

Markandeya Gorantla[1], Agenor Mafra Neto[2], Rodrigo DaSilva[2], Rafael Borges[3], Ruben Machota[3], Ligia Bortoli[3], Sashidhar Burla[1], Sharadraj[1] and Suhasini Guruswamyachar[1]

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The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is a native pest in the tropical regions of the United States. This pest has developed resistance to Bt corn hybrids just 3 years after commercialization in Brazil and became a challenging pest for control. These implications have paved the way to investigate the efficacy of a novel control tool, SPLAT FAW, a Specialized Pheromone Lure Application Technology based on controlled release of a semiochemical that exploits mate-seeking behavior of fall armyworm in corn-growing fields in Argentina and Brazil. In Argentina, SPLAT FAW was applied by tractor twice at a rate of 500 g per ha (1,000 500-mg dollops per ha) at the V5_V7 stage and V10 stage of the crop. Fields treated with SPLAT FAW showed a 68% reduction in delta trap capture rates, with highest moth catch of 20% on average in treated fields versus 61.75% in control fields during V9 and V10 stage. Percent plant damage was high in the V10 stage both in SPLAT FAW-treated and control fields, 34.72% and 57.11%, respectively. According to Davis damage scale, plant damage in SPLAT FAW-treated fields varied from

34.72% to 38.19%, while it eventually increased from 27 to 57.11% at V4, V7, V9, and V10 stage in control field. An average of 38.5% of leaf damage reduction was observed in the SPLAT FAW-treated area, with corn ear damage reduced by 27.4% at the R6 stage. In Brazil, SPLAT FAW was applied twice at the same application rate as in Argentina, once at the seedling stage and again at the V4-V5 stage, by tractor. SPLAT FAW-treated fields showed a trap shutdown rate of 67%, with highest number of moths captured in control using water traps at V3 stage. According to Davis damage scale, plant damage was scored at higher than 3 between V2-V10 stages in control field farmer practice area. The results revealed that percent leaf damage was reduced to 30% and plant infestation by fall armyworm larvae was reduced by 48% on average. Average percent plant damage in SPLAT FAW-treated and control fields was 13.8% and 19.76%, respectively. The Number of larvae was reduced to 48% (115 larvae) in the SPLAT FAW-treated field, compared to 225 larvae in control from V2-V10 stage. Corn ear damage will be observed at R6 stage in SPLAT FAW-treated and control areas.

O1-5. Effectiveness of locally recruited egg parasitoids against the fall armyworm in sorghum in Africa

M N Ba[1], A Lamine[1], L Karimoune[1], A Doumma[2] and R Muniappan[3]

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The fall armyworm (FAW), *Spodoptera frugiperda*, an insect native to tropical and subtropical Americas has recently spread to Africa and become a serious pest mainly to maize but also sorghum in some places. The emergency response relied on the spray of synthetic insecticides. Biological control can offer an economically and environmental friendly alternative and contribute to an Integrated pest management approach. Consequently, surveys of FAW natural enemies were conducted in maize and sorghum fields in different locations in Niger in 2017 and 2018. The parasitoids encountered included several Braconidae, Ichneumonidae and Tachinidae fly parasitizing larvae of the fall armyworm. In addition two egg parasitoids were also encountered among which, *Trichogramma* sp. and *Telenomus remus* Nixon (Hymenoptera: Platygastridae). Interestingly *T. remus* is the main egg parasitoid of *S. frugiperda* in the Americas where it is also used in augmentative biological control programmes. The effectiveness of the two egg parasitoids was assessed in the laboratory. The most effective parasitoid is *T. remus* as it parasitized up to 75% of FAW eggs compare to only 27% for *Trichogramma* sp. Likewise *T. remus* yielded more progeny (7-fold) than *Trichogramma* sp. Females of *T. remus* had a lifespan of nearly 17 days, and the development from egg to adult took 10 days at a temperature of 27.8 ± 1°C and a relative humidity of 85.5 ± 0.5%. Culture of *T. remus* has been successfully established in the laboratory, laying the groundwork for using *T. remus* in augmentative releases against the FAW in Africa.

O1-6. Assessment of bio-pesticides against fall armyworm

Y Dhoj[1], K Ghimire[2] and GC A[3]

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The fall armyworm (FAW), *Spodoptera frugiperda*, is a pest native to the Americas and is especially devastating to maize and rice. A recent report of FAW incidence in India has alarmed Nepal considering the pest's rapid migration. Farmers have long been using synthetic pesticides to control disease and pests. However, inappropriate use of hazardous pesticides has caused several health and environmental issues. Biopesticides are the best alternatives to synthetic pesticides and it is urgent to assess effectiveness of

biopesticides suitable for Nepal against FAW. The paper attempts to review the globally practiced biopesticides against FAW. The result showed that among 12 registered biopesticides, several were found effective against FAW, and the most effective were neem-based pesticides and Bt.

O1-7. Bio-pesticides and farmer scouting for fall armyworm management

M Tamò, G Tepa-Yotto, G Goergen, O K Douro-Kpindou and K Fiaboe

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The fall armyworm (*Spodoptera frugiperda*), FAW, is difficult to control with pesticide application because of the cryptic feeding habit of the developing caterpillars. While synthetic pesticides can provide some control, they should not be used as the first and sole option, for obvious environmental, ecological and human health-related reasons. Bio-pesticides are emerging as a true and efficient alternative to chemicals, if used against the most exposed FAW stages, eggs and young caterpillars. They can be produced locally, and provide additional income to disadvantaged groups such as women and youth. One of the critical factors in applying bio-pesticides for FAW control is the timing of the application. In collaboration with several partners, IITA is developing a smartphone app, Farmer Interface Application, FIA, to enable low-literacy farmer to scout their own field at the right moment, monitor the presence of FAW, and get guidance on how and what to spray. Users can navigate in the FIA through simple to understand symbols as action buttons. There will also be provision for voice commands in local languages for certain actions or required inputs. The FIA integrates short educational/training animation videos which will display in local languages 1) how the FIA works; 2) some basic aspects of pest biology and ecology, including recognition of life stages and damage symptoms; 3) when and how to scout; 4) when and how to take appropriate protection measures, e.g. spraying bio-pesticides.

O1-8. Tailoring IPM technologies against fall armyworm for the small-scale maize production systems agro-ecologies in Africa

K K M Fiaboe, G Tepa-Yotto, M Tamo, P Chinwada, G Goergen, S Ajala, D Chikoye, R Djouaka, A Togola, A Fotso-Kuate, A Abang and M G Saethre

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Fall armyworm (*Spodoptera frugiperda* (JE Smith), Lepidoptera: Noctuidae) a devastating pests in maize production, confined for long in the Americas, which became invasive in Africa since 2016. Across the continent emergency interventions were quickly adopted by national authorities mainly based on chemical pesticides. Unfortunately, three years down the line, little effort has been made to domesticate technologies adopted from the Americans. Scientists from different fields of expertise at the International Institute of Tropical Agriculture have conducted trials in different agro-ecologies to assess performance of current practices and potential IPM components to consider in the fight against this pest in the local context. Current practices in small-scale farming conditions are documented, efficacy trials of various chemical, botanical and bio-pesticides were conducted, indigenous and exotic natural enemies assessed, potential of different lines to resist to or tolerate FAW was assessed, spread potential, early warning and decision making thresholds tested and various cultural practices tested for their efficacy in managing FAW in the small-scale farming condition in Africa. The present paper discusses the implication for the small-scale farming systems in Africa.

O1-9. Towards developing IPM options for the fall armyworm (*Spodoptera frugiperda*) in maize in Africa: current status and prospects

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Fall armyworm (*Spodoptera frugiperda*) is one of the devastating pests of maize first reported from Africa in 2016. The present massive application and indiscriminate use of pesticides in Africa against FAW necessitated to look for environmentally sound control options. Different control options have been tested to reduce the damages caused by this pest. Pest monitoring and early warning including mobile app and pheromones traps, were developed, tested and massively deployed. Handpicking and crushing egg masses and larvae; application of soil and sand to leaf funnels; spray plants with sugar solution to attracts ants to feed on FAW larvae, were some of the cultural and physical control options practiced by smallholder farmers. Botanicals including water extract of neem and other locally grown medicinal plants; intercropping maize with legumes and uses of the push pull technology were other options farmers are using depending on locations and farming system. Seven species of native natural enemies were reported as new association with *S. frugiperda*. Enhancing the roles of native biological control agents including the larval parasitoid (*Cotesia icipe*) and egg parasitoids (*Telenomus remus* and *Trichogramma chilonis*) as augmentative release could play a significant role in developing integrated management strategy against the pest. There is an urgent need to test efficacy of various management options and develop appropriate strategy for S. *frugiperda* management.

O1-10. Fall armyworm in Cambodia: Surveillance, detection and response

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In July 2018, fall armyworm was first detected in Asia. The pest was first reported in Karnataka state, India. By the end of 2018, it was confirmed in Sri Lanka, Bangladesh and Myanmar. Fall armyworm occurrence was also confirmed in Thailand and China by the end of the first quarter of 2019. USAID IPM IL delegates conducted the first awareness raising lecture in Cambodia in March 2019. A discussion with the leadership of Cambodian general directorate of agriculture ensued. Following this discussion, Cambodian NPPO, IPM program and university faculty joined regional workshops in Thailand and India on fall armyworm invasion in Asia. An outbreak of plant damages on corn were reported from Malai district in Banteay Meanchey province of Northern Cambodia in May 2019. Field collection confirmed that the damages were associated with fall armyworm infestation. This constitutes the first report of fall armyworm incidence in the country. Subsequently, pheromone-based surveillance coupled with a field survey to estimate the extent of the damage was conducted in five key provinces in Northern Cambodia. A survey of fall armyworm parasitoid was taken out with an objective of identifying locally occurring natural enemy that can be mass-reared and released as a part of the response against the pests' invasion. This talk will report the progress of this surveillance and response programme.

2. Herbicide-resistant weeds – a global perspective

Otganizers: Baruch Rubin and Samunder Singh

Lead

O2-1. Herbicide-resistance in dryland farming: Global status

Baruch Rubin

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Herbicide-resistant weeds (HR) are global problem in agricultural habitats including crops grown under dryland and irrigated conditions. In arid and semi-arid countries, and many Mediterranean-climate countries, rainfall events occur only during the short wintertime allowing one crop per year only. Under these conditions, where the main competition between crops and weeds is on water, the farmer has limited choice of crops, favoring reduced tillage and monoculture of cereals or/and pulses. Uncertainty of having crop to harvest leads the farmers to avoid pre-emergence application of herbicide whilst over- relying on post-emergence herbicides comprising little or no-soil activity. Lack of crop rotation results in repeated use of herbicides with same or similar mode of action (MOA) resulted in a strong selection pressure that facilitated the evolution of herbicide-resistant grass and broadleaved weeds (HR). The main grass weeds infesting winter crops that evolved HR are *Lolium* spp. (ryegrass), *Avena sterilis* (sterile oats), *Phalaris minor* (littleseed canarygrass) and *Phalaris paradoxa* (hood canarygrass). The repeated use of ACCase (acetyl CoA carboxylase)- and ALS (acetolactate synthase)-inhibiting herbicides for grassweed control, resulted in more than 100 cases of reported HR weed populations in the region many of them multiple resistant to more than one MOA. The main broadleaved weeds that evolved HR, belong mostly to the *Brassicaceae* and *Asteraceae* families with hundreds of HR populations, many of which conferring multiple resistance. The wide spread of HR weeds under dryland farming associated with low profit commodity crops and lack of alternative chemical weed management practices pose a real threat to the dryland farming system.

Invited

O2-2. Herbicide resistant weeds – detection, monitoring and management

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Herbicide resistant weeds are the most challenging problem in the current weed management even in those countries where herbicide-tolerant crops are commercially cultivated. Tank-mix or rotation of herbicides with different modes of action (MOA) is a commonly proposed method to delay herbicide resistance development and to manage herbicide resistant weeds. Prior to implementation of tools for managing herbicide resistant weeds, it is essential to diagnose herbicide resistance as early as possible. We developed various methods for rapid detection of herbicide resistant weeds such as growth pouch test, trimmed seedling and stem node assays, chlorophyll fluorescence assay, and spectral image analysis. Regular monitoring of herbicide resistant weeds in terms of their geographical distribution and expansion is prerequisite for a final implementation of management strategy to manage herbicide resistant weeds. Nationwide monitoring of herbicide resistant weeds in Korean paddy fields showed region-specific distribution of herbicide resistant weeds, suggesting

that weed management should be region-specific as well. For management of herbicide resistant weeds, one-shot application of pre-mixed herbicides with different modes of action (up to 4 different modes of action) is the most commonly used tool. Due to the increasing threat of herbicide resistant weeds, sequential application of pre-emergence herbicides at machine transplanting of rice followed by post-emergence one-shot pre-mixed herbicides becomes a common practice for herbicide resistance management in rice cultivation.

O2-3. Management options for herbicide-resistant weeds

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Weeds are a major constraint to crop production in Australian cropping systems. They cost more than AU$ 4 billion to Australian grain and cotton growers. Because of the intensive use of herbicides with the same mode of action, several weeds have developed resistance to commonly used herbicides. In fallows and cotton production systems, glyphosate is used widely, which has resulted in the evolution of glyphosate-resistant weeds. In Australia, more than 15 weed species have developed resistance to glyphosate. Management of these weeds needs to be based on integrated systems. Chemical and non-chemical control measures need to be integrated to achieve effective and sustainable weed control. Some examples of non-chemical control methods are crop competition, crop rotations, harvest weed seed control, targeted tillage, etc. This presentation will provide a brief overview of the tactics available to control herbicide-resistant weeds in Australian cropping systems.

O2-4. A computational predictive approach to address target specific resistance to pesticides

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AgPlenus aims to discover and develop effective and safe agrochemical products through utilization of proprietary computational predictive technologies. The Company's current product focus is on herbicides, insecticides and fungicides, and it has already established a promising pipeline and is collaborating with leading market players including BASF and ICL. AgPlenus is a fully owned subsidiary of Evogene Ltd. (TASE, NASDAQ: EVGN). AgPlenus' unique discovery and optimization technologies combine state-of-the-art biology-driven, target-based, computational-chemistry capabilities with extensive chemical and biological know-how. We have successfully generated workflows and models that address key challenges in product development, such as efficacy improvement, toxicity reduction and overcoming of resistance. The increasing amount of biological data along with the development of sophisticated tools have a tremendous impact on the ability to overcome Target Specific Resistance (TSR). Approaches based on these advancements will enable prudent selection in advance of both biological targets of interest and promising starting-point compounds for discovery and optimization. Additionally, molecular-dynamics-based free-energy calculation methodologies will facilitate design of new resistance-avoiding compounds as well as re-design of existing compounds to overcome resistance mutations. As part of our proprietary computational platform, PointLead, we have generated a computational scheme that addresses TSR through integration of genomic and structural data and use of the abovementioned methods. Implementing free-energy calculations, we were able to retrospectively explain the effects of known resistance mutations in some case studies that are relevant to crop protection, qualitatively as well as quantitatively. This enables us to design/re-design crop protection compounds that will effectively bypass TSR.

O2-5. Omics to elucidate extrachromosomal DNA-mediated herbicide-resistance mechanisms

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Evolution of herbicide resistance in weed species is a major constraint to crop production around the globe. Many agriculturally important weed species have naturally evolved resistance to several major herbicides. The investigation of physiological, genetic, and molecular mechanisms of weed resistance to herbicides have uncovered several novel, and exciting results related to fundamental, evolutionary mechanisms of herbicide resistance in weeds, specifically, to glyphosate, one of the important herbicides used in crop production. Because of wide acceptance of Roundup Ready crops in many countries, glyphosate has been used extensively for weed control, consequently, many weeds have developed resistance to glyphosate. The target site of glyphosate is 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), an important enzyme in shikimate pathway. Several types of mutations including amplification of EPSPS gene can bestow weed resistance to this herbicide. Recently, our genomics and molecular cytogenetic research indicated that the *EPSPS* gene amplification in glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*), was driven by extra-chromosomal, circular DNA (eccDNA) molecules. Each eccDNA carried one copy of the target gene *EPSPS*. However, freed from the rules of mitosis, EPSPS genes can multiply rapidly during the growth of the sporpohyte and produce copy number variation in somatic cells. The somatic cells with amplified *EPSPS* survive in the presence of the herbicide, and this acquired trait is transmitted to the germ cells and the progeny. Importantly, it appears that the eccDNA replicons are transmitted by an unknown mechanism of tethering to mitotic and meiotic chromosomes and modulate rapid glyphosate resistance response.

O2-6. Herbicide resistance in wheat and rice – new challenges for the chemical industry

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One of the biggest challenges for the country is increasing food production for growing Indian population. It becomes more critical for staple foods like wheat and rice. In the recent past wheat and rice are encountering very serious threat of growing herbicide resistance/tolerance of weeds especially to Acetyl coenzyme A carboxylase (ACCase) inhibitors: but it is now well known fact that *Phalaris minor* in wheat and *Echinochloa colonum* in rice is showing herbicide resistance to FOP chemistry reducing the efficacy drastically especially in states like Punjab, Haryana for wheat and Kerala, Tamil Nadu and Andhra Pradesh for rice. Similarly, inhibitors of acetolactate synthase (ALS) enzyme (also known as acetohydroxyacid synthase, or AHAS) which affect grasses and dicots alike off late recently *Phalaris minor* in wheat and *Cyprus difformis* in rice is showing herbicide tolerance to sulfonylureas (SUs). It has become a challenge for the chemical industry to find new chemistries to manage the weeds. It is a big stumbling block in terms of huge costs to develop new chemistry and even if we do, it is one in a billion to get a new molecule satisfactorily. Hence, chemical industry is trying to work for integrated approach. Similarly, Adama India is trying to address the issue with differentiated solutions consisting of molecules with different site of actions. Hopefully, Adama India will work for better management of wheat and rice weeds.

O2-7. Management strategies for herbicide resistant weeds in India

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Phalaris minor has become the most dreaded wheat weed in north India due to multiple resistance to isoproturon, diclofop, fenoxaprop, clodinafop, pinoxaden, sulfosulfuron, mesosulfuron + iodosulfuron (Atlantis), and fenoxaprop + metribuzin (ACM9) mediated by enhanced metabolism and target site mutation. While *P. minor* was still a challenge; resistance also evolved in *Avena ludoviciana* to clodinafop, fenoxaprop, sulfosulfuron, ACM9 and Atlantis; *Rumex dentatus* and *Chenopodium album* to metsulfuron, sulfosulfuron, carfentrazone, Atlantis and *Polypogon monspeliensis* to sulfosulfuron and Altantis. This sudden spurt in resistant weeds and the absence of an effective new herbicide has made weed management most challenging. An integrated approach using agronomical, chemical, mechanical and biological methods is required for effective weed control. Herbicides have become an integral part of any control measure and in the absence of a new molecule, there is need to fall back on old chemistry, herbicide mixtures and their sequential application. Studies conducted in Haryana State using various combinations and sequences provided satisfactory control of resistant weed species; however, none of the herbicides alone was satisfactory, thus adding cost. Pendimethalin alone or mixed with PRE followed by POE herbicides provided effective control. Isoproturon that was earlier banned due to overwhelming resistance in *P. minor* may come back for its effective control of *C. album*, *P. monspeliensis* and *R. dentatus*. A rapid screening test developed is very helpful in selecting effective alternate herbicide. Wheat seed treatment with *Bacillus* and *Providentia* spp. improved wheat vigour and lowered herbicide toxicity; the results on *P. minor*; however, were inconsistent.

O2-8. Glyphosate-resistant weed impacts at a global scale

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Much of global crop production for food and fiber depends of the use of herbicides to control weeds, which negatively impact production and product quality. Great strides have been made in the discovery of novel herbicides and in the development of traits to broaden the set of herbicides that can be used in diverse crops. Along with these developments, however, the on-going issues of herbicide resistant weeds have complicated what once seemed to be the modern miracle of weed control with herbicides. Glyphosate has had a major impact on global weed control in many crops, cropping situations, ecosystems, and urban environments. Dubbed a “once in a century” herbicide, it has been used for many years as one of the major herbicides in the world. Once glyphosate was thought to be immune from resistance issues because of its unique mode of action on a critical plant pathway for production of vital amino acids. Today, we know that nature has found clever ways to develop plant resistance go glyphosate. The role of this important herbicide in crop production and in resistant weed issues will be covered in this presentation.

3. Integrated pest management (2)

Organizers: Axel Dinter and Dinesh Rathi

Lead

O3-1. Rynaxypyr® (Chlorantraniliprole): A diamide insecticide with low toxicity to beneficial arthropods and honey bees providing excellent tools (Coragen® and Ferterra®) for use in India integrated pest management (IPM) programs

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Rynaxypyr® insecticide (chlorantraniliprole) is an anthranilic diamide insecticide (IRAC group 28) with a novel and very specific mode of action activating insect ryanodine receptors causing impaired Ca2+-ion regulation, paralysis and ultimately death of sensitive species. Anthranilic diamide insecticides exhibit >500-fold differential selectivity toward sensitive insects over mammalian receptors. In worst-case laboratory glass plate tests, the two sensitive indicator species, *Aphidius rhopalosiphi* (DeStephani-Perez) (Hymenoptera: Braconidae) and *Typhlodromus pyri* Scheuten (Acari: Phytoseiidae), were not sensitive to the formulated product Coragen® at up to 750 g Rynaxypyr® per ha, the maximum rate tested, indicating low toxicity for non-target arthropods. Low risk for non-target arthropods was confirmed in a wide range of tests with numerous other beneficial arthropods (e.g. parasitoids, predatory mites, predators like chrysopids, anthocorids, coccinellids and syrphids) under worst-case laboratory and field conditions including important fall armyworm pest antagonists. An added advantage of beneficial safety is to reduce or remove the risk of insect pest flares, which commonly occur when key predators and parasitic wasps are affected by insecticide sprays. Overall, Rynaxypyr® and the formulation Coragen® demonstrated low risk to numerous non-target arthropod/organism species including honeybees, foliage and soil-dwelling beneficial arthropods, earthworms, and soil micro-organisms or to have rather low and transient short-term impact. Rynaxypyr® insecticide formulations are excellent tools that became globally widely recommended in integrated pest management (IPM) programmes and conserve naturally occurring beneficial arthropods in the field as well as protect predators and parasitic wasps released for greenhouse pest control**.**

Invited

O3-2. Susceptibility of *Tuta absoluta* populations to insecticides in South Africa

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The tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a serious pest of tomato and control relies mainly on the application of insecticides. Resistance has been reported to various insecticides in South America and Europe. This invasive pest was first detected in South Africa in 2016 and the status of susceptibility to insecticides registered for its control is unknown. The aim of the study was to determine baseline susceptibility of *T. absoluta* collected from two localities in South Africa to registered insecticides (spinetoram, spinosad, chlorantraniliprole, emamectin benzoate, indoxacarb, lufenuron and lambda-cyhalothrin). A leaf dipping bioassay (IRAC method 022), was conducted. Mortality was assessed after 72 hours of exposure to all the active ingredients, except for lufenuron (growth regulator) which was assessed after 96 hours. Mortality data from the dose-response bioassays were subjected to probit analysis using

POLO SUITE®. The LC50 values estimated for all the active ingredients were well below the recommended dosage rates, except for lambda-cyhalothrin. This was, however, expected since it is known that this pest evolved resistance to pyrethroids. Since the levels of susceptibility is high, it is important to put insect resistance management program in place to maintain susceptibility of *T. absoluta* to insecticides in South Africa.

O3-3. Fall armyworm (*Spodoptera frugiperda*): An invasive pest & its management strategy

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Fall armyworm (FAW), *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae), is native to tropical and subtropical regions of the Americas and is the key insect pest of maize in tropical regions. In India, the occurrence of this invasive pest was first reported in 2018 in Karnataka. Since then, it is spreading to other parts of the country and causing heavy crop losses. In African countries, synthetic insecticides have been widely used to slow its spread and minimize damage to maize fields. Although synthetic insecticides play an important role in FAW management, it has developed resistance to many insecticides. Considering the seriousness of the pest and insecticide resistance, an immediate action plan is required before the pest reaches the alarming stage. The present study aimed to develop a comprehensive Insect- Pest and Resistance Management Strategy to manage FAW. This is based on timely and need based application of insecticides, rotation of insecticides with safer botanicals along with other pest management tools such as pheromone for monitoring. Initial application of Neem based formulation @ 2 ml/L (ONTEEM) as the first spray at V2-V3 (7-14 days) followed by a novel insecticide combination of Avermectin + Organophosphate (ELEKTIN) @750 gm/ha at pest ETL was found to be the best strategy for effective and resistance management against fall armyworm. Thus, the integration of various techniques effectively controls the FAW menace and helps to avoid resistance build-up and pest outbreak. Judicious use of pesticide reduces the number of sprays and helps to conserve natural enemies and environment.

O3-4. Tetraniliprole, a new tool for management of Lepidopteran and Coleopteran pests

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Tetraniliprole, is a novel anthranilic diamide insecticide, discovered and developed by Bayer AG for the management of Lepidopteran and Coleopteran pests intended for key insecticide markets world-wide. Tetraniliprole can control economically important pests of broad-acre, fruit and vegetable crops including; foliar feeding caterpillars, stem borers, leafminers and beetles. It also offers useful activity against, some sucking pests when used in combinations. The favourable beneficial profile of Tetraniliprole is highly suited for integrated pest management (IPM) systems. The biological profile of Tetraniliprole against important pest species will be presented, including examples of how Tetraniliprole products can fit with conventional and IPM practices for controlling rice stem borers and apple codling moth. Tetraniliprole is a member of the established Ryanodine receptor modulator (IRAC Group 28) Mode of Action (MoA). Insecticide resistance management (IRM) compliant strategies with other MoA insecticides, biological and agronomic practices will be discussed.

O3-5. Effect of Alltech 5075 on entomopathogenic nematodes, root-knot nematodes and their infestation on tomato plants

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An organic product consisting of proprietary blend of fermentation and plant extracts with micronutrients (ACS 5075, Alltech®, Inc., Nicholasville, KY USA) was evaluated against four strains of entomopathogenic nematodes (EPN): *Steinernema feltiae* (SB12 (1), a wild enviroCORE strain and a commercial form e-NEMA), *S. carpocapsae* (e-NEMA), *Heterorhabditis bacteriophora*. Effects on egg hatching and survival of root-knot nematodes (RKN) were also examined. In greenhouse trials, prophylactic treatment was conducted to study the effect on RKN infestation. The mortality and survival of EPN infective juveniles (IJ) was recorded after 24 h treatment with four different concentrations of the product (4%, 7%, 8%, 10% ACS 5075) compared to control. There was no significant difference in survival of IJ with 4% product compared to the control. Further experiments on RKN were conducted at concentrations below 4% within the range of 0 - 3%. 10.5% RKN egg hatching was observed when exposed to 3% ACS 5075 concentration compared to 100% hatching in the untreated. A significant ($P<0.05$) reduction in juvenile survival was observed at 0.5% treatment, however, it dropped to zero when treated with 1% and above for *M. javanica*. Prophylactic treatment of ACS-5075 on *M. javanica* infected plants was found effective in terms of all growth parameters with 2.04- and 1.4-fold reduction in number of galls at 1% and 3% treatment concentrations, respectively. The product shows potential as a sustainable soil health alternative causing no harm to EPN at certain concentrations, while promising against RKN and towards plant growth promotion.

O3-6. Toxicity of imidacloprid on cabbage white butterfly, *Pieris rapae*

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Cabbage crop is attacked by *Pieris rapae* (Lepidoptera: Pieridae), which causes a lot of damage to cabbage crop varieties. Imidacloprid is a perfect insecticide. The usage of imidacloprid and nano imidacloprid test against *P. rapae* gave promising data. Results showed the LC_{50} of 133 and 31 ppm after *P. rapae* treated with different concentrations of Imidacloprid and nano Imidacloprid. Also, under field conditions, when *P. rapae* were treated with the Imidacloprid and nano Imidacloprid, the number of eggs significantly lower (55 ± 6.1 and 5 ± 7.2 eggs/female) as compared to 289 ± 6.9 eggs/female in the control. The percentage of egg hatching, larval mortality, malformed pupae and malformed adults significantly decreased in Imidacloprid treatments and almost reduced after nano Imidacloprid treatments. The weight of cabbage fruits significantly increased to 2566 ± 43.01 and 1210 ± 40.09 kg/ feddan as compared to 1780 ± 55.43 and 1200 ± 33.11 kg/ feddan in the control during season 2017 and 2018, respectively.

O3-7. Toxicity of spinetoram 120 SC on eggs and larvae of the pink bollworm, *Pectinophora gossypiella*

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The susceptibility of lab and field population of pink bollworm (PBW) to spinetoram 120 SC was assayed using diet incorporation and diet overlay method against neonates and 2nd instar larvae of PBW. The ovicidal activity was assessed by a surface coating method. The mortality data showed that spinetoram is highly toxic to neonates as well as to 2nd instar larvae of PBW. The variation in toxicity of spinetoram between neonates and 2nd instar larvae is due to variation in their behaviour. Neonates are initially more mobile whereas 2nd instar larvae bore inside, thereby, consuming more toxin in diet incorporation assays, thus, is found to be more susceptible. The LC_{50} is lower for the 2nd instar larvae (1.425-0.258 ppm from 24 to 48 h) as compared to neonates (5.293-2.014 ppm from 24 to 48 h). However, the diet overlay method was found to be more sensitive than the diet incorporation method against both neonates as well as 2nd instar larvae of PBW. Spinetoram efficacy data on eggs showed that only 46 to 52% eggs hatched as compared to 91% hatchability in the control. However, all the hatched larvae from treated eggs died within 24 h while in control, no mortality was observed. The neonate mortality in case of treated eggs may be due to the ingestion of spinetoram as they feed on eggshell during or after hatching. However, 48 to 54% treated eggs did not hatch so this indicated that spinetoram has some ovicidal activity.

O3-8. Bioefficacy of pendimethalin in paddy husk biochar amended direct seeded rice

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Crop residues are the largest renewable resources on earth, commonly burned in the field. These residues can be utilized by converting them into biochar and add to soil for fertility improvement and carbon sequestration. However, its incorporation in soil reduces efficacy of herbicides in the soil due to greater sorption and thus has implications on current weed management. Direct seeded rice (DSR) culture has severe weed population and is dependent on pre and post emergence herbicides for satisfactory weed control. In a field experiment, DSR crop was applied with different doses (1.0, 1.5 and 2.0 kg/ha) of pendimethalin (a pre emergence herbicide) to see its efficacy under paddy husk biochar (PHB) (4 t/ha) and without PHB amendment. At 20 days after sowing (DAS), density and dry weight of both grassy and broadleaved weeds were higher under the PHB amendment compared to no PHB. PHB amendment did not cause any change in density and dry weight of sedges. Higher doses of pendimethalin i.e. 1.5 and 2.0 kg/ha reduced density and dry weight of weeds progressively however 2.0 kg/ha dose reduced tiller count of direct seeded rice. Pendimethalin dose of 1.5 kg/ha under PHB had satisfactory weed control and at the same time did not impact rice tillers. Thus, it can be included that satisfactory weed control in PHB amended DSR can be obtained by increasing the rate of pendimethalin to 1.5 kg/ha.

O3-9. Diamide insecticides against fall armyworm (FAW), *Spodoptera frugiperda* and impacts on natural enemies

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Efficacy of two new diamide insecticides viz. (chlorantraniliprole & flubendiamide) WG against the invasive fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) and their compatibility with the common predators wolf spider, *Lycosa pseudoannulata* (Boesenberg et. Strand) were determined in the laboratory and farm based on mortality using LC_{50} values and reproductive capacity of surviving females. Lab test showed high efficacy of chlorantraniliprole against FAW with the mortality of 80-100% followed by Flubendamite and but its toxicity to the predators was less with the mortality range of 46-56% and 36-47 % for earwig *Forficula auricularia*. and spider respectively. In field condition, both diamde caused similar mortality of 64.49% FAW at 72 HAT but it showed less toxicity predators with 27.30-35.71% and 26.11-30.78% mortality of Earwig and wolf spider respectively. The laboratory and field test indicate that higher efficacy of chlorantraniliprole & flubendiamide against FAW as well as their less disruptive effect to natural enemies would be better choice for integrated management of FAW in maize ecosystem of Bangladesh.

O3-10. Investigation of nanoparticle formulations of imidacloprid and sulfur pesticides on common pistachio psylla, *Agonoscena pistaciae* (Hemptera: Psyllidae)

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Agonoscena pistaciae is one of the most important pistachio pests in Iran. The spread and outbreak of this pest necessitate a review of chemical control to reduce the amount of pesticide use. Recently, one of the new methods of pest control is the use of nano-admixture formulations. These formulations reduce the risks of chemical pesticides, controls the release of pesticides from nanoparticles, protect pest proteins against environmental factors such as light, heat and increases the impact of pesticides, and reduce the possibility of occurrence pest resistance. In this study, formulations of slow release of degradable and biocompatible light imidacloprid and sulphur were prepared by encapsulating them with Zinc Oxide nanoparticles. Identification, structural properties and morphology of formulations were performed by using FT-IR, XRD and SEM methods. The loading capacity of pesticides in nanoparticles was investigated by performing a dialysis bag test. The surface of the nanoparticles was relatively soft and uniform, and the loading capacity of the nanoparticles was about 85%. Controlled release of nanoparticles *in vitro* conditions indicated a specific and controllable function of new nano formulations. The insecticide efficiency of new formulations in *in vivo* conditions on *A. pistaciae* showed a significant decrease in the pest control dose and environmental hazard. Thus, the use of nanoparticles increases the surface to volume ratio of insecticide particles, and increases the mortality. Use of nanoparticles as a carrier also results in faster degradation of insecticides in the environment.

O3-11. Efforts to use soft pesticides for the control of insect pests as contribution towards a safe environment

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In the last decades during the post-war period, agriculture has developed towards methods that are more intensive. In the Sudan Gezira cotton spraying started as early as season 1945/46 when only 1% of the cotton area was sprayed once. The number of sprays per season went up, reaching 9.25 sprays in season 1978/79, which might be attributed partly to the rapid resurgence of insects' pests as a result of the use of non-selective insecticides. The joint use of natural enemies and selective pesticides might attribute to combat this problem. Studying the side effects of pesticides is of prime importance to save the natural population and encourage their role as biological control agents. This paper discusses the various methods which can be used to study the side effects on natural enemies and the results of some studies carried on the side effects of some insecticides on natural enemies both at small- and large-scale levels in Sudan. The study includes testing the side effects of some insecticides and their impact on bio-safety on two predators at the small-scale level at the Gezira Research Farm, Wad medani. The Impact of Polo (diafenthiuron) on natural enemies in the cotton-based ecosystem of the Gezira Scheme (Large Scale) was tested in the Study. The results indicated that Polo was relatively safe both at small scale and large-scale level to the natural enemies observed during the study and can be included in IPM programs.

O3-12. Forest pests and their management practices in an urban forest of Odisha

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Larger forest patches in urban areas are highly valuable recreation sites that provide the urban population with various ecosystem services. The growing need to intervene against forest pests needs to be clearly but carefully communicated to the urban forest visitors in order to minimize conflicts. In this paper, a survey with 14 complete responses, conducted in the forest district of the “Khorda” in East Coast Odisha, India, Sheds first light on visitors' perceptions of biological pests and their management. Results of a series of Logit models indicate a clear predisposition against pesticide or biocide interventions, while at the same time, showing remarkable positive tendencies towards mechanical interventions or measures taken on the individual-tree level. There are positive correlations between the age and the knowledge about pests (Kendall-Tau-b $\tau B = 0.165$) and between the age and the knowledge about pest regulation ($\tau B = 0.182$). Positive correlations also exist between the level of education and pest knowledge ($\tau B = 0.1$) and knowledge about their regulation ($\tau B = 0.08$), respectively. Overall, a large majority of the respondents would be willing to participate in a volunteer mapping of pests while visiting the forest. The results of this study can be used to inform urban forest management to modify and optimize their communication and information policies concerning pests and substantiated interventions.

4. Pest, host plant, and environmental interactions: Effect of climate change in managing insect pests

Organizers: Megha N Parajulee and K Murugan

Lead

O4-1. Effect of elevated CO_2 on ecologically intensive arthropod pest management in cotton agroecosystems

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Global warming has the potential to cause a vicious cycle of disturbance in global ecosystems which produce mostly negative impacts on local natural fauna and flora. A positive relationship exists between environmental CO_2 concentrations and environmental temperature while the combined effect may potentially bring about environmental climatic anomalies such as changes in localized vegetation, rises in sea levels, and changes in rainfall, drought, and flood patterns. Increased CO_2 concentrations can directly affect crop plants as well as the associated arthropod pests of the crop. Increased environmental CO_2 concentration also affects the biology and behavior of beneficial arthropods such as predators and parasitoids. Changes in microclimate, fauna and flora can promote an insect pest to invade new habitats; therefore, the invasion of new species can be a serious problem in delicate agroecosystem. We have demonstrated that the increased CO_2 concentrations increased cotton bollworm (*Helicoverpa zea*) feeding and lifespan but it decreased their fecundity. In contrast, the cotton aphid (*Aphis gossipii*) showed increased fecundity. Elevated CO_2 may also affect the third trophic level (i.e., predators and parasitoids), rendering a complex tri-trophic influence. Texas High Plains is the home of the largest contiguous cotton patch in the world, with 5% of the world cotton produced within a 250-km radius. An integrated cropping system approach has been used to address pest management issues in the Texas High Plains, consisting of agronomic, cultural, biological, chemical, plant physiological, and spatial methods. The presentation highlights the cotton cropping systems influenced by climate variability, including erratic rainfall events and increased drought, coupled with declining irrigation water availability, affecting management practices for production profitability in Texas cotton.

Invited

O4-2. Emerging insect pests in Indian agriculture due to climate change

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Effect of climate change on agricultural pests is mutli-dimentional and research on its effects against pests in India is lacking. Climate change is an important determinant in influencing the abundance and distribution of emerging and invasive pest species. Agriculture would need to undergo dramatic adjustment as increase in the incidence and pest load could be anticipated with climate change. Temperature and precipitation can strongly influence the life history and fitness of ectotherms (insects). Cotton whitefly, mealybugs, thrips of several species, and wheat, barley and oat aphids are some of the examples that can be significantly influenced by the temperature changes. Biological invasions are a major threat to global food security and livelihoods, with developing countries being the most susceptible. The impacts from invasive insect species (IIS) can be compounded by climate change. Increased global trade in agriculture has increased the chances of introduction of IIS such as papaya mealybug, tomato pinworm and maize fall armyworm to new areas.

Many invasive species have the ability to expand rapidly to higher latitudes and altitudes as the climate warms, outpacing native species. Climate-driven changes such as range expansion of species, increased frequency of insect generations, increased herbivory, and others present challenges and opportunity for sustainable agricultural programme. Therefore, anticipatory research to overcome the adverse impact of unfavourable climate/weather is necessary and inevitable.

O4-3. Effect of climate change on the interaction of agricultural insect *Spodoptera litura* and microbial pathogens

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Temperature has the potential to significantly impact plant diseases through affecting both the host crop and pathogen. Temperate climatic zones that include seasons with cold temperatures are likely to experience longer periods of temperatures suitable for pathogen if the climate change renders elevated temperatures than previously experienced. Because insects are cold-blooded organisms, temperature is perhaps the single most important environmental factor influencing insect behavior, distribution, development, survival, and reproduction. Fungal pathogens of insects are favored by high humidity and their incidence would be increased by climatic changes that extend periods of high humidity while the incidences are reduced in drier conditions. We investigated the bioactivity of two widely utilized entomopathogens (*Beauveria bassiana* and *Metarhizium anisopliae*) against *Spodoptera litura* through the assessment of larval tolerance and regulation of antioxidants and non-target impact on the earthworm, *E. eugeniae*, compared with commercial pesticides. The entomopathogenic fungus exposure resulted in the modification of the levels of detoxification enzymes as well as significant increases in catalase and superoxide dismutase activity after exposure to the entomopathogenic fungus. Bioassay results showed that *B. bassiana* and *M. anisopliae* displayed larval mortality against third and fourth instars. Correspondingly, sub-lethal concentrations of *B. bassiana* showed development impairment as compared to *M. anisopliae*. Gut-histology revealed that mycotoxin dosage (4×10^5) showed significant changes in the midgut tissues as compared to control larvae. Mycotoxins *B. bassiana* (5×10^8 conidia/ml/kg) and *M. anisopliae* (5×10^8 conidia/ml/kg) showed less toxicity on earthworms as compared to monocrotophos insecticides (10 ppm/kg). Current results suggest that the fungal mycotoxins of *M. anisopliae* and *B. bassiana* reduced the development of lepidopteran pests while having lower impact on beneficial earthworms compared to available insecticides.

O4-4. Climate change mediated effect on butterfly conservation – mosquito vector management: A case study

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Global warming and climate change will trigger major changes in diversity and abundance of arthropods, geographical distribution of insect pests, population dynamics, insect biotypes, herbivore-plant interactions, activity and abundance of natural enemies, species extinction, and efficacy of crop protection technologies. Climate change is already having an impact on biodiversity and is projected to become a progressively more significant threat in the coming decades. Mosquitoes are the most economic group of insects in terms of public health significance and transmitting dreaded diseases like malaria, filariasis and dengue and climate is

principal determinant factor influencing their activities and disease transmission. The present paper addresses (i) impact of elevated CO_2 and temperature on the feeding biology of butterflies with special reference to host plant diversity in Western Ghats, Southern India and (ii) effect of elevated temperature on the efficiency of biopesticides in mosquito management. Mosquito breeding sites have been established at different temperature regimes of Tamil Nadu [Ooty (25ºC) with the elevation of 2,623 m, Coimbatore (34.7°C), Madurai (37.5°C), Sivakasi (39.2ºC), and Chennai (43.2ºC). Over the years, extensive use of commercially available synthetic pesticides against crop insects and mosquito vector has led to their bioaccumulation in the environment causing increased resistance and reduction in soil biodiversity. Further, 90% of the applied pesticides enter the various environmental resources through surface run-off, exposing the farmers and consumers to various health issues. Therefore, growing attention has been given toward the development of alternate environmentally friendly pesticides/insecticides that would complement an efficient pest management system and prevent chronic exposures to diseases. Biopesticides such as azadirachtin and its nanoinsecticdes have been used to control the larval populations of malarial vector, *Anopheles stephensi*, filarial vector, *Culex quinquefasciatus* and dengue vector, *Aedes aegypti*. Studies have been conducted on laboratory lethal toxicity and field applications of these biopesticides at different agroclimatic regions of Tamil Nadu. The results revealed that higher temperature favored higher larval populations, but it also suppressed the efficacy of biopesticides in managing mosquito larvae at the breeding sites.

O4-5. Correlations between graoe stem borer Celostern ascabrator (Cerambycidae: Coleoptera) incidence and weather parameters

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More than 100 pests are known to attack grape in India and the stem borer C. scabrator is emerged as a major pest in grape growing regions of North Karnataka (Karnataka: India) causing more than 90.00 % grape vine damage Though both adults and grubs were found to damage the grape vines, grubs cause significant damage by tunneling action for a period of 6-8 months which results in drastic yield reduction and ultimately death of grape vines. Adults emerge by cutting circular emergence hole on grape vine. Studies were carried out between 2015-2017(104 weeks) on population dynamics of stem borer grubs at grape orchards of Vijayapura and correlations were made with weather parameters. Activity of feeding grubs is indicated by the presence of fresh frass or sawdust extruded from the bored tunnels out through cracks in, or damage to the vine's trunk, or other weaknesses in the wall and which often collects at the base of the vine. Such tunnels were designated as live tunnels. Thus, population dynamics of grubs was studied by adopting frossing index method (Goodwin et al., 1994) from each experimental area by randomly selecting 100 grape vines and number of live tunnels/week were recorded. The data was expressed as percent live tunnels/week. The grub activity was positively correlated with maximum temperature (r=0.241, p=0.0133), negatively correlated with minimum temperature (r= -0.364 p=0.0001) , maximum relative humidity (r= -0.424, p=0.00001),minimum relative humidity (r=-0.450, p=0.0001) and rainfall(-0.274, p=0.0048).With sunshine hours the grub activity was positively significantly correlated (r=0.560, p=<0.00001).

O4-6. Climate change and insect pests: Variation in insect population and damage in tomatoes along an elevational gradient in Nepal

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Understanding the relationships between temperature at different elevations and proportional occurrence of insect pests may help predict the impacts of global warming on pest management. A field study in Nepal was conducted using the natural laboratory that the Himalaya Mountains provide to explore the interrelationships between elevations and levels of abundance and damage from insect herbivore (Tobacco caterpillar, Spodoptera litura, Tomato fruit worm, Helicoverpa armigera, and South American Leaf Miner, Tuta absoluta) in tomatoes along an elevation gradient in Nepal ranging from 300 meter above sea level to 1300m representing different climatic zones where tomatoes are grown. Field data on incidence, abundance and level of damage from insect pests were combined with local temperature data. Lab-based herbivore bioassays with H. armigera were also conducted to compare plants resistance grown at different elevations. Results suggests that herbivore populations increased towards higher elevations whereby plant damage from herbivory increased towards lower elevations. Temperature decreased with elevation and variation in temperatures within each region impacted the proportion of herbivore population and damage differently. Insect population was increased with increasing temperature at highest elevation whereas it was reduced its low-elevation counterpart. Whereas, plant damage was increased with increasing temperature in two lower elevations whereas no trend was evident at the highest elevation. Plants at higher elevation exhibited enhanced resistance to insect herbivore suggesting plasticity in plant defense responses. Insights from the study emphasized the interactive role of climatic factors and plants' traits to predict the climate change-mediated effects on insect-plant interactions.

O4-7. Management of blueberry maggot with extreme temperatures

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Extreme temperatures were investigated to manage immatures of the blueberry maggot (Rhagoletis mendax Curran- Diptera: Tephritidae), a key pest of cultivated blueberries in North America. The effect of cold temperatures on survival of blueberry maggot was researched by exposing pupae at -20oC for 2, 4, 7, 10 and 15 days in the fall and allowing them to overwinter for at least 181 days at 4oC. Exposure of pupae to cold temperatures (i.e. -20oC) for at least 2 days can be a valuable non-pesticidal method to treat reusable containers such as it would prevent further dissemination of the insect, in compliance with directive D-02-04 of the Canadian Food and Inspection Agency. To estimate lethal combinations of high temperatures/duration of exposure, blueberry maggot pupae were immersed in water at various temperatures during either 1 or 30 s in the laboratory. Treatments such as 70oC (1 s) or 55oC (30 s) caused 100% mortality of blueberry maggot pupae. In a lowbush blueberry field, soil temperatures at 0, 1, 2, 3, 4 and 5 cm depth were measured with thermocouples following the passage of a flamethrower attached to a tractor in the fall. While the temperatures reached up to ca. 80oC for ca. 1 s at the soil surface, they were <10oC at depths of 3, 4 and 5 cm. In field situations, the energy required to kill all pupae would be expensive to deliver with a flamethrower and this would also cause environmental concerns.

5. Pest and disease resistance gene mapping and cloning

Organizers: Sambasivam Periyannan and Rajeev Varshney

Lead

O5-1. Foliar disease resistance in groundnut: dissection and deployment

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Foliar fungal diseases i.e., late leaf spot (LLS, caused by *Cercosporidium personatum*) and rust (caused by *Puccinia arachidis*) are the most devastating disease in groundnut that can cause 50–70% yield loss. Realizing the potential of genomics-assisted breeding (GAB) in developing improved varieties in less time, we have dissected the genetic basis of resistance to LLS and rust and then deployed marker-assisted backcrossing (MABC) to improve foliar diseases resistance in many popular groundnut varieties. In this context, initially we used SSR markers and QTL mapping approach to identify resitance loci to LLS and rust on genetic map. Subsequently, two next-generation sequencing based approaches namely QTL-seq and genotyping-by-sequencing (GBS) were used that identified two major QTLs located on A02 (LLS resistance) and A03 (LLS and rust resistance) pseudomolecules. Further analysis identified a R-gene cluster with two conserved Tir-NBS-LRR genes including one resistance gene (AH13G54010.1) with co-segregating SNPs between resistant and susceptible parents and bulks (G143854163A, G143855518A for rust; C143855539T, G143855898C for LLS). In parallel, rust resistance was introgressed into three rust susceptible varieties ('ICGV 91114', 'JL 24' and 'TAG 24') through MABC. After 2–3 backcrosses and selfing and field evaluation, 12 introgression lines (ILs) were nominated to AICRP-Groundnut of Indian Council of Agricultural Research for commercial release of superior varieties for cultivation. Two ILs (ICGV 14421 and ICGV 13189) in the genetic background of ICGV 91114 and one IL (ICGV 13207) have been found promising for possible notification for commercial release in India in near future.

Invited

O5-2. White rust resistance in *Brassica juncea* - mapping and gene identification

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White rust caused by oomycete pathogen Albugo candida is a significant disease of crucifer crops including *Brassica juncea* (mustard), a major oilseed crop of the Indian subcontinent. Almost all the released lines grown commercially in India are susceptible to the disease; causing significant yield losses. Earlier resistance-conferring loci named AcB1-A5.1 and AcB1-A4.1 were mapped in east European gene pool lines of *B. juncea*, Donskaja-IV and Heera, respectively. A set of *B. juncea* (AABB), *B. rapa* (AA) and *B. nigra* (BB) lines were tested for resistance to six isolates of *A. candida* collected from different mustard growing regions of India. Donskaja-IV was found to be completely resistant to all the tested isolates making this locus interesting for further genetic dissection and molecular characterization. Sequencing of a BAC spanning the locus AcB1-A5.1 showed the presence of a single CC-NB-LRR protein-encoding R gene. The genomic

sequence of the putative R gene with its native promoter and terminator was used for the genetic transformation of a susceptible Indian gene pool line Varuna and was found to confer complete resistance to all the isolates. This is the first white rust resistance-conferring gene described from Brassica species and has been named BjuWRR1. Allelic variants of the gene in *B. juncea* germplasm and orthologues in the Brassicaceae genomes were studied to understand the evolutionary dynamics of the BjuWRR1 gene. Another resistance-conferring locus AcB1-A6.1 has been mapped in vegetable type mustard, Tumida. Candidate genes are being identified in the loci AcB1-A6.1 and AcB1-A4.1.

O5-3. Fast-tracking disease resistance through targeted gene capture and enrichment techniques

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Plant diseases caused by pathogenic fungi are major constraints in global agriculture. Of importance is the Puccinia fungus that causes rust disease in wheat. With the evolution of highly infectious forms in major wheat belts, rust pathogens continue to threaten global food security. Worldwide, the incidence of rust disease is managed effectively using host plant-mediated genetic resistance. Ancestral species of cultivated wheat provide a rich source of resistance gene diversity to aid efforts at introgression breeding to combat recently evolved rust races. However, due to cross incompatibility barriers, the conventional breeding methods available to introduce these alien resistance genes into commercial wheat cultivars are often laborious and time-consuming. One good strategy to by-pass the above complication is to isolate the targeted genes and transfer directly into commercial wheat varieties. To facilitate rapid gene isolation, we propose new biotechnological tools based on targeted DNA sequence capture and sequencing and validated through the identification of five resistance genes to wheat stem rust disease.

O5-4. Breeding for disease resistance in rice for the northeast Thailand using marker assisted selection

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Thai glutinous rice cultivar RD6 is well known for its cooking and eating qualities and make is the most popular in North and Northeast regions of Thailand. However, it is susceptible to blast and bacterial blight (BB) diseases. The utilization of host plant resistance is offers the most effective strategy to control the diseases. This study focused on the pyramiding of four blast resistance QTLs located on chromosomes 1, 2, 11 and 12, from P0489 and Jao Hom Nin and single BB resistance gene (xa5) from IRBB5 in to the background of RD6. The introgression lines were tested for broad spectrum diseases resistance level under greenhouse and field conditions. Moreover, yield potential and the grain qualities were also evaluated. The results showed that the RD6 introgression lines carrying a high number of resistant QTLs provided a wide spectrum of resistance to the blast and BB pathogens prevalent in the region under greenhouse condition. The multi-location yield trails were carried out during the rainy season of 2015-2018. The results found that the ILs with QTLs/genes were outstanding resistance for leaf and neck blast diseases, but only the IL (BC2F5 2-8-2-52) showed resistance to BB. Multi yield trails revealed that almost the ILs were exhibited superior in

grain yield slightly greater than the recurrent parent RD6. Almost the agronomic traits and grain characteristics were close similar to the original RD6. The present study deliver the RD6 improved lines to sustain rice productivity of the Northeast Thailand.

O5-5. Genetic characterization and KASP SNP designing for shoot fly morphological traits - seedling leaf blade glossiness and trichome density on sorghum chromosome 10 and their functional validation

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Shoot fly (*Atherigonia soccata*) is one of the most destructive insect pests of sorghum (*sorghum bicolor*) during the early stages of crop production areas of India and worldwide. Breeding for sorghum cultivars with host plant resistance (HPR) is the most feasible strategy to minimize losses caused by shoot fly resistance (SFR). In parallel, the development of breeder friendly marker linked to SFR genes is essential in sorghum breeding through marker-assisted selection (MAS). In the present study, 1894 SFR fine mapping population was developed from introgression line parents J2614-11 resistant and RSG04008-6 susceptible. Using genotyping by sequencing (GBS) technologies 152 selective recombinant fine mapping population was screened for SNPs on sorghum chromosome SBI-10L.Variant genomic SNPs identified for causal phenotypic variation were annotated for their functional role and are converted to competitive allele specific PCR (KASP) assay and will be validated in sorghum germplasm and breeding material. Functionally prioritized SNP based candidate genes were selected for gene expression analysis. Primers were designed and synthesized for expression profiling. Out of the fine mapping population parents, their donor grandparents (IS18551, BTx623) and contrasting progeny for the glossy (gl) and trichome density (Td) was sown in triplicates for expression profiling. Promising results were identified and genes having a role in glossiness (wax synthesis) pathway and trichome density (cell differentiation) have shown differential gene expression in parent and contrasting genotypes. O-methyl transferase, cyclin-dependent kinase, and gl15 genes showed Differential expression.

O5-6. Fine mapping and identification of candidate genes for insect and disease resistance in mungbean

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Mungbean (*Vigna radiata* (L.) Wilczek) is an important legume crop of Asia. Major and common insect pest and diseases of mungbean in Asian countries include bruchids (seed weevils; *Callosobruchus* spp.), powdery mildew disease (*Erysiphe polygoni*) and *Cercospora* leaf spot disease (*Cercospora canescens*). Although attempts to map gene(s)/QTLs controlling resistance to these insect and disease for marker-assisted selection (MAS) in mungbean have been made since the early era of genomics, the progress on genomics research of these biotic stresses is very slow due to the lack of genomic resources and tools. However, with a recent release of a whole genome sequence of mungbean, gene/QTL for the resistance to bruchids, powdery mildew

and *Cercospora* leaf spot have been finely mapped and candidate genes for these traits have been identified. Candidate gene for the resistance to bruchids appears to encode polygalactorunase-inhibiting protein that inhibits digestive enzyme polygalactorunase in the midgut of the bruchids. Candidate gene for the resistance to powdery mildew is a susceptible gene (S gene) encoding plant-specific proteins structurally related to metazoan G-protein coupled receptors. Candidate gene for the resistance to *Cercospora* leaf spot produces a protein that is involved in regulation of gene expression. Genic markers for these candidate genes have been developed for MAS.

O5-7. Molecular mapping of QTLs related to rice brown planthopper (BPH) resistance and identification of stable resistant lines from wild rice introgressions

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Brown planthopper, *Nilaparvata lugens* is the most devastating rice insect pest which sucks phloem sap resulting in death of rice plant and the damage is called as "hopper-burn. Swarna, a popular variety and KMR 3 the restorer line of the rice hybrid KRH 2 are susceptible to BPH. 100% yield loss was reported in Swarna variety during pest outbreaks. As part of a research program on increasing yield of elite lines through introgression from the wild progenitor species, several high yielding introgression lines were developed and evaluated for BPH resistance. 320 introgression lines (BC2F6) from three crosses Swarna/*O. nivara* (IRGC-81848-S), Swarna /*O. nivara* (IRGC-81832-K) and KMR3/*O. rufipogon* were screened for BPH resistance in the greenhouse by standard-seedbox-screening-test on 0-9 scale for three seasons. Six introgression lines from 93 BILs of Swarna/*O. nivara* (IRGC-81848-S) viz., 212(S), 215(S), 221(S), 224(S), 228(S) and 230(S) were found to be resistant to BPH. The population was advanced to BC2F8 generation in 2016 and was screened for BPH resistance in 2016, 2017 and 2018. In the repeated screenings, these six lines were found to be consistently resistant to BPH. These sets of BILs were genotyped using 111 random-polymorphic-SSR-markers with genome wide distribution. Based on mean phenotypic data, 16 QTLs were identified for BPH resistance located on 9 chromosomes. Among these, 8 QTLs consistently appeared across years and mean data with LOD values ranging from 5.9 to 18.5 with a phenotypic variance of 2.9%. 12 QTLs were observed for the year 2016 while 16 QTLs were detected in 2017. All the resistance alleles were from *O. nivara.*

O5-8. Dissecting the genomic regions associated with charcoal stalk rot resistance in tropical maize (*Zea mays* L.) using genome wide association mapping

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Post flowering stalk rot (PFSR) is a serious biotic constraint of maize. In Asia, PFSR is reported from major maize growing countries, including China, India, Indonesia, Pakistan, Philippines, Thailand and Vietnam. Among different PFSR, charcoal rot caused by *Macrophomina phaseolina* is one of the major diseases in the Asian region. Resistance to charcoal rot is a complex polygenic trait, and hence difficult to incorporate the resistance in the elite germplasm. Identification of genomic regions contributing to resistance could be useful in enhancing charcoal rot resistance in elite breeding germplasm. Genome wide association studies (GWAS) was conducted in 367 CIMMYT maize inbred lines. Trials were conducted under artificial inoculation

conditions at Hyderabad during the years 2013 and 2014 and at Ludhiana during 2013. Heritability estimate of phenotypic trials across three locations were 0.53 and BLUP estimates were generated. GWAS was carried out using high density genotyping by sequencing (GBS) SNPs using single locus mixed model analysis which corrects for population structure and kinship. Results revealed 10 highly significant SNPs ($P \leq 3.17 \times 10\text{-}5$) on chromosome 2, 3, 4, 5, 6, 8, 9 and 10 associated with charcoal rot resistance with lowest p-value for SNP S3_220734197, on chromosome 3. In GWAS, a narrow sense heritability of 0.52 was estimated. Haplotype trend regression analysis was carried out using 39 haplotype blocks formed from significant SNPs identified 19 genetic variants with Bonferroni cut off value of 0.05. Genomic regions identified need to be further validated through linkage mapping for further deployment in breeding program.

O5-9. Marker assisted stacking/pyramiding of rust and powdery mildew resistance genes (Sr2/Lr27/Yr30, Sr24/Lr24 and Sr36/Pm6) for durable resistance and sustainable agriculture in bread wheat (*Triticum aestivum* L.)

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Wheat production is essential for food security and rust diseases continually pose a threat to wheat production at national and international level. In recent years, climate change and intensive crop cultivation practices are promoting powdery mildew disease as a potential yield threat to wheat. Resistant cultivars are the economic, most reliable, sustainable and environmentally safest way to control the rust and powdery mildew diseases. Most of the rust resistance genes are all stage resistance (ASR)/major gene and therefore succumb to new variants of the respective pathogen soon after their deployment, whereas adult plant resistance (APR)/minor genes have small to intermediate effects when present alone. High and durable rust resistance can be achieved by combining the ASR and APR genes together. Stacking/pyramiding of stem rust and powdery mildew resistance genes, Sr2/Lr27/Yr30, Sr24/Lr24 and Sr36/Pm6, in step wise and simultaneous manner was attempted with recipient parent viz., Lok1 using donor parents viz., Kingbird (Sr2+), TR380-14*7/3Ag#14(Sr24/Lr24) and Cook (Sr36/Pm6). Presence of the rust resistance genes were carried out using molecular markers, gwm533(Sr2+), Sr24#12(Sr24) and stm773(Sr36/Pm6) in the backcross derivatives. In each generation, genotypes with all the three genes combination were forwarded and the stable lines were selected at BC3F5 generation. Seedling and adult plant reaction of the stable lines showed resistance to stem and leaf rust and powdery mildew. Use of gene stacks/pyramids of major (Sr24/Lr24 and Sr36/Pm6) and minor gene (Sr2+) that confer resistance to most of the pathotypes of rusts and powdery mildew could impart durability and sustainability to the cultivars than single gene deployment.

O5-10. Identification and validation of SNP markers associated with blast disease resistance in finger millet (*Eleusine coracana* L. Gaertn.)

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Finger millet is one of the few crops that feature novel genetic traits viz., unique nutritional advantage, health benefits and environmental sustainability requiring lower inputs. Blast disease is the most important biotic constraint affecting yield and quality of produce in most of the finger millet growing areas. Conventional breeding has not been completely successful in developing resistant varieties adapted to different agro-climatic situations. About 24 genotypes (8 resistant, susceptible parental accessions and 16 individuals resistant (8) and susceptible (8) extreme F5 RILs derived from the population GPU 28 (R) × KM 252 (S)) were subjected for ddRAD-seq (double digested Restriction site Associated DNA) paired end sequencing using Illumina HiSeq 1000 platform. A pseudo-assembly has been created and annotated using high quality sequence reads in the range of 403 to 2042 Mb. A total of 352631 SNPs from 45618 tags were identified and among them 144 SNPs were found common between resistant and susceptible groups. A total of 67 SNPs were subjected to functional annotation in a Plant Resistant Gene (PRGdb) database, around 138 resistant genes hits were found from rice, wheat, maize, barley, tomato. A total of 67 SNPs were designed for SNP genotyping through KASPar assay, 52 were amplified and 11 are consistently differentiating resistant and susceptible genotypes on validation panel of 50 released varieties. A marker-trait association has also performed using 20 polymorphic SNPs on GPU28×KM252 RIL population. These validated SNPs will hasten the process of blast disease resistance breeding cultivars suitable for different agro-climatic conditions.

O5-11. Identification of novel genomic resources and DNA markers for sheath blight (*Rhizoctonia solani*) resistance in rice

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Sheath blight (ShB) caused by *Rhizoctonia solani* is one of the most destructive diseases of rice. Breeding for ShB resistance has been difficult, mainly because of lack of resistant sources. In this context, 225 rice landraces of Karnataka were screened against *Rhizoctonia solani* and resistant and moderately resistant sources were identified. Landraces Nizam shait, Byalearya (sheath blight Relative lesion height- 15 %), Bangarkovi (RLH-17 %) and Kiruvanna (RLH-19 %) were resistant with relative lesion length 10% to 19%. Landrace Jigguvaratiga and Jaddu showed moderate resistance. Sheath blight resistance in rice is typically quantitative trait. Though many QTLs conferring ShB resistance have been identified, majority of them are also associated with morphological characters. Resistant and moderately resistant landraces were analysed with 120 SSR markers for their association with ShB resistance, plant height and 50 % flowering by single marker analysis (SMA). Seventeen markers showed association with ShB resistance as well as plant height and 50 % flowering except, RM3685 (R2 % 58.79) which was associated only with ShB resistance. Mapping population was generated and DNA markers associated with sheath blight resistance were identified using bulked segregant analysis (BSA). The SMA reconfirms the association of RM5556 (R2 % 28.29) and RM6208 (R2 % 20.06) markers for ShB resistance, but RM5556 is also associated with plant height. In silico analysis of RM6208 region reside the protein stearoyl ACP desaturase, which may be involved in the defence mechanism against plant pathogens and RM5556 loci encodes a protein of unknown function.

6. The challenge of coconut rhinoceros beetle (*Oryctes rhinoceros*) to palm production and prospects for control in a changing world

Organizers: Trevor Jackson and Sean Marshall

Lead

O6-1. The challenge to palm production from the spread of CRB-G

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Oryctes rhinoceros (Linnaeus 1758) (Coleoptera: Scarabaeidae: Dynastinae) (coconut rhinoceros beetle; CRB) invaded the Pacific during the first half of the 20th century, causing widespread severe damage to coconut palm. CRB was brought under control by widespread release of *Oryctes rhinoceros nudivirus* (OrNV) between the 1960s to 1980s allowing for the successful management of populations in Pacific Region. For ~40 years after adoption of this biocontrol strategy, no new outbreaks of CRB were reported from un infested palm growing islands in the Pacific allowing continuity of palm-based village economies. However, the situation has recently changed. CRB invasions into completely new areas were recently reported in the Pacific – Guam (2007); Port Moresby, Papua New Guinea (2009); Honolulu, Hawai'i (2013); Honiara, Solomon Islands (2015); and Rota, Northern Mariana Islands (2017). Common to all new outbreak areas was the high incidence of severe palm damage not seen since the introduction of OrNV. Molecular analyses determined that these outbreaks were all caused by a previously unrecognized haplotype, designated as CRB-G. Although OrNV is generally present at high incidence in established populations of CRB, virulent OrNV infection was absent from the invasive CRB-G populations, which suggested resistance. Bioassays confirmed CRB-G was not susceptible to the OrNV biocontrol isolates commonly used. A search is underway for new candidate biocontrol agents (currently focused on novel OrNV isolates). We will discuss current efforts being employed to slow the spread of CRB-G both within and between islands, and research to identify longer term biological control measures for use against CRB-G

Invited

O6-2. Possibility of evolution in culture of *Oryctes nudivirus* in relation to infectivity against apparently resistant and susceptible biotypes of the coconut rhinoceros beetle *Oryctes rhinoceros* (L.)

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A brief review is given of the early years of release of *Oryctes Nudivirus* (OrNV) against the Coconut rhinoceros Beetle (CRB) *Oryctes rhinoceros* (L.) in Fiji. Comments are given regarding the current occurrence of apparently OrNV-resistant and OrNV-susceptible biotypes of CRB in South-East Asia and the South Pacific. The complete genome of an OrNV isolate from Malaysia is available. As OrNV has been cultured over decades in cells of *Heteronychus arator* (F.)(HA) for release in the South Pacific, it would be worthwhile to compare the complete genomes of OrNV isolates long cultured in HA, with the known complete Malaysian isolate genome, and the full genomes of OrNV freshly isolated from field populations of susceptible CRB, to check if changes have evolved which adapt cultured isolates to infect HA cells but reduce or cancel their ability to infect the target *O. rhinoceros*. Depending on the results found, infectivity of field isolates against larvae and adults of resistant, and susceptible, CRB biotypes, could be compared with

that of HA-cultured isolates. Search could be made in regions where OrNV is endemic, and particularly where the resistant CRB biotype occurs, to look for OrNV genomes which can attack this biotype. Also the possibility of changes in the HA culture cells which alter the outer coat of the resulting virion, hence perhaps its infectivity towards CRB cells, could be checked. Might it be possible to establish tissue culture of O. rhinoceros cells (thus moving beyond HA culture) for propagation of OrNV isolates, since O. rhinoceros is the ultimate target?

O6-3. Integrated control strategies of *Oryctes rhinoceros* in Malaysian oil palm plantations

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The rhinoceros beetle, Oryctes rhinoceros (Coleoptera: Scarabaeidae) is a notorious pest of oil palms especially during replanting in Malaysia. As a response towards the high infestation by the rhinoceros beetle, a holistic approach of Integrated Pest Management (IPM) of the beetle was established. Pheromone trap was used to control the migration of the adults within the infestation area. The installation of one trap per two hectares of planted area proved to significantly control the adult population in a heavily infested area. According to the research findings, the application of entomopathogenic fungi, Metarhizium anisopliae on the breeding sites has successfully reduced the larvae population in between 50% – 80% in the field. Apart from the fungi, the Oryctes nudivirus (OrNV) was also used as microbial control of the rhinoceros beetle. In a recent study, the cells – propagated OrNV observed to show varied effectiveness on the different life stages of rhinoceros beetles and have high potential for mass production in the future. Further incorporation of the pheromone trap with the fungi and virus revealed improved effectiveness on the management systems of rhinoceros beetle in the oil palm plantations in Malaysia.

O6-4. Management options for the coconut rhinoceros beetle (CRB), *Oryctes rhinoceros* L. (Coleoptera: *Scarabaeidae*) in Papua New Guinea and Solomon Islands

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Oryctes rhinoceros L. is one of the key pests of both coconut and oil palms. The beetle is native to south east Asian region but has spread to other tropical regions of the world including the Pacific. Initial incursion of O. rhinoceros into Papua New Guinea was around 1942, where it was believed to have hitch hiked on war ships during World War II. The control of the initial incursion of the beetle in Papua New Guinea has been through the natural infection and transmission of *the Nudivirus* complimented by pheromone trapping. However, the incursion of the *Nudivirus* resistant strain of the beetle (CRB-G) into both Papua New Guinea and Solomon Islands in 2010 and 2015 respectively has posed a whole new set of challenges for management. A range of studies have been conducted to evaluate control options for the beetle in oil palm. This presentation provides results of the control options implemented for both strains of the beetle in the two countries, and outlines recommendations for further work.

O6-5. Status of a major outbreak of coconut rhinoceros beetle, *Oryctes rhinoceros* biotype G, on Guam and attempts at establishing biological control

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Coconut rhinoceros beetle (CRB; *Oryctes rhinoceros*) was first detected on Guam in 2007. An eradication attempt using mass trapping and sanitation failed when the beetle spread to all parts of the island. *Oryctes rhinoceros nudivirus* (OrNV) and green muscardine fungus (GMF; *Metarhizium majus*) where introduced as biocontrol agents. GMF successfully established as a classical biocontrol agent and a 2015 survey indicated that between 10% and 38% of Guam's CRB were infected by this fungus. However, the preferred biocontrol agent for CRB, namely OrNV, failed to have any effect. This lead us to discover that the Guam CRB population is genetically distinct from other Pacific island populations and it is being referred to as the CRB-G biotype. CRB-G is resistant to all available isolates of OrNV, previously the most effective biocontrol agent for CRB, and it appears to have other characteristics, which make it more invasive and harder to control than other CRB biotypes. There were no range expansions of CRB between 1980 and 2007. However, CRB is now on the move with detection on Guam in 2007, Port Moresby area, Papua New Guinea in 2009, Oahu, Hawaii in 2013, the Honiara area, Guadalcanal, Solomon Islands in 2015, and Rota, Northern Mariana Islands in 2017. It is significant that all of these new invasions involve CRB-G. Thus, CRB-G is a regional problem which poses significant risks to Pacific island economies and ecosystems. Status of the Guam CRB-G outbreak and current research focused on establishing effective biocontrol on Guam will be discussed.

O6-6. Management of coconut rhinoceros beetle, *Oryctes rhinoceros* (L) Scarabaeidae: Dynastinae, in Solomon Islands

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Oryctes rhinoceros, coconut rhinoceros beetle (CRB) was first confirmed as present in Honiara, Solomon Islands in January 2015. The invading CRB pest was confirmed to be the CRB-G biotype of the species; CRB-G is not susceptible to the commonly used *Oryctes* nudivirus isolates in use to control another biotype (CRB-S) elsewhere in the South Pacific. Delimiting surveys carried out by the Ministry of Agriculture and Livestock from 2015-2019 indicated that the beetle has now spread from Honiara on Guadalcanal island to many more islands, spanning most of the nine provinces in Solomon Islands. The Ministry of Agriculture and Livestock have been doing field research on the control of this destructive invasive pest since 2015. Through strategic collaborations with overseas partners, the Ministry of Agriculture and Livestock has been involved in the development of interim management programmes that are now being implemented, including: sanitation programmes to destroy breeding sites (rotting palm logs, green manure, compost and chicken manure), internal quarantines on shipping and the use of currently available biocontrol options (e.g. *Metarhizium majus*) as part of developing an integrated pest management (IPM) strategy to improve control this beetle in Solomon Islands.

O6-7. The CRB-G action network as a response to the spread of the invasive rhinoceros beetle, CRB-G

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The coconut rhinoceros beetle (CRB) (*Oryctes rhinoceros*) has been causing problems for Pacific Island states since its inadvertent introduction to the region more than 100 years ago. The initial wave of invasion was contained and supressed by the release of the biocontrol agent, *Oryctes nudivirus*. The biocontrol campaign was so successful that there was no significant further spread of the beetle and economic damage was limited to particular situations which provided abundant breeding sites for the beetle (Felled palms for replanting or from typhoons, sawmills, etc). The situation changed with fresh outbreaks of voracious beetles in Guam, Hawaii, PNG and Solomon Islands reported from 2007 onwards. All outbreaks were found to be virus-free and, in 2017, recognised as being caused by a new biotype defined as CRB-G. CRB-G poses a critical danger to economic development and village livelihoods as it is voracious, resistant to the virus biocontrol strains currently in use, spreads steadily and is causing >50% palm losses in areas where it is established and uncontrolled. Researchers called for action in 2015 and, when the true potential for damage had been recognised by 2017, formed an action network to address the problem. To prevent disaster throughout the whole tropical Pacific region, immediate action is needed to eliminate beetles and destroy breeding sites to limit spread. For long-term control, self-replicating biocontrol agent(s) to repeat the success of the original biocontrol programme are needed. The CRB-G action network is now operational and welcomes support internationally and from within the affected states.

O6-8. Coconut rhinoceros beetle OrNV resistance and effects on coconut trees in Palau in the Palau Archipelago

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There is a confirmed presence of *Nudivirus* (OrNV) resistant CRB-G, *Oryctes rhinoceros*, CRB, in Palau, the versus other CRB types. The spread of the resistant CRB-G has resulted in the devastation of palm trees throughout the Pacific and South eastern Asia. In Palau, Damage Assessment Surveys and collections were conducted on coconut trees at representative locations throughout all the states of Palau in 2016, 2017, 2018 and 2019. DNA analysis was used to determine distribution of CRB-G as well as incidence of *Nudivirus* infection in each sample. Results show slow recovery/reduced damage in coconut tree fronds over time as well as very high rate of infection of all CRB with the *Nudivirus*. The reduced tree damage and high rate of infection of the beetles, as well as visual assessments of CRB samples gut damage, lead to the preliminary conclusion that the OrNV in Palau CRB is virulent and sample tissue analysis confirm verified this finding. Further development of growth chamber has allows for growth from outer lying more vulnerable states for infection with the local extracted virus to see effects in a closed setting. This is one of the largest collections and assessment in the region and the first sites where the resistant strain was found infected by the *Nudivirus*. Further assessment is necessary but immediate focus of all parties should be made to identify and test virulence of OrNV in Palau in order to control CRB for the region.

O6-9. Performance of botanical cake and paste against coconut rhinoceros beetle in juvenile palms

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The rhinoceros beetle is one of the most important pests of coconut in all coconut growing areas. A field study was carried out in major coconut growing tracts of Tamil Nadu (Aliyarnagar), Andhra Pradesh (Ambajipeta), Karnataka (Arsikere) and Maharashtra (Ratnagiri) through ICAR-AICRP on Palms centres during 2016-19 to evaluate the efficacy of CPCRI-botanical cake and paste for the prophylactic management of rhinoceros beetle infesting juvenile palms. Around 2-3 year old palms were selected for the experiment following RBD with 5 treatments and 5 palms per treatment. Botanical cake (15 g), paste (15 g), neem cake + sand (150 g each) and chlorantraniliprole 0.4% GR (in perforated sachets in the innermost leaf axils @ 6g/palm) were added in the innermost leaf axils, once in 4 months and naphthalene balls (12 g), once in 2 months. Observations on leaf damage and spindle damage were taken at 3 months interval. During post treatment observations, chlorantraniliprole treated palms showed minimum leaf damage in Aliyarnagar (13.1%), Ambajipeta (11.6%) and Ratnagiri (8.5%) followed by botanical cake and paste (14.6, 13.0 and 9.8%, respectively). In Arsikere, botanical cake and paste (7.0%) was found to be the best treatment followed by chlorantraniliprole (8.4%). Spindle damage was the lowest in botanical cake and paste treated palms in Ambajipeta (14.5%) and Arsikere (25.0%) whereas, chlorantraniliprole recorded minimum spindle damage in Aliyarnagar (35.2%) and Ratnagiri (9.5%). Chlorantraniliprole was found to be the best treatment, however botanical cake and paste is a better eco-friendly alternative for the prophylactic management of the beetle.

7. Phytiatry (plant medicine) as a distinct university science for modern world agriculture

Organizers: Eleftherios (Eris) C Tjamos and Epameinondas Paplomatas

Lead

O7-1. Master or doctorate degrees in plant protection insufficient to create phytiatry doctors

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A plethora of Master degrees in Plant Protection is currently offered by many Universities around the world. These programs, focused on specific research aspects include advanced plant protection courses. Graduates, however, although able to conduct research, lack the specific broad knowledge of plant Medicine doctors needed in the everyday world agriculture (diagnosis of pests and diseases, plant clinic services, agronomists in the private sector, etc.). Similarly, Ph.D. degrees offered on several disciplines of plant protection are very concentrated on intense research creating scientists able to continue on research but not as practicing plant doctors. International Ph.D. programs on Plant medicine are offered at the Universities of Florida and Nebraska that educate Plant Medicine doctors able to handle applied plant protection aspects. Even though, some Universities in Korea, Japan or China have adopted these initiatives, however, they are not attractive to young students, because they have been designed as very time-consuming programs. The unequivocal need for specifically educated scientists at graduate level has been presented by our laboratory in many congresses and symposia around the world. As for studies in master or Ph.D. level to cover the whole span of plant protection actions we should go through post graduate programs focused on every day knowledge applicable in the fields and orchards. This will offer direct valuable service to the farmers, to the world agricultural economy, and contribute in preventing dispersal of diseases and pest by specialized scientists and not by insufficiently educated agronomists, microbiologists, chemists or even not agronomically trained individuals.

Invited

O7-2. Significance of identification of abiotic plant diseases in applied plant medicine

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A high percentage of plant losses are due to abiotic diseases which include nutrient deficiency, drought stress, extreme temperatures, toxicities (overdose of fertilizers, herbicides, insecticides, air pollutants, heavy metals, salinity, etc.), sunscald, freeze injury, wind injury, chemical toxicity, or improper cultural practices, such as overwatering. The damage caused by biotic and abiotic diseases can appear very similar. Even with a close observation of symptoms, accurate diagnosis can be difficult and often leads to erroneous diagnosis of plant diseases. Through the use of successive steps it is possible to distinguish between the causes of abiotic vs biotic stress and ultimately to identify the specific agent that causes damage to the plant. A plant doctor should have the appropriate skills to synthesize the knowledge from different disciplines (Plant Physiology, Plant Pathology, Entomology, Weed Science and Pesticide Science) and identify the effects of disease (biotic and abiotic) on the field. Particular emphasis should be given on the impact of abiotic or biotic stress on plant functions in order to understand the visible reactions to the appearance of symptoms, assess the cause of the damage, and lead to the right disease diagnosis. Multiple abiotic problems may contribute to a plant decline, and both abiotic and biotic diseases often occur on the same plants. The accurate aetiology of abiotic

disorders in diagnostic Plant Medicine is crucial and significant efforts have to be achieved in order to train Plant Doctors with the proper knowledge on these diseases.

O7-3. Plant clinic diagnosis worldwide and amateur plant doctors versus phytiatry doctors

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Plant clinic or plant health clinic concept is emerging area in modern agriculture which provides crop care solutions for the farming community and also links the farmers with scientific community. In India Plant Health Clinic is a part of Plant Protection department of Agricultural Universities. Global Plant Clinic (GPC), a part of CABI and agricultural organizations in different countries provides training on agriculture farming to the farmers and also train the plant doctors and agricultural scientist for the betterment of practical advices to the farmers. Another important aspect is who should be a Plant Doctor. Plant Doctors, plant health practitioners academically trained across agricultural science discipline, including both pest-related (entomology, plant pathology, nematology, weed science, and other pests) and plant-related (agronomy, horticulture, soil and water science, etc.) disciplines, need to be the important components for Plant Doctor courses which directly serve agriculture and the general public, through the prevention, diagnosis and management of plant health problems. Plant Medicine or Phytiatry as Medicine in Plants and Veterinary in animals could be a University science directly connected with all aspects of basic and applied topics of various related sciences. Farmers need to follow scientific methods and technologies for the successful agriculture outputs. This is indeed very essential since presently youth is not attracted towards the farming sector. .Lack of Plant Medicine Doctors allows amateurism and unqualified non-technical persons to teach and guide farming community which may lead to several losses to the crop.

O7-4. Universal threats from emerging and phyto-quarantine pests and pathogens to global agriculture due to the lack of phytiatry doctors

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World distribution maps of pest and plant diseases demonstrate that dissemination of hundred destructive agents during the last decades constitute serious and threatening factors for global agriculture and food security. Available data clearly demonstrate that the time elapsing between emergence of a new pathogen or pest in an orchard or field and the actual time of response and identification by plant health experts is a rather slow procedure. Unfortunately, there is a huge gap between the initial stages of spotting and identifying a phytopathological problem in the field till the experts undertake the necessary steps. One of the key reasons for this delay is the limited or lacking coordination among farmers, agronomists, plant protection scientists along with administrate people. I believe that loose or lacking coordination and delayed reaction of plant pest specialists is mainly due to the absence of plant medicine doctors available at crucial numbers around the actual sites of world farming. Phytiatry doctors able to suspect emerging dangerous pests on certain local hosts and provisionally identify them before the involvement of specific scientists working in the laboratories. Thus, experienced and properly educated scientists able to spot and identify pathogens and pests are badly needed to act at a very initial stage in sites of the appearance of a new pathogens or pest. Those who are multidisciplinary educated to be to help confront by delaying or preventing pest and pathogen dispersal to restrict the immense impact on local or international farming. Outbreaks of emerging plant diseases and insect pests are increasing at an alarming rate threatening the food security needs of a booming world

population. Thus, responsible organizations, scientific societies, universities and institutions have to react and not run behind the problems. To demonstrate our arguments, we will analyze four serious cases. Two in Europe (Greece and Italy) a Second in California in USA and one in Bangladesh Asia.

O7-5. Improving small holders' access to plant health knowledge services: The role of ICT based plant clinics in bridging the gap

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The National Sample Survey shows that only around 41% of the farmers in India are receiving agricultural extension services. Further, the source of extension services among these farmers indicate that only 11% have obtained support from the government enabled extension services from Agricultural officers, Krishi Vigyan Kendra's and State Agricultural Universities. Over 20% of the information flow is through peer farmers followed by both digital and print media to an extent of 19.6% which is followed by private dealers (7.5%). Of the several agricultural extension services, access to timely and quality information on plant health is crucial to smallholders as it is directly linked to crop losses ranging between 30-40% in productivity due to pest and disease occurrence. Plant Clinics model led by CABI has been field-tested since 2012 in South India and the key learning indicates it as a demand-driven agricultural extension tool appropriate to smallholders in plant health management. Over a period of 7 years, to improve the effectiveness and efficiency in plant health services, a diverse set of ICT tools have been deployed. The paper will deal with the processes, challenges and key lessons in harnessing ICTs for pest management at the Plant Doctors level for data and information management tools, accessing technical contents through Plantwise Knowledge Bank and documenting the status of site-specific pest and diseases among smallholders in India. While at the farmer's level, ICT tools have been used to timely delivery of pest and disease status and necessary agro advisories for its effective utilization.

8. Fall armyworm-control technologies and management advocacy for Asia

Organizers: Srinivas Parimi, Zhenying Wang, Bhagirath Choudhary and Mao Chen

Lead

O8-1. Biotech and insecticide approaches for fall armyworm control in Brazil and IRM recommendations

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The fall armyworm is a serious cross-crop pest in Brazil. Because of intensive farming with successive plantings of soybean, cotton and maize crops, the problem of insecticide resistance represents a growing threat to the sustainability of Brazilian agriculture. We have been conducting insecticide resistance monitoring of the fall armyworm populations collected from major Brazilian agri-ecosystems for more than two decades. This monitoring program has been partially sponsored by IRAC Brazil. Baseline susceptibility data were established to major insecticides including carbamates (1A), organophosphates (1B), pyrethroids (3A), spynosins (5), *Bacillus thuringiensis* (11A), pyrroles (13), benzoylureas (15), diacylhydrazines (18), oxadizines (22A), semicarbazones (22B), diamides (28) and baculovirus (31). Our insecticide resistance monitoring program is based on diagnostic concentration/dose bioassays and F2 screeening to some insecticides. A stair-step increase in the frequency of resistance to some insecticides (e.g. pyrethroids, benzoylureas and others) has been detected throughout years, reaching values greater than 0.7 at some locations. After the commercial release of Bt maize in Brazil in 2008, resetting to insecticide susceptibility was detected to some insecticides (e.g. benzoylureas, spynosins) due to fitness costs associated with the resistance. Because of the high adoption of Bt crops in Brazil, field-evolved resistance of fall armyworm to Cry1 proteins has already been documented, which are affecting the durability of current pyramided Bt maize hybrids. Our research also demonstrated a high risk of resistance evolution of fall armyworm to Vip3A and diamide insecticides. Therefore, urgent actions of IRM strategies need to be implemented in Brazil.

Invited

O8-2. Fall armyworm control with Bt maize and resistance management on small holder farms

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Genetically modified Bt maize is used effectively to manage Lepidoptera pests such as the Fall armyworm (FAW) (*Spodoptera frugiperda*) (Lepidoptera: Noctuidae) and stem borers such as *Chilo partellus* (Lepidoptera: Crambidae) and *Busseola fusca* (Lepidoptera: Noctuidae) that attack maize. While Bt technology protects maize plants against damage by lepidopteran larvae, this benefit will not be sustained if pest resistance evolves to the Cry toxins expressed in these plants. Insect resistance management (IRM) strategies such as seed blends and the high-dose/refuge strategy are commonly employed to delay resistance evolution. The success of these strategies is however determined, amongst others, by the frequency of resistance alleles in the pest population. The aims of this study were to determine efficacy of single-gene Bt maize expressing Cry1Ab protein and a pyramid event that expresses Cry1A.105+Cry2Ab2 proteins for control of FAW and to determine the frequency of resistant alleles in the South Africa population of this pest.

The pyramid event provided very high levels of control of Fall armyworm. F2 screenings of 117 families showed a low frequency of resistance alleles against the Cry1A.105+Cry2Ab2 maize, and a high frequency of Cry1Ab resistance alleles. While the high dose/refuge IRM strategy is effective IRM strategy in industrial farming systems, its application has unique challenges in small holder farming systems.

O8-3. Fall armyworm, *Spodoptera frugiperda* (J E Smith): incidence, host range and its management

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The invasive fall armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith) was reported for the first time on maize causing severe damage in Karnataka, India during May 2018. Thereafter, the pest has spread to most states of India and now reported from many south Asian countries. The biology under laboratory condition showed that the fecundity was 1064 eggs. Incubation, total larval and pupal period were observed from 2-3, 14-19 and 9- 12 days, respectively. The larval population varied during different growth stages of the crop on maize in Shivamogga and Davanagere districts during *Kharif* and *Rabi* seasons. Heavy population buildup of *S. frugiperda* in Karnataka on sorghum was recorded in Kalaburgi, Raichur, Koppal and Shivamogga districts in November and December months. The damage on maize during July 2018 to February 2019 varied between 20.0 to 80.0 per cent. The management practices like installation of pheromone traps, removal of eggs and use of two rounds of insecticides (Chlorantraniliprole, spinetoram and emamectin benzoate) were found to be effective in reducing the larval population and recorded higher yield. Efficacy of various aspects on *S. frugiperda* is discussed in this paper.

O8-4. FAW management: balancing farmers' needs, product development and regulations

Charlie Ni and Vineet Singh

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Fall armyworm (FAW), *Spodoptera frugiperda* presence and damage werefirst reported in India in July 2018, since then it has been detected in ASEAN and China. The Food and Agriculture Organization expects FAW to continue spreading in Asia-Pacific. As it has a very wide host range, multi crops, especially grass hosts such as corn, sugarcane, etcare preferred. Crop damage results mainly from larvae consuming leaf tissue, destroying potential future plant growth and cause final yield loss, which can reach 30-60%. In order to manage FAW successfully in Asia Pacific, we need balancing the farmers' needs, product development and regulations. Which means for the short term, we need align with local government to get proper effective commercialized products for emergency use, meanwhile, we shall develop full solutions ASAP including seed treatment, seeding time in furrow application, early post-emergence protective application and late crop stage rescue application. In the long run, new mode of action (MOA)Lepidoptera compounds without cross resistance with existing MOA are extremely required.

O8-5. Migratory routes of the invasive fall armyworm in eastern Asia

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The fall armyworm (FAW), an invasive pest from the Americas, is rapidly spreading through the Old World, and has recently invaded the Indochinese Peninsula, China and Korea. In the Americas, FAW migrates from winter-breeding areas in the south into summer-breeding areas throughout North America where it is a major pest of corn. Asian populations are also likely to evolve migrations into the corn-producing regions of eastern China, where they will pose a serious threat to food security. To evaluate the invasion risk in East Asia, the potential routes and mechanisms by which FAW moved from Africa into India, Indochina and then into China was modelled by a trajectory simulation approach, combined with flight behaviour and meteorological data. Our results reveal that (i) FAW could potentially have reached India and Indochina by natural migration from Africa with the help of Somali Jet, which is characterized by persistent, high-speed winds over the Arabian Sea, southern Asia, and the Bay of Bengal; (ii) FAW will annually expand from its new year-round breeding regions in the Indochinese Peninsula and southern China into the two main corn-producing regions of eastern China (North China and Northeast China) by July, *via* separate eastern and western migration pathways involving the northward movement of four generations; and (iii) there is a high risk that FAW will invade Japan and Korea in the summer monsoon season in June and July. Information on migration pathways and timings can be used to inform integrated pest management strategies for this emerging pest

O8-6. Biotech approach for fall armyworm control in Asia

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Fall armyworm (FAW), *Spodoptera frugiperda*, used to be a major insect pest only in tropical and subtropical areas of the Americas, however since its first discovery in central and western Africa in early 2016, it has rapidly spread to almost all Sub-Saharan Africa. At the end of July 2018, FAW was detected in India and Yemen as the first occurrence in Asia. In December 2018, it was discovered in Thailand and it is now in most of the Asian countries including China, Vietnam etc. FAW is now probably the most dangerous invasive insect pest in Asian countries because it is a new invasive pest and there is not much good management experience in Asia. FAW feeds on a wide range of host plants including corn and rice, which are the two major staple corns in Asia. In this talk, we'd like to provide a current view of FAW spreading in Asia, its impact on corn and other crops, options for effective control of FAW, especially biotech approach. Efficacy levels of Bt corn products on FAW were provided to demonstrate biotech approach value. Most importantly, we'd like to raise the awareness of this devastating insect pest to millions of small holder farmers in Asian countries.

O8-7. Contrasting insecticide strategies to control fall armyworm – perspectives from Americas, Africa and Asia

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The challenges and management of *Spodoptera frugiperda* in corn in Latin American, African and Asian countries contrast markedly, due to biological, socio-economic and even political factors. This presentation aims to contrast the current practice in different countries, the rationale behind insecticide interventions and focus on options for African and Asian countries. In the vast corn areas of tropical Brazil pest damage has been successfully managed by the sustained use of effective insecticide chemistries and planting insecticidal GM Bt varieties. Selection pressure has resulted in reduction in field performance to almost all chemical groups and first generation traits. Whilst, the newer Bt corn remains effective, today there is a greater reliance on insecticide sprays. African and Asian *S. frugiperda* populations have caused considerable economic damage, and are believed to be originated from non-insecticide resistant populations in Caribbean/Florida. Severe damage may be related to varietal susceptibility and the lack of natural enemies. In Africa, corn is traditionally a low input crop, advice is often inadequate, and farmers are not equipped and cannot pay for expensive treatments. In India,although the infrastructure is well established and most chemical solutions are available, affordability remains an issue.The experiences in LATAM especially, give Asian and African countries useful ideas how to plan control strategies, which include integrated pest management and insecticides resistance management measuresto make control more sustainable. Further approvals of Bt traits and new effective chemical solutions, may help farmers to manage *S. frugiperda* in future.

O8-8. Fall armyworm, *Spodoptera frugiperda*, current situation and potential impact on corn production in China

Zhenying Wang, Jingfei Guo and Kanglai He

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The fall armyworm (FAW), *Spodoptera frugiperda* (Smith), is native to the tropical and subtropical regions in Americas and wasfirst detected in China in January 2019. Until end July of 2019, it had spread to 22 provinces from south to central and northwest of China, affecting 840000 ha corn. The provinces where FAW occurred till early June belong to the South Hilly Corn Region and Southwest Mountain Corn Region, and part of Qinghai-Tibet Corn Region with about 15% of corn planting in China. However, as the FAW population increased from those regions where FAW occurred in China, which migrated northward with the movement of the Asian monsoon to Huang-Huai-Hai Summer Corn Region in June at seedling stage of summer corn, and even to the south Gansu province of the North Spring Corn Region in July, where some summer corn hasbeen planted. The Huang-Huai-Hai Summer Corn Region and the North Spring Corn Region are the two major corn planting areas with nearly 80% corn planting acreage. The situation of fast spread of FAWnorthwardscaused extensive concernand threatens the corn production in China. Chinese authorities have employed an emergency action plan to monitor and tackle the pest in order to reduce the potential damage in major corn planting regions.

O8-9. Mating disruption: A revolutionary tool for area-wide sustainable management of fall armyworm

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The fall armyworm (FAW), *Spodoptera frugiperda*, was first confirmed outside of its native Americas in Africa in early 2016. Since then it has rapidly spread across Sub-Saharan Africa, infesting tens of millions of hectares of corn, sorghum and millet. In mid-2018, FAW occurrence has been confirmed in India and continued to spread quickly into Southeast Asia and China. This invasion of FAW caused significant yield loss to corn and other crops. Government bodies, research institutes, crop-protection industries, and farmer groups have responded to this invasion by educating farmers on how to manage the pest with locally available tools. However, presently available tools and technology are limited to the application of insecticides or treating seeds with insecticides. Asian corn growers may benefit from adopting some of the methods of FAW management in its native habitats. This involves using all tools available to us, including innovative, advanced technologies such as mating disruption and genetically modified crops. Pheromone based mating disruption, as a foundation for managing FAW, is tested and proved to be effective in Americas. The high cost involved in synthesizing the sex pheromone has likely been a barrier for adoption of this technology in low-cost, large hectarage row crops like corn and rice. However, recent advancements in the syntheses of these pheromones, and the arrival of invasive species like the FAW, create a potential for more widespread adoption of mating disruption as a viable and economically-feasible pest control method in row crop agricultural systems in Asia.

O8-10. Integrated solutions for the management of fall armyworm in corn

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Fall armyworm (FAW), *Spodoptera frugiperda*, has been a pest for over 200 years in the Americas, where the preference and damage to corn has been severe. FAW was first discovered in Asia on corn in Karnataka, India in 2018 and is now present in most corn production regions. With the ability to cause complete yield loss, FAW presents a threat to farmers and food security in Asia. CortevaagriscienceTM offers integrated solutions to mitigate the threat of FAW. Integrated solution begins with a seed applied technology, Lumivia® (containing IRAC Group 28 chlorantraniliprole) that moves systematically into the plant and controls multiple lepidopteran pests, including FAW. Lumivia® enables an early and healthy stand establishment in corn. Lumivia® is registered for protection against seedling infestations of FAW in the United States and Brazil. Infestations of FAW that occur after stand establishment can be managed with applications of spinetoram, a member of the spinosyn class of insecticides (IRAC MoA Group 5). Spinetoram provides effective control of fall armyworm at a rate of 30 gai/ha. Spinetoram controls insects by ingestion and through contact, providing quick knockdown and residual activity. Spinetoram has been awarded the Presidential Green Chemistry Challenge Award in the United States for its positive environmental profile and margin of safety.When used in an integrated approach, Lumivia seed applied technology and spinetoram insecticide, provide for a complementary and superior performing approach for the management of fall armyworm.

O8-11. Efficacy of Coragen® 18.5SC (chlorantraniliprole) against the new invasive pest fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in Indian maize

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Fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is an important and destructive insect pest of maize, which was reported for the first time in India in May 2018. Apart from several other recommended crop protection techniques for FAW, insecticides play a very important role in the management of this invasive insect-pest. Coragen®, a synthetic insecticide containing the active ingredient chlorantraniliprole (anthranilicdiamide chemistry), which targets the insect ryanodine receptor, is a premier choice for management of *S. frugiperda* across the globe. After the first reported incidence of FAW in India, several field trials were conducted to test the efficacy of Coragen® 18.5 SC in various maize growing regions of western, central and southern India. Field test results show that Coragen® 18.5 SC at dose range from 40 to 50 GAH was most effective against this invasive pest. Coragen® provided minimal percent foliage damage, significant reduction in percent cob damage and significantly higher grain yield per hectare versus the untreated control and market standard (Emamectin Benzoate 5G @10GAH). Chlorantraniliprole has a very favorable mammalian toxicity profile that provides good relative safety for mixers, loaders, and applicators. It also has benign ecotoxicological attributes that conserve non-target beneficial arthropod populations in the crop ecosystem such as predators, parasitoids and pollinators. Due to this excellent property, Coragen® and its other chlorantraniliprole formulations fit well into integrated various Pest Management (IPM) programs.

O8-12. Community-based participatory integrated pest management of fall armyworm (*Spodoptera frugiperda*) in India

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The global agriculture saw the uprising of fall armyworm (FAW) in 2016 in Africa, which invaded different geographical regions in the following years, and reached India in 2018. A pest of gregarious hunger, intense feeding, and favorer of maize, FAW has spread to major maize growing areas across India. Since its first reported infestation, the fall armyworm has already resulted in substantial losses in maize production in Southern, Central & Northern India and is likely to pose a grave danger to farmers' income, livelihood and national food security. In Kharif 2019, a nation-wide project Safeguarding Agriculture & Farmers against Fall Armyworm (Project SAFFAL) www.fallarmyworm.org.in in collaboration with FMC India and other downstream industry has shown a path forward to effective management of invasive FAW in India. The presentation will discuss the salient features of our grassroot approach that intends to address the knowledge gap,comprehend the nature of FAW, its biology and life cycle, feeding habits, adverse economic impact assessment, distribution and migration, and best practices to effectively manage FAW in India

O8-13. Biocontrol options for management of FAW

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The fall armyworm (*Spodoptera frugiperda*) (JE Smith) (FAW), which was reported in India during July 2018, has created total distress to the smallholder farmers not only in India, but also in the neighbouring Asian countries. Documentation of natural field occurrence of two egg parasitoids, one egg larval, two larval, two larval pupal, several predators and two entomopathogens as natural enemies of FAW in India indicates the need to focus on feasible biocontrol measures to tackle this invasive pest, which is known to develop resistance to most of the chemical insecticides. ICAR-NBAIR, armed with its large repository of bioagents, has evaluated all the promising bioagents including egg parasitoids, entomofungal pathogens, Bt, NPV and entomopathogenic nematodes. Based on the results of laboratory and small plot studies, the promising bioagents were further field evaluated in different parts of the country through the AICRP on Biological Control. Demonstration trials have also been conducted in farmers' fields to create awareness amongst farmers. However, the major challenge is to make the potential bioagents (including biopesticides) available to the farmers. Hence, future thrust should be on fine tuning the validated mass production technologies and transferring them to commercial units for upscaling. It would be most appropriate to link the biocontrol modules with other compatible strategies like the Pheromone technology and the Push Pull Strategy. The need of the hour is for all the affected countries to come together, exchange notes and materials, organize training programmes and together fight against this common enemy.

O8-14. Fall army worm, *Spodoptera frugiperda* (J.E. Smith) invasion and step forward in Bangladesh

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Abstract: The occurrence of a new destructive pest fall armyworm (FAW), *Spodoptera frugiperda* was noted for the first time in Bangladesh at the beginning of November 2018. Since its first detection in the country, FAW has continued to spread rapidly and covered 34 districts in the same cropping season. A preliminary field assessment was made in affected areas by using pheromone traps and crop damage assessment. This assessment reveals invaluable practical experience on FAW prevalence in maize and its extent of damage in the cropping season of its first attack. An average of 30-40% damage in the vegetative stage of maize was detected depending on global positioning system, but the yield was not high. Existence of some important natural enemies of FAW was identified in the maize ecosystem, which might have regulated the population in reproductive stage of the crop. This preliminary finding will be advocated for IPM strategy for implementation across the country to combat the FAW population for ensuring food security. In response to the report of its arrival, Ministry of Agriculture and FAO Bangladesh organized a mission to build awareness among the stakeholders through training on prevalence of FAW with early monitoring techniques, consequent risks and some recommendations on its management strategy for implementation as immediate and medium-term solution. The mission started with utilization of the experts from different organizations with specific assignment of capacity building is being emphasized to the practical assessment and the use of FAW management tools.

9. The impact of climate change on weeds

Organizer: Bhagirath S Chauhan

Lead

O9-1. Global climate change and Invasive species: lessons learned and where to from here

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Climate change is currently one of the most serious threats to agriculture, partly through the likelihood of increased periods of more intense drought. This change is becoming an added complication to management of weed species in various ecosystems. Atmospheric CO_2 concentration is increasing dramatically and it is likely to reach up to 550 µmol mol^{-1} by 2050. However, the possibility of reduced soil moisture will not act in isolation on plant growth and productivity, since simultaneous changes to atmospheric carbon dioxide levels are likely to complicate the responses of individual plant species to drought events. In this respect, carbon dioxide is known to be essential for plant growth, and decades of research into the phenomenon of increased availability of this essential, input has concluded that it has the capacity to significantly increase plant biomass. This effect has been observed in crop and weeds. Thorough though this previous research has been, there is still a paucity of information regarding the combined and interactive effects of elevated atmospheric carbon dioxide and drought on weed species. In the extant research, the effects of increased atmospheric carbon dioxide and coincident drought on the growth of economically important crops appears to have been somewhat prioritised over that of weeds. However, since weed infestation also presents a significant impediment to crop productivity, it is equally important to focus on the effect that alterations to external conditions, due to climate change, will have on weed species. In this symposium, we will present how environmental and agricultural weeds species responded elevated CO_2. We also will also present the how the herbicide-resistant and herbicide-susceptible biotypes of various weeds species under different CO_2 concentrations and soil moisture levels. We examined, physiological, morphological and biochemical changes in weeds species. This work will provide information on the potential growth patterns of this weed in agricultural settings and lead to further work on competitive interactions of this species with others, including economically important crops.

Invited

O9-2. Elevated CO_2 and temperature effect on biology and damage potential of bioagent *Zygogrmma bicolorata* and growth of Parthenium weed

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Climate change is happening at a fast pace around the globe and significantly impacting the plant growth and ecosystem dynamics besides causing global warming. *Parthenium* weed has become one of the most problematic weeds in India, Australia and many other countries. It has infested large area in non-cropped, forest and cropped land in India. *Parthenium* weed is likely to show increased growth rate in a climate enriched with CO_2 and increased temperatures. The bioagent, *Zygogramma bicolorata* Pallister has been emerged as a potential bioagent to suppress, *Parthenium*. Its grubs and adult feed on the leaves and cause

heavy damage to the plant. The experiments were conducted in open top chambers (OTC) to see the effect of elevated CO_2 and temperature on biology, population dynamics and damage potential of *Z. bicolorata* and on growth of *Parthenium* weed as well. Reduction of leaf nitrogen in *Parthenium* foliage with increased carbon and C: N at elevated CO_2 over ambient CO_2 indicated the dilution of biochemical constituents in host plant. Elevated CO_2 and temperature resulted longer growth duration of eggs, grubs and pupa of *Z. bicolorata*, but with high consumption of *Parthenium* foliage by them in comparison to ambient conditions. Elevated CO_2 and temperature also had a significant effect on the intrinsic rate of increase ®, finite rate of increase (λ), net reproductive rate (R_0) and gross reproductive rate (GRR). The study showed that elevated CO_2 and Temp levels changed the quality of the *Parthenium* leaves which resulted increased consumption of leaves by bioagent but caused slower growth, longer developmental period with reduced reproduction efficiency of the bioagent. The growth of *Parthenium* was found increased under elevated CO_2 and temperature. This was inferred that reproduction efficiency of *Z. bicolorata* is likely to be reduced, but consumption rate of beetle will be increased due to less nitrogen in *Parthenium* leaves.

O9-3. Impact of climate change on herbicide efficacy

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Measurements of atmospheric carbon dioxide levels over the past century have indicated a steady increase which is of global concern. As a result, increases in carbon dioxide concentration, temperature and drought could occur at varying intervals. It addition, studies have indicated that global warming will alter climatic patterns, and increase the frequency of high rainfall events which will affect not only crops but also weed species. In addition, herbicide efficacy is also affected by changing climatic conditions. Agriculture is the backbone of the Australian economy contributing AU$ 56 billion per year to the Gross National Product, however, weeds are a major constraint to crop production in Australian cropping systems. They cost more than AU$ 4 billion annually to Australian grain and cotton growers. In India, the losses due to weed infestation and crop damage are even higher; AU$ 16 billion per annum. Herbicides are now widely used to control weeds in both countries. As a consequence of over-use of herbicides, a significant number of weed species have evolved resistance in both countries. Therefore, there is a need to better understand the impact of climate change on herbicide efficacy. In this presentation, we will provide a range of examples to illustrate these issues and some of the management implications to overcome the problem.

O9-4. Effective and economic ecological weed management approaches for managing weeds in rice in the era of climate change

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Rice will continue to be one of the major staple food to feed expected 9 billion global population by 2050. Weeds are major constraints in limiting rice productivity to meet the increasing food demand. Weeds are more severe constraints in dry-direct-seeded with lower environmental foot print. Climate resilient rice cultivars, with greater competitiveness against weeds, play a key role in ecologically managing weeds. Crop

competitiveness was found to increase with adequate land preparation using techniques like stale seed bed; early seeding/ planting, adjusting row spacing and seed rates, using allelopathic plant residue mulches; adopting brown manuring practice and optimal nutrient and water management in terms of application time and quantity. Limited knowledge is available on the impact of climate change on weed ecology, weeds competitiveness with rice and efficacy of weed management practices used in rice. The C4 weeds with increased temperatures and C3 weeds with increased CO2, are expected to have greater competitive advantage. Weedy rice (C3) may become more problematic as it is more competitive than rice and it responds to climate change in the same way as rice (C3). The response of herbicides tolerant weeds to climate change will be critical for their effective management. Greater understanding of climate change impact, on weeds and rice, is essential for evolving effective and economical ecological weed management strategies for rice during the era of climate change.

O9-5. Tolerance mechanism of alligator weed (*Alternanthera philoxeroides*) to glyphosate under high manganese stress

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Alligator weed *Alternanthera philoxeroides* (Mart.) Griseb. is one of the ten most harmful invasive alien weeds in China. Glyphosate efficacy is often reduced by existing of some metal cations in the solution. Excess manganese stress is becoming much serious with the trends of acid rain in China. For alligator weed which is growing in middle Mn (0.31 mM) and high Mn (2.45 mM), shoots fresh weight reduction declined significantly by 17.4 % and 44.6 %, respectively, compared to that of normal Mn（0.0091 mM, control） at 20 days after glyphosate（68 g ae/ha） application (DAA), and the number of surviving rhizomes in both middle and high Mn treatments was approximately 3 times more than that of normal Mn at 50 DAA. The 14C-glyphosat absorption by alligator weed was not reduced under high Mn stress 3 days after 14C-glyphosate application, even more 14C-glyphosate was translocated to underground parts. On the other hand, The Mn content which is extracted by deionized water in alligator weed in middle and high Mn treatments were 6.13 and 23.30 times more than that of the control, respectively. These results indicated that alligator weed showed tolerant to glyphosate under high Mn stress, and its mechanism is not due to the decrease of absorption and translocation of glyphosate. The increasing of the hydrosoluble form of Mn in the weed which is antagonistic to glyphosate might be the major mechanisms that causing alligator weed tolerant to glyphosate under high Mn environment.

O9-6. Herbicide resistance development and management strategies

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Herbicides are widely recommended for controlling weeds in all over the world in cropping systems. Current study attempts to a greater integration of ideas into the development of herbicide resistance, this can lead scientists to focus less on simply defining herbicide resistance and more towards comprehensive illustration of the herbicide resistance development in agriculture. Weed researchers in collaboration with biologists can work in synergy to come up with better method and innovation aimed to curtain herbicides resistance challenges. Herbicides exert undue pressure on weed fitness and the diversity of weed community's changes over time in response to both herbicides and other strategies imposed on them. Repeatedly and intensively,

the regular application of herbicides with similar effect may swiftly result in population shifts to tolerant, difficult to suppress and ultimately result to weed community that is herbicide resistant, particularly in absence of using herbicides with different modes of action. Weed expert and evolutionary biologists have to work in synergy toward an improve and broader knowledge of plant resistant development. This collaboration is likely to proffer innovative solutions to the herbicide resistance challenges.

O9-7. Weed competition under changing climate

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An increase in atmospheric CO_2 concentrations and the associated rise in the temperature and variable precipitation pattern will have a pronounced effect on weed growth, and understanding the effects is important for effective weed control in the futuristic environment. The rise in CO_2 and temperature has variable effects on plants depending upon the photosynthetic pathway. Altered precipitation, evaporation and temperature patterns due to climate change have resulted in weed flora shifts in northern coastal areas and especially, there has been a preponderance of invasive alien species in wetlands, uplands and in aquatic systems. Various summer season weeds such as *Cyperus rotundus, Amaranthus viridis, Physalis minima, Ageratum conyzoides, and Parthenium hysterophorus* have extended their growth and flowering stages in the winterseason also, which will pose a great problem for weed control in winter-season crops. *Parthenium*, a C_3-C_4 intermediate plant, used to be in dormancy and rosette stages in the cold months of December-January. Various issues, such as rapidly increasing requirement for food due to an ever-growing population, ever-increasing influx of new invasive weeds, the likely impacts of climate change upon weed distribution and abundance, and the advent of special threats such as the evolution of weeds that are resistance to herbicides and to the adoption of reduced tillage agriculture, have all necessitated the re-evaluation of our current weed management approaches.

Oral

O9-8. Effect of planting time and weed management practices on weeds and productivity of potato

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Slow initial growth of the potato coupled with wider spacing, high fertilization and irrigation favours the weeds to grow at faster rate and resulting in 37–51% reduction in tuber yield. Temperature variation is also known to influence the occurrence of type and density of weeds in crops. The present trial was conducted to study the effect of time of planting and herbicide use on the dynamics of weed population and on potato productivity. The soil was sandy loam with 61.5% sand and, 12.1% silt and 26.4% clay, medium in fertility with 0.37% organic carbon and a pH of 7.6. Potato variety Kufri Badhsa was planted on November, 15 and 25 during the both the years. The experiment was laid out in split-plot design with three replication. Weed free condition obtained the highest tuber yield (42.80 t/ha) which was followed by farmers practice (one weeding at 20 DAP supplemented with one earthing up at 40 DAP) and with pre-emergence application of metribuzin (0.5 kg/ha) and atrazine (0.5 kg/ha). Early post-emergence application of isoproturon (1.0 kg/ha) and paraquat (0.5 kg/ha) could not provide satisfactory season long weed free condition.

O9-9. Comparative study of a weeding earthing – up machine' biological efficiency with different rates of Oxadiazon 250 g/l against upland rice weeds and their secondary effects on ferruginous soil agrochemical properties, in Burkina Faso

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A comparative study of a weeding earthing – up machine' biological efficiency with different rates of Oxadiazon 250 g/l against upland rice weeds and their secondary effects on soil agrochemical properties, has been done at Kou Valley, in Burkina Faso. The experimental design was a randomized Fisher block of seven treatments (untreated control, manual wedding, mechanical weeding SBK2 and four rates of Oxadiazon 250 g/l). The weeds counting and their dry biomass were done using a square quadrant of 0.25m². The coefficients efficiencies were evaluated with Vilitsky (1989) formula. The ammonium, nitrogen nitrate soil contents and available phosphorus content were determined by spectrophotometer. The available potassium contents were evaluated by flame photometer. The average coefficients efficiency of the mechanical weeding was 74.33 compared with the untreated control according to their weeds dry biomass. Between Oxadiazon rates, those of 3.33 L/ha and 4.00 L/ha were the most efficient means respectively with 63.88 and 73.55 according to their dry biomass. At the flowering stage, absorption of ammonium nitrogen, available phosphorus and potassium by rice was important at manual and mechanical weeding but low at the different rates of Oxadiazon. All these factors allowed the manual and mechanical (SBK2) weeding to get a yield increase of 23 and 18 times the one of the untreated control. The weeding earthing up machine SBK2 augurs of a new integrated method against upland rice weeds preserving consumer health and the environment.

O9-10. Advantage of cultivar mixture to reduce herbicide doses: steps towards sustainable weed management

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Crop competitive ability allows minimizing use of chemical materials for weed control. Mixture of crop cultivars with different type of growth can lead an efficient method to decrease empty space for weeds to get established. Accordingly, less-weed require less Herbicide dosage to control. Field experiment was carried out to evaluate efficacy of reduced dose of Herbicide Imazethapyr when is applied on a mixed-cultural of soybean cultivars. Two soybean cultivars with different growth type consisting of stand cultivar (Nekador) and climbing type of growth (Telar) were chosen. The experiment was arranged in split-plot with four replications. Climbing cultivar was more competitive than stand cultivar. As it's early coverage between crop rows allows less emergence of weed seedlings. Cultivar mixture was also successful in decreasing weed density and biomass. Both, the pure climbing cultivar and cultivar mixture provide higher Herbicide effect, as there was no significant difference between 75% and 100% of RD. In contrast, stand cultivars required higher Herbicide dose to achieve acceptable weed control. However, climbing cultivars are more competitor against weeds, their high and continued vegetation growth led to lower grain yield, cultivar mixture of climbing cultivar with high grain production and stand cultivar with higher competitive ability provides a cropping system that produces more yield and depends less on herbicide for weed control.

10. Outsmarting the red palm weevil: A global challenge

Organizers: B Sarath Babu, Hassan Al-Ayedh, Jose Romeno Faleiro, Thaer Yaseen and Shoki Al-Dobai

Lead

O10-1. Red palm weevil, *Rhynchophorus ferrugineus* (Olivier), management: Is it working?

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Red palm weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) is a serious threat for the date palm, *Phoenix dactylifera* L., growers Worldwide. Based on its rapid transcontinental spread, increasing host range and massive economic losses, FAO has declared RPW as category-1 pest of date palms. This global menace is a great challenge for the scientists to develop the most effective and efficient management techniques to save this valuable natural resource. The core issue in successful management of RPW is the failure in early detection of its infestation. Our research team is working on integrated approaches including: RPW DNA barcoding, scrutinizing some non-invasive approaches for early detection of RPW infestation, searching for the most-suited pesticides/biopesticides and their delivery systems, and developing RNAi-biotech-based control measures of the RPW. Present talk will try to answer the question: is current RPW management working?

O10-2. Enhanced vigilance, phytosanitation and enforcement of internal quarantine regulations to stop the spread of red palm weevil in the near East and North Africa

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The importance of formulating quarantine protocols implementing strict phytosanitary measures to combat RPW has been emphasized by FAO. This paper attempts to discuss the existing surveillance mechanism, lack of awareness on unauthorized movement of planting material and internal quarantine regulations in date palm growing countries of the Near East and North African region (NENA). The analysis lucidly brings out the challenges in enforcement of regulations on the internal movement of planting material while emphasizing the need for strict enforcement of these regulations in order to stop the alarming spread of red palm weevil in the NENA region. Although a Plant quarantine law exists at GCC level and a decree banning the import of palms of all kinds exists in most of the NENA countries, there still occurs unauthorized movement of date palm offshoots for farming and large palms for ornamental gardening. The movement of planting material within the NENA countries has been a concern in spite of the regulation in force in most of the countries in the region, prohibiting the unauthorized movement of planting material with RPW infestations. A weak surveillance mechanism in the region can't be allowed to continue as it hinders the sustenance of pest free areas, besides diluting the success achieved in controlling the pest. The reporting obligations of new cases of infestation which must be based on the relevant international standard for phytosanitary measures (ISPM). Small farmers in the entire NENA region maintain the orchard as a family property and as heritage in the affluent GCC countries were RPW management practices by the farmer are minimal. In the GCC countries the State intervenes to provide RPW control at no cost to the farmer. Furthermore, the NENA countries do not have a consistent policy in place for the establishment of Certified Date Palm Nurseries and tissue culture production of palm saplings for supply of RPW-free palms except some efforts in this direction in countries

like Algeria. This paper highlights the challenges faced by the NENA countries to address the issue of, enhanced vigilance, phytosanitation and enforcement of internal quarantine regulations to stop the spread of red palm weevil in the Near East and North Africa.

O10-3. Red palm weevil: A global overview

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The Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) has its home in South Asia where it is a major pest of coconut. After gaining foot hold on date palm in the Middle East during the mid-1980s it has significantly expanded its geographical and host range covering almost the entire globe, except the cold Polar Regions and is reported on 40 palm species worldwide. Detection of palms in the early stage of attack is the key to the successful management of this pest. However, the hidden nature of RPW within the palm makes detection of RPW infested palms extremely difficult. Lack of efficient biological control agents for use in the field is also a major challenge. There exist gaps and challenges in almost all the components of the current RPW-IPM strategy. FAO calls for the urgent need to combat RPW by collaborative efforts and commitments at the country, regional and global levels. This presentation gives an overview of the current situation of RPW and elaborates on the key elements of the core RPW-IPM techniques involving early detection, trapping of adult weevils, preventive and curative chemical treatments, removal and disposal of severely infested palms, implementing phytosanitary measures and GIS based data management in area-wide RPW-IPM programmes for efficient monitoring and evaluation of the control strategy.

O10-4. Updates on pesticide resistance in red palm weevils: challenges, management strategies and future research directions

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Red palm weevil, *Rhynchophorus ferrugineus* (Olivier), is a serious coleopterous pest of palms with wide host range. The populations of RPWs dispersed around the world due to negligence and bad practices of the custom and quarantine department. The invaded populations of RPWs spread aggressively in the new habitat on date palm plantations in Gulf Cooperation Countries (GCC). They feed voraciously within the palm trunk, which ultimately kills the palms by destroying their vascular system. The concealed habitat of RPWs and high reproduction potential made it difficult to control their populations. Currently, numerous insecticides are being utilized for the management of RPWs. However, the date palm producers in the Kingdom complained the RPW control failure by insecticides. Reduced susceptibility of RPWs to insecticides probably because of the development of the resistance. In addition, the current published scattered reports on the development of pesticide resistance in RPWs worsen the situation regarding their management. This challenging situation demands the designing of an eco-friendly novel RPWs management strategy with special emphasis on the incorporation of newly discovered genome editing technologies.

Invited

O10-5. Development of date palms fumigation technique for controlling red palm

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Red palm weevil (RPW) is an invasive pest that has become the most devastating and widespread date palm trunk pest responsible for the destruction of date palm plantations in the Kingdom of Saudi Arabia. Due to cryptic mode of habitat, novel designing of environmentally safe control method of RPW is very important. Fumigants have long been praised as attractive alternative pest management option as they are known for their quickest action for controlling all life stages of pests. However, RPW Controlling Date Palm Fumigation Technique is a challenging task due to the escape of poisonous phosphine gas into the surrounding that de, mands over-dosing of Aluminum phosphide. In the current study, we have rationalized the Aluminum phosphide usage by reducing phosphine gas escape using specially designed airtight date palm phosphine suit. Our refined application methodology led us to successfully control RPW populations within the palm trunk without the escape of phosphine gas. The findings of the current study enabled us to recommend Aluminum phosphide tablets in a right dose under specially designed unique date palm phosphine suit as a promising RPW controlling strategy.

O10-6. Innovative program to control red palm weevil, *Rhynchophorus ferrugineus*

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Ministry of Environment Water and Agriculture has developed an innovative multidisciplinary approach for integrated pest management of the red palm weevil, consisting of 12 components. These components are: *Database*, GIS and remote sensing, field monitoring, detection and early reporting of palm weevil, integrated pest management and control practices, good preventive practices, information and awareness program, research, extension and awareness program, training and capacity building program, mechanism to ensure participation of farmers and their associations, coordination mechanism and involvement of the private sector and stakeholders, nurseries for tissue culture offshoots, plant quarantine regulations and phytosanitary procedures, and finally monitoring and evaluation system. Each one of these components consists of many different activities and the benefits of each of these activities add up to ultimately give the expected strength of this program. The program was applied in the kingdom and principally depends on comprehensive periodic date palm testing every 45 days. The program proved to be effective and has achieved the best results in terms of getting areas completely or partially free of infection with the red palm weevil.

O10-7. Socio- personal dimensions of red palm weevil management of coconut in homestead farming systems

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Coconut based farming system supports over 13.8 crores of farm families in India. The incidence of red palm weevil emerged as a serious problem of coconut cultivation causing yield loss and affecting livelihood security of small and marginal farmers. Series of studies conducted since 2010 among the farming community revealed the low level of knowledge and adoption of integrated pest management (less than 10 %) as well as lack of skill in identification of early symptoms of pest infestation. The existing extension approaches or strategies needs reorientation and paradigm shift in achieving optimal results depending on the technologies, social systems and resource of farming community. The spatial pattern of red palm weevil incidence in contiguous area of 2000 ha indicated aggregate distribution in patches as per indices of dispersion, patchiness, cluster dispersion and mean clouding. The field level infestation ranged from 1.54 to 19.9 percentages and significantly more in non-bearing palms. In terms of infestation, 18.67% of 5410 holdings studied in Edava Gramapanchayath, reported red palm weevil infested palms and survey in 7068 homesteads among 1,74,733palms in Bharanikkavu Gramapanchayath showed infestation in 5120 palms. It was also found that coconut gardens with more number of palms had more infested palms. Therefore, field situation of marginal and small holdings demands shifting the pest management strategies from adoption unit approach to area wide community approach. Spatial variation in pest population plays major role in developing strategies for an effective area-wide pest management program at community level. This approach leads to a more effective and sustainable pest management than individual farmer based approach. ICAR – CPCRI pilot tested area wide community management extension approach (AWCA) during 2016 as participatory action research program involving all stakeholders. Coconut land-cover map was developed using satellite data. Spatial analysis of the pest distribution was carried out in GIS to understand the spatial pattern of the pest incidence in the coconut land-cover. Using this spatial analysis and social dimensions as decision making tool, management strategies were developed for the pest management. Innovative extension components such as poster campaigns, stakeholders meetings, coconut Plant protection and Surveillance Groups (CPPSG), operation of integrated coconut field clinics (ICFC) and intense field extension activities organized for social mobilization and . The average red palm weevil incidence (percentage of palms) could be reduced to 0.38 percent from 2.93 percent with the integrated community extension interventions. The focus on community extension approach in wider area could overcome the inefficiency of individual level technology adoption and wide variation of farmers' socio-economic resource base.

O10-8. Smart vigilance and stimulo-deterrence in the bio-suppression of red palm weevil infesting coconut

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Asiatic red palm weevil, *Rhynchophorus ferrugineus* Olivier, a concealed tissue borer is the fatal enemy and destructive pest on coconut palms. Smart detection sensors based on vibration signals of grub activity was found as a non-disruptive innovative tool for sensible early detection. In this attempt, a pattern could be decoded by the typical vibration and noises produced by the feeding grubs of red palm weevil in the lower order frequencies of 10 to 4000 hz. A time amplitude domain waveform devoid of ambient noises and persistent signals of grub feeding could be ascertained after subjecting to reverse transformation and several modes of normalization process. Sustained surveillance and systematic scouting on palms as part of smart vigilance is equally important for pest diagnosis and timely adoption of curative management strategies. Crop

pluralism induced heterogeneity in coconut plantation by systematic planting of intercrops (nutmeg, rambuttan, banana, papaya, curry leaf) produced volatile cues that could disorient red palm weevils away from palm source by stimulo-deterrence (push-pull doctrine), thus infusing less susceptibility to weevil attack than in plantation with coconut as monocrop. No red palm weevil incidence was observed in such ecological engineering coconut garden whereas it exceeded the action threshold of 1% in mono-cropped garden. Diversity distraction of pests on the other hand could attract a wide array of pollinating foragers (bees, flies, ants) as well as defenders (entomophaga). Average yield of Kalpa Sankara palms for four years exceeded 135 nuts per annum in coconut plus intercrop system. This concept could frame coconut farming to fullness, double farmer's income and avoid invasion by the deadly pest.

O10-9. Controlled release dispenser for delivery of red palm weevil, *Rhynchophorous ferrugineus* pheromone

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Red palm weevil (RPW), *Rhynchoporous ferrugineus* is a key pest of coconut, *Cocos nucifera*, date palm and ornamental palms. Aggregation pheromone (4 methyl 5 nonanol + 4 methyl 5 nonanone (9:1) loaded in polymer membrane dispensers are being used for mass trapping of the weevils. Though effective, the polymer membrane dispensers have high release rate ranging from 10 – 30 mg/ day. This warrants replacement of the lure in 3 – 4 months interval which adds up to the cost of the labour and chemistry. Nano materials are a novel carrier/ dispenser for the volatile signaling molecules with controlled spatiotemporal release rates. A controlled release dispenser was developed for loading the RPW pheromone. Characterization by Field Scanning Electron Microscopy (FESEM) and X - ray Diffraction (XRD) confirmed the ordered structure of the pores on the matrix. Pheromone when loaded in nanomatrix showed delayed dissipation as compared to pheromone alone when assayed by Thermal gravity analysis (TGA). Fourier transform infrared (FT-IR) measurements confirmed the presence of pheromone in the nanomatrix. Further, studies on release rate of the entrapped pheromone in the nanomatrix using the Gas Chromatography revealed lower release rate of volatiles compounds as compared to the commercial lures having polymer membrane. The release rate from the nanomatrix was sufficient to cause physiological response that was ascertained by electrophysiological techniques (electroantennogram). Field test of pheromone loaded in nanomatirx captured more weevils than unbaited traps. On longevity of pheromone lures the commercial lure containing 800 mg pheromone was exhausted in three months, whilst the pheromone loaded into nanomatrix could be used for a period of six months from installation date. The nanomatrix developed for delivery of RPW pheromone will aid to scale down the cost in trapping weevils.

O10-10. Essential oil repellents against red palm weevil *Rhynchophorus ferrugineus* Oliver (Curculionidae: Coleoptera) on coconut

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Red palm weevil, *Rhynchophorus ferrugineus* Oliver (Curculionidae: Coleoptera) is a deadly, concealed, borer pest of coconut. Prophylactic treatments with potential repellent is effective management strategy. Present study was undertaken to evaluate the behavioural response of weevil against essentials oils [citriodora oil (*Eucalyptus citriodora*), thymol oil (*Thymus vulgaris*), betel leaf oil (*Piper betle*), ajovan oil (*Trachyspermum ammi*), basil oil (*Ocimum basilicum*), black pepper oil (*Piper nigrum*), nutmeg oil (*Myristica fragrance*) and Cashew Nut Shell Liquid (CNSL) (*Anacardium oxidentale*)]. The weevils were provided a choice between the odour arm containing essential oil (1000 ppm) and the control arm having zero air. Maximum repellency was exhibited by ctiriodora oil with 30% of beetles oriented towards citriodora oil, 40% towards CNSL, 55% beetle towards black pepper oil and over 70% , 60% and 45% of the beetles moved towards the control arm in which the pure air was passed. Whereas about 60-70% of weevils moved towards the odour arm when other essential oils were tested. GC-MS profile of citriodora oil was analysed to identify its components. Repellent property of citriodora was confirmed by wind tunnel assay in which 13.33% beetles exhibited up wind flight response. 23.33% beetles exhibited downwind flight response after moving up to mid point. 63.33% beetles remained at the point of release in the wind tunnel. Gel based slow release matrix (calcium alginate) of essential oil (2.5%) was developed and place on coconut leaf axil@5g/palm in two sachets. It reduced the incidence from 5.19% to 1.3%, over a period of three months.

11. Pollination management under protected cultivation

Organizers: Balraj Singh and Kumaranag

Lead

O11-1. Pollination and pollinators in protected cropping: an Australian perspective

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Horticultural crops are increasingly being grown within protecting structures due to increased pressure on arable land, the need for greater efficiency of water and fertiliser use, climate change and demand for improved product quality. However, growing crops under protected cropping conditions restricts entry of wild pollinators. A wide variety of greenhouse crops require insect pollination and managed pollinators such as European honeybee, *Apis mellifera*, and bumblebees, *Bombus* spp., which have been used in a number of countries. In Australia, the use of these species is not viable; honeybees are poorly adapted to the greenhouse environment and also pose health risks to workers, and bumble bees do not occur on mainland Australia. Research is underway at Western Sydney University to identify suitable alternative pollinators for greenhouse crops. Stingless bees (Meliponini), particularly *Tetragonula* spp., show promise because they lack a sting, are able to be managed in hives, and are polylectic. We have shown them to be effective pollinators in capsicums and they are frequent floral visitors to greenhouse strawberries. Furthermore, they can orientate and effectively forage in structures with coverings that impact light quality (including UV spectrum). However, restricting stingless bees to greenhouse monoculture will likely impact their nutrition and colony health. We are therefore assessing individual bee and colony health under prolonged greenhouse conditions, including the use of supplementary feeding. Previous Australian work has assessed the solitary bees *Amegilla* spp. for buzz pollination of solanaceous crops such as tomato. While they are effective, difficulties with their management prohibit commercial use.

O11-2. Role of honey bees in hybrid seed production of vegetables and seed spice crops

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Seed production in cross pollinated vegetables and seed spices exclusively depends on the insect pollinators, mainly honey bees. The precise movement of pollen between the parental lines can be achieved by honey bees with little manipulation of their population. Hybrid seed production in vegetable cole crops like cauliflower, radish, beet root, cabbage has been increased by many folds with the introduction of single colony of *Apis mellifera* under enclosed as well as open field conditions. The quality fruit and seed production in cucurbit vegetables is found to be positively correlated with pollinator population. Seed spices like coriander, fennel, cumin, fenugreek, thyme, being highly cross pollinated crops, heavily dependent on bee assisted pollination. Managed bee pollination in coriander, fennel and fenugreek resulted in 20-25 per cent increase in the seed yield along with enhancement in the seed quality and essential oil content. Wild honey bees like *Apis dorsata* and *Apis florea* are equally contributing in production of seed spices in arid regions of Rajasthan. Decline in the population of wild honey bee species due to loss of nesting places,

indiscriminate hunting and injudicious use of pesticides and fungicides during the seed production had negative impact on seed spices production. Honey bees can be effectively managed for production of quality seeds in vegetables and seed spice crops with scientific management practices. Conservation of wild pollinators by habitat manipulation and adopting alternative pest management measures could be beneficial in developing robust seed production system for vegetables and seed spices.

Invited

O11-3. Utilisation of stingless bees under protected cultivation

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Inaccessibility of natural pollinators to flowers under protected cultivation can be managed by the introduction of native pollinators, which are able to adapt to the conditions of the closed environment. Efficiency of insects as crop pollinator depends on their biological characteristics in relation to the crop and the environment in which they are needed. Stingless bees being polylectic, tolerant to high temperature and active throughout the year, can be efficiently utilized under protected cultivation in the tropical climate. Characters of stingless bees *viz*., floral and resource constancy, harmlessness nature also suit them best for pollination under protected conditions. Though, protected cultivation with automated control arrangement, exhaust fans with thermostat and misting arrangement is found more suitable to stingless bees, provision of green net cover around the hive and sugar solution in the absence of nectar was found to increase the efficiency of stingless bees. Among the cucurbitaceous crops, *Cucumis sativus* is most widely grown in green houses worldwide, its flowering phenology ensures better cross pollination for higher fruit set and yield. Studies revealed an increase in quantitative and qualitative parameters of even the parthenocarpic cucumber by augmented pollination using stingless bees inside green houses. Nowadays, farmers are also practising stingless bee pollination under protected cultivation in crops like cherry tomato, coccinia, bittergourd, etc.

O11-4. Pollination of cucurbits through native bees under polyhouse conditions: Scope and limitations

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Protected cultivation of vegetables is gaining popularity in India as it aids in breaking seasonal barriers and also to get higher quality yield from lesser land. Since majority of vegetable crops are cross pollinated, they need to be visited by different insect pollinators to produce fruit or seed, which is a major limitation under protected cultivation. Bumble bee, *Bombus terrestris* is widely used in Europe and other temperate countries for polyhouse pollination. However, this species is not present in India and introduction of this invasive species is discouraged. Accordingly, a need is felt to have native pollinator species amenable for use in polyhouses for pollination. We undertook studies at ICAR- Indian Institute of Horticultural Research, Bengaluru, India to evaluate native pollinators for their pollination efficiency under polyhouse conditions. Three species *viz*., *Apis cerana, Tetragonula iridipennis* (Hymenoptra: Apidae) and *Chrysomya megacephala* (Diptera: Calliphoridae) were used to assess their foraging behavior and pollination efficiency on cucumber and watermelon grown under an insect proof polyhouse. A colony of *A. cerana* with a strength of eight

frames was maintained inside polyhouse by providing two side openings. Two hives of *T. iridipennis* were also hung from top at crop canopy level, while adults (about 2000 No.) of *C. megacephala* were released from laboratory culture. It was found that *A. cerana* and *T. iridipennis* foraged actively on both male and female flowers thus facilitating pollen transfer. Fruit set, fruit yield and quality in plants exposed to bees were compared with those excluded from insects and hand pollinated. *A. cerana* was the most efficient pollinator followed by stingless bee while *C. megacephala* did not forage the desired extent on cucurbit flowers. The methodology and limitations in using these species for polyhoue pollination are discussed.

O11-5. Foraging behavior and pollination studies of carpenter bee, *Xylocopa fenestrate* on ridgegourd, *Luffa acutangula*

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Carpenter bees (*Xylocopa* spp.) are effective pollinators of cucurbits. In order to study the foraging behaviour of *Xylocopa fenestrata* on ridgegourd, four characters namely, frequency of flower visit, time taken per trip, pollen load per trip and time spent per flower were investigated. The mean frequency of *X. fenestrata* visit on ridge gourd was found to be 5.12±0.453 per minute. The highest frequency of visit per minute was recorded to be 6.8±0.466 at 1700-1800 hours of the day. The average frequency of flower visit was recorded to be 5.3±0.437 per minute. The maximum time taken per trip was recorded to be 34.3±1.844 minute and the minimum was recorded to be 16.9±0.849 minute. The average pollen load carried by *X. fenestrata* per trip was recorded to be 23.39±0.995 mg on ridge gourd. The average time spent by *X. fenestrata* per flower was recorded to be 19.26±1.248 seconds. In the *Xylocopa* pollination (XP_3) treatments, the number of fruits/plant was 17.81±0.325 against 16.78±0.58 and 5.22±0.41 in open and pollinator exclusion treatments, respectively. Similarly, the fruit set in *Xylocopa* pollination (XP_3) treatment was observed to be 34.91 per cent as against 32.98 and 10.31 per cent in open and pollinator exclusion treatments. Yield increase per hectare was observed to be 71.35±0.901 (q) against 53.90±0.890 (q) and 20.70±1.588 (q) in open and pollinator exclusion crops, respectively. Bee pollination treatments also showed 224.5 % yield increase over 160.4 % in open pollinated crop.

O11-6. Understanding the contribution of floral resources to effective pollinator populations in agro-ecosystems

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Most of the horticulturally important food crops are reliant upon pollination in order to set seed or fruit. Many of these crops are serviced by managed honeybees specifically brought in for the peak flowering period, although the role of native wild pollinators is becoming increasingly realised and important in the wake of wide-scale honeybee decline. With the abundance and fitness of wild pollinator populations intrinsically dependent upon the availability of floral resources, not only during peak crop flowering but also year round, the surrounding land use and vegetation matrix have the potential to influence crop pollination and thereby the horticultural production. Consequently, we conducted an investigation to assess floral resource quality and quantity both on farm and within the wider vegetation matrix within cherry and apple farms in three growing regions within central-eastern Australia. We used a comparative approach, to determine the floral resource quality and quantity available to pollinators throughout the year on farms and within the wider vegetation matrix surrounding these farms and also determined how this, in turn, affects the pollinator assemblage.

O11-7. Scientific stingless bee rearing and its pollination potential on horticultural crops grown under protected conditions in Nagaland

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Pollination is one of the important ecological processes on earth delivered by nature. Most of the plants depend on pollination services for the production of fruits and seeds. Among different pollination agents, bees are the important ones comprising of stingless bees, honey bees, bumble bees, solitary and other social bees. In Nagaland, farmers are practising stingless bee culture traditionally since time immemorial. Being the biodiversity hotspot, different species of stingless bees are present in different parts of the state but *Tetragonula iridipennis* Smith is the most dominant along with *Lophotrigona canifrons*, *Lepidotrigona ventralis* and *Tetragonula laviceps.* Pollination potential studies of *T. iridipennis*, were undertaken on different horticulture crops (cucumber, tomato and ash gourd) under protected conditions. Different types of wooden boxes having different dimensions were designed for domiciliation of stingless bees and ease of honey extraction. Total four treatments *viz*., *T. iridipennis* pollination, *Apis cerana* pollination, open pollination and control (pollinator exclusion) were compared for quantitative and qualitative yield parameters. Data were recorded on relative abundance, foraging rate, foraging speed and loose pollen grains to ascertain the pollination efficiency. Among all the tested hives, hive having different brood and honey chamber was found the best with ease of honey extraction and brood development followed by single chambered hive of thick wooden sides. Data on crop production revealed many fold increase in production and quality in bee pollination treatments as compared to control. Stingless bees are more efficient pollinators of cucurbit crops under protected cultivation.

O11-8. Foraging behavior of stingless bees under protected vegetable cultivation

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Meliponiculture has been practiced in different tropical and subtropical countries for many years. The commercial use of stingless bees as a promising candidate for crop pollination in vegetables under protected cultivation has increased the scope for promoting the stingless bee keeping in many countries including India. In this study, two stingless bee (*Tetragonula iridipennis*) colonies with approximate population of 1500 bees were kept inside a greenhouse of 2000 m^2area grown with Fadia hybrid cucumber at Reddiyarchatram, Dindigul District, Tamil Nadu. Stingless bee foraging activity on cucumber flowers inside the greenhouse begun at 07.15 h and ceased around 17:50 h. The peak foraging activity was noticed between 9.30h and 11.00 h with maximum forager population of 12 nos./flower/ 10 min. to gather the floral rewards. The forager activity declined during 12 noon to 15.00 h with minimum forager population of 2 bees / flower / 10 min and found completely ceased during late evening hours. The observations on rewards collection in cucumber revealed that the floral handling time varied among the foragers. The nectar foragers took a mean of 12.4 sec in a flower to gather the nectar. It is concluded that stingless bees found actively involved in collection of rewards in greenhouse cucumber and their foraging activity can improve its pollination potential and fruit yield of cucumber.

O11-9. Impact of distance from native vegetation and pesticide spray regime on potential pollinator abundance and diversity in mango farms, Northern Territory, Australia

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Abstract: Insect pollinators significantly improve mango fruit set and yield, yet little is known about their spatial distribution within orchards. We conducted eight pollinator surveys within plantations of cv. Kensington Pride mangoes in the Darwin (n=6) and Katherine (n=2) regions of the Northern Territory, Australia from June to July 2019. Diurnal and nocturnal surveys were conducted on trees located at increasing distances (up to 400m) from crop edges adjacent to native vegetation. A total of 135 insect morphospecies from Diptera (n=52), Hymenoptera (n=50), Coleoptera (n=12), Lepidoptera (n=11) and other taxonomic groups (n=10) were observed as mango floral visitors. In Darwin farms, the stingless bee *Tetragonula mellipes* was the predominant floral visitor, followed by a *Mesembrius* sp. hoverfly. The Katherine sites were dominated by *T. mellipes* and two other stingless bee species, but hoverflies were almost entirely absent. There was a strong edge effect in the distribution of fixed residence foragers such as stingless bees, solitary bees and wasps. In contrast, Diptera were equally distributed across all distances from the crop edge. The intensity of pesticide spray regime was negatively correlated with pollinator abundance and diversity. Stingless bee populations in particular decreased drastically after foliar sprays and did not recover up to ten days after application. Our results demonstrate that stingless bees are common naturally occurring floral visitors in Northern Territory mango farms. Moving stingless bee hives into mango crops may provide a more even distribution of stingless bee pollination service throughout the orchards, and potentially increase productivity of mango farms

O11-10. Native bees: Alternative pollinators in Australian apple orchards

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Owing to its geological history, Australia possesses a distinctive bee fauna (~2,000 species) that have evolved in concert with the native flora (predominantly Myrtaceae), however, little is known about the potential role that native bees can provide to Australian food production. An improved understanding of these currently undervalued natural resources is imperative to strategic food management, especially given Australia's dependence on managed colonies of a single introduced species (European honey bee *Apis mellifera*, Apini, Apidae) -the most commonly deployed pollination-vector in horticultural settings globally. Our research team is assessing the pollination potential of native bees on apple crops in a quantifiable manner across two distinct landscape matrices in New South Wales: a region where orchards are surrounded by pristine native woodlands (Blue Mountains), and one where agricultural land-clearing has left sporadic remnants of native bush (Central West). We are discovering which native bee species visit flowers of apples (Pink Lady & Granny Smith), and more importantly which species are effective pollinators. Apples in our study areas are visited by a variety of native bees, including meliponine stingless bees (*Tetragonula*, Meliponini, Apidae), stem-nesting allodapine bees (*Exoneura*, Allodapini, Apidae) and ground nesting halictid sweat bees (*Lasioglossum*, Halictini, Halictidae). Investigations of foraging behaviour, broad-scale visitation rates combined with fine-scale individual bee behaviours on flowers, are augmented by studies of: natural history (nesting behaviour); bee-mediated pollen transport (advanced genomic tools); assessments of functional

morphology (pollination guilds); and the influence of surrounding habitat at the landscape spatial-scale (geographic information systems).

O11-11. The role of stingless bees *Tetragonula iridipennis* in seed production of chilli, *Capsicum annum* under greenhouse condition

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The role of stingless bees, *Tetragonula iridipennis* in enhancing the yield of chilli hybrid KBCH-1 was carried out in University of Agricultural sciences, GKVK, Bengaluru during 2018-19. The result on foraging activity of stingless bees was peak between 10:00 h to 12:00 h. The maximum and minimum time spent for pollen collection was 6:20 sec and 2:70 sec and for nectar collection time spent was 16.20 sec (maximum) and 10.00 sec (minimum) by *T. iridipennis*. The effect of number of bee visits on quantitative parameters *viz*., per cent fruit drop, per cent fruit set, fruit weight, fruit girth, fruit length, number of seeds/capsule and seed weight from zero to eight bee visits was recorded. The quantitative yield parameters were maximum in six and eight visits of stingless bees compared to zero bee visit. At zero bee visits the flower drop was 100.00 per cent and fruit set was not initiated. In stingless bee pollination, the flower drop (18.65%), fruit set (81.35%), fruit weight (5.75g), fruit length (4.50cm), fruit girth (0.98cm), number of seeds/capsule (62.72) and seed weight (4.60g) was maximum compared to control (without bees) *i.e*., flower drop (35.75%), fruit set (64.25%), fruit weight (5.60g), fruit length (3.50cm), fruit girth (0.90cm), number of seeds/capsule (30.63) and seed weight (3.89g). No significant differences were observed in qualitative parameters of chilli fruits and seeds in different treatments except for the percent germination, which was highest for seed obtained through stingless bee pollination. The study showed that proper management of stingless bee colonies in protected cultivation enhanced the yield parameters of chilli.

O11-12. Status of bumble bee, *Bombus haemorrhoidalis* Smith rearing and its use in pollination

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Bumble bee rearing and utilization in crops grown under protected cultivation has taken the shape of an industry in Western World. However, in India, *Bombus haemorrhoidalis* is the only bumble bee species reared successfully on smaller scale and experimented for its usefulness in pollination of crops at Solan. In the present investigations, *B. haemorrhoidalis* queens, collected from field, were reared under laboratory conditions at 27±1^{0}C temperature and 65-70 per cent RH on 50 per cent sucrose solution and fresh/stored pollen collected from honey bee colonies. The successfully reared laboratory colonies were shifted to field for further development. The success rate of colony development under laboratory conditions and field established colonies was more in queens collected during April in comparison to those collected in March and February. The wooden domicile along with fresh pollen and 50 per cent sucrose solution are most favourable for rearing of *B. haemorrhoidalis* under laboratory conditions. Nosema, conopid fly and bee moth larva were found infesting queens and workers during colony development, which necessitates development of management strategies for its successful rearing. The bumble bees have also been proved effective in

pollination of cucumber, tomato and bell pepper crops grown under protected cultivation. This paper will discuss the status of rearing of *B. haemorrhoidalis* and its use in pollination in India.

O11-13. Estimation of optimal pesticide application time on mustard, *Brassica juncea* (L.) based on temporal foraging activity of pollinators

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In India, *Brassica juncea* is a predominant crop and covers more than 90% area of the mustard. The out crossing in *B. juncea* varies from 7.6% to 22% and most of that pollination is carried out in nature by virtue of entomophily. Pollen is heavy and sticky in nature therefore, insects play pivotal role in pollination. The foraging initiation and foraging cessation of the pollinators were recorded to determine and create conscience about the wise use of pesticides application time during the specified time of blooming period. The foraging initiation and cessation of pollinators were recorded on sunny days with normal weather conditions. The foraging initiation and cessation of all the pollinator species varied. During 2018-19, earliest foraging initiation was recorded with *Apis dorsata* (07:55 h) followed by *Apis mellifera, Apis florea, Apis cerana* and *Syrphus* sp. The pollinator species, which cease its foraging activity very late was *A. dorsata* (18:16 h) before that *A. mellifera, A. florea, A. cerana* and *Syrphus* sp. Based on foraging initiation and cessation of pollinators, application of pesticides for pest management should be admissible only after total cessation of foraging (18: 16 h) by pollinators, which would in turn help in augmentation and conservation of these pollinators, thereby maximizing the pollination to enhance crop productivity.

O11-14. Role of honey bees in Niger (*Guizotia abyssinica*) pollination

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Niger is an important edible oil seed crop which depends on honey bees for effective pollination. Niger is being widely cultivated in India and Ethiopia. Despite its importance, the floral biology and its interaction with pollinators is poorly understood. The present study was conducted at the University of Agricultural Sciences (UAS), Gandhi Krishi Vignana Kendra (GKVK), Bangalore (13° N & 77°35' E; 930m above MSL), Karnataka, India, to understand the foraging behavior of honey bees on niger and their role in pollination. Abundance of bees was positively correlated with floral abundance (r = 0.99). Among them, Apis florea and A. cerana were dominant. Activity of these bees commenced around 0730 h. Apis cerana had two peaks, one between 1000-1100 h and another between 1600-1700 h, while A. florea had a single peak of activity between 1100-1400 h, which indicated a temporal difference in the activity of the two species probably to avoid competition. The time spent (in seconds) per capitulum by A. cerana and A. florea was 9.63±1.33 and 14.9±2.94, respectively; and per floret a bee spent 1.33±0.27 and 1.83±0.39, respectively. Apis cerana foragers were found to be more efficient pollinators since they deposited greater number of pollen grains on stigmatic surface per visit (8.15±5.76) than A. florea (6.90±3.98). Niger was found to be completely cross pollinated since there was no seed set when flowers were excluded from pollinators and also when the flowers were selfed. Under open pollination condition, the seed set was highest (78.27±5.20 %).

O11-15. Effect of microclimate inside the protected cultivation structures on stingless bee *Tetragonula iridipennis* smith survival and pollination

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The survival of stingless bees in protected cultivation conditions namely poly house and screen house conditions was studied by observing the colony growth parameters. Two colonies of stingless bees were placed in a poly house. Similar arrangement was made at a net house. Weekly observations such as number of bees entering and exiting the colonies for a period of five minutes, number of bees/ $5cm^2$ area inside the hive, number of pollen pots, number of honey pots and volume of brood cells were observed in both the protected cultivation units, the results of observation are as follows. The stingless bees kept inside a poly house with tomato crop in flowering stage and which was not sufficiently ventilated, gradually declined in strength from 35.0 to 9.75 per 5 min (counted at hive entrance) and the hive was abandoned by the bees in 5 weeks. The temperature gradually increased inside the hive from 38.5 to 41.5 ^{o}C. The stingless bee colony kept inside a screen net house with cucumber crop in its flowering stage that was sufficiently ventilated, maintained uniform strength of bees and the volume of brood cells gradually increased. The temperature inside the hive varied from 28 to 31 °C. Thus maintaining a well ventilated screen house with suitable micro-climate improved the possibility of utilising stingless bees in pollination of vegetables in protected cultivation

12. Biotechnology and integrated pest management

Organizers: Karim Marediam Ruth Mbabazi Pooja Bhatnagar and Kiran Sharma

Lead

O12-1. Evolving role of biotechnology applications in integrated pest management (IPM) worldwide

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Biotechnology applications offer tremendous opportunities for integrated pest management programs worldwide. The new tools and applications of modern biotechnology encompass rapid diagnostic kits, molecular markers, genetically engineered crops as well as gene-editing approaches. The emerging tools and applications of modern biotechnology are at various stages of development. Both, public and private sector organizations are engaged in biotechnology research and development globally. This symposium will present case studies of various applications of modern biotechnology in IPM programs and highlight opportunities and challenges in the use and management of biotechnology applications in IPM.

Invited

O12-2. Biotechnology for aflatoxin free groundnuts for Africa and Asia

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Aflatoxins are the most powerful carcinogens in nature produced by the fungal genus *Aspergillus*, contaminating various agricultural commodities, predominatly in maize, groundnut, cotton, chillies and nuts. Despite years of breeding efforts for developing aflatoxin resistance in groundnut, confirmed sources of resistance to aflatoxin have not been identified, due to poor understanding of host resistance mechanisms and the lack of reliable markers consistently associated with aflatoxin resistance. This lack of resistant lines against *A. flavus*/*A. parasiticus* infection necessitated the deployment of genetic engineering strategy to develop double defense strategy by expressing antifungal plant defensins and using host-induced gene silencing (HIGS) of key aflatoxin biosynthetic pathway genes in groundnut. This pronged strategy provided robust shield against several *Aspergillus flavus* strains and resulted in significant decrease in aflatoxin contamination. In addition, efforts are ongoing to identify proteome and metabolome signatures underlying the resistance mechanisms in these "novel resistant events" towards developing new breeding techniques (NBTs) for precision breeding for aflatoxin resistance.

O12-3. Pod borer resistant Bt cowpea for West Africa

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Cowpea (*Vigna Unguiculata* Walp) is an important crop in West Africa. But, its average yields are low, 200-400 kg/Ha. Insect pests constitute a major yield limiting factor. Among them Maruca (*Maruca* vitrata (Lepidoptera: Cambridae) was described as the most destructive insect pest of cowpea. Efforts to find a resistance source were not successful. To control Maruca, farmers spray insecticides, 6-10 times. The development of a transgenic cowpea was regarded as a sustainable solution to the problem of the pod borer. The African Agricultural Technology Foundation (AATF) created a public private partnership to develop the Bt-cowpea Project. Monsanto offered the Cry 1Ab gene from *Bacillus thuringiensis*, subsp kurstaki strain HD-1. The transformation of the cowpea (variety IT86D1010) was carried by the CSIRO using *Agrobacterium tumefaciensis*-mediated transformation; the gene construct used the plasmid PMB4 as a vector. Several cowpea events expressing Cry1A were generated then, tested in West Africa under severe artificial infestation conditions. Event 709A was selected as the best; it was subsequently used to introgress the Cry1Ab gene into farmers preferred varieties. With Bt-cowpea the number of insecticidal sprays was reduced to 2. Results of farmers managed trials showed that Bt-cowpea gives 20-80% higher grain yield than the conventional control. Bt-cowpea will serve as a backbone for an IPM program on cowpea. To delay the emergence of a biotype of *M vitrata* resistant to Bt-cowpea a second transgene Cry 2Ab-events are under test.

O12-4. Transgenic Bt maize and lepidopteran resistance: a Michigan USA perspective

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Transgenic Bt maize was commercialized in the U.S. in 1996 and is now planted on over 80% of the total maize acres. Control of the original key target pest, European corn borer, has remained effective. However, over time, secondary ear-feeding caterpillars have become a problem in traited corn, and in at least one case, a species was removed from a Bt trait label due to lack of control. There is an increasing concern in the viability of remaining effective toxins.

O12-5. Technology applications for enhancing crop breeding: An industry perspective

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Multiple technology approaches are needed to sustain genetic gains achieved through plant breeding, and address the major challenges associated with climate change as well as tolerance to biotic stress factors. Incorporating single genes into crops that enable plants to withstand these stresses is a demonstrated approach (Bt cotton, Bt brinjal) but one which has faced increasing difficulty in gaining approvals or release. To aid the crop breeder, molecular marker and genomics approaches have been used successfully and now the focus is on predictive breeding models for making decisions in breeding programs. Integrating doubled haploids

has been a proven enhancement in breeding programs. More recently, digital agriculture has offered new methods of assessing crop performance and new breeding techniques have opened a myriad of opportunities in new product development.

O12-6. Bt brinjal (eggplant) experiences of Bangladesh

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Eggplant (*Solanum melongela* L.) commonly known as Brinjal or aubergin is one of the most popular vegetables in Bangladesh grown across the country throughout the year. Bt eggplant- resistant to notorious pest brinjal fruit and shoot borer, the first GMO crop in Bangladesh is gaining popularity among the farmers. Initially it was distributed among the 20 farmers in 2014, with short span of time of 5 years, adoption increased in more than 27 thousand farmers. Field performance of Bt brinjal is quite satisfactory. Fruit infestation in non-Bt was 36.70 to 45.51% while it was only 0.0 to 2.27% in Bt brinjal varieties. Studies revealed that farmers saved 61% of the pesticide cost using Bt technology. For sustaining the technology, farmers and seed producers were trained, strengthened insect resistance management program, made communication with the stakeholders. The success of Bt brinjal will pave way for other GMOs which are in pipeline for ensuring food security, improving the livelihoods of the farmers and protecting the environment.

O12-7. Regulatory and policy aspects of biotechnology applications for IPM

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Diffusion and adoption of agricultural biotechnology tools and products are offering solutions to mitigate losses from insect pests, diseases, drought, salinity and other constraints in agriculture to enhance agricultural productivity, environmental quality as well as food security. Favorable policies and regulations are essential for safe development and transfer of biotechnology products from laboratory to farmers' fields and to market place. Access, utilization, deployment and management of biotechnology tools in pest management programs require a wide range of policies related to intellectual property rights, biosafety regulations, communication, and product stewardship.

O12-8. Multiplexed gRNA-based transient CRISPR-Cas9 modules targeting multiple sites in begomovirus genome limit the escape mutant formation and disease development

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Recently, CRISPR-Cas9 technology has been applied for checkmating few DNA viruses of plants, but this technology had limited success considering the evolution of escape mutants. We employed a novel

multiplexed gRNA-based CRISPR-Cas9 approach to target multiple sites of the viral genome. We demonstrate the approach by targeting genome of chilli leaf curl virus (ChiLCV), which is one of the most menacing viral pathogen affecting yield of chilli crop in India. This approach successfully destroyed the genome of ChiLCV without relapse of any functional escape mutants. Six individual gRNA spacer sequences were designed from the genome of ChiLCV. The cleavage behaviour of these spacer sequences was confirmed through In vitro assay. Based on combinations of the above-mentioned spacer sequences, a total of nine-duplex and two-triplex CRISPR-Cas9 expression constructs were developed. The efficacy of these constructs was tested for transient inhibition of ChiLCV infection in Nicotiana benthamiana. All the constructs caused significant reduction in accumulation of viral DNA. Amongst these, three constructs (gRNA5+4, gRNA5+2 and gRNA1+2) were most useful in reducing viral titre and symptoms. We employed T7E1 assay and sequencing of the targeted viral genome to detect prominent escape mutants, if any. The results show potential of employing a multiplexed genome editing technique for immunity to begomoviruses.

O12-9. Genome editing in the light of global food security – biotic stress resilience

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Food and Agricultural Organization (FAO) projections show that feeding a world population of 9.1 billion people in 2050 would require raising overall food production by around 70 per cent. Moreover, climate change resulting in pest outbreak and increased disease incidence pose a catastrophe to global crop production. In this light, recent revolution and rapid progress in targeted alteration of DNA sequences by genome editing could prove as a boon for agriculture. Genome editing methods, particularly the Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/Cas9 (CRISPR-associated protein9) site-directed nucleases, has emerged as one of the foremost systems to edit the crop genome. Application of this method is rapidly increasing, with the possibility of its expansion in almost any crop genome sequence to generate novel variations and accelerate breeding efforts to fight biotic stresses. This technique could change or 'switch off' DNA sequences in a very precise way, without foreign genes being introduced, hence it is considered different than GMOs.

O12-10. Engineering disease resistance through a precise CRISPR/Cas9-cytidine deaminase fusion base editing system

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Pepper anthracnose is the most devastating disease of chilli (*Capsicum annuum* L.) in the tropical and sub-tropical regions of the world. Transcriptome dynamics in the pepper-anthracnose interaction have revealed that members of ERF and NAC transcription factors act as a major susceptibility source during anthracnose infection. Targeted base editing promotes the conversion of one target base into another without the need of a foreign DNA donor or double stranded DNA cleavage. We have developed a CRISPR–Cas9 nickase-cytidine deaminase fusion to achieve targeted conversion of cytosine to thymine in the NAC72 locus of *Capsicum annuum* towards development of durable resistance to *Colletotrichum truncatum*, the most belligerent anthracnose pathogen. The results from this study will be discussed to prove that base editing could facilitate precision molecular breeding in plants for specific trait improvement.

13. Biological control – prospects and associated challenges

Organisers: Chandish R Ballal, Jagadeesh Patil and Richa Varshney

Lead

O13-1. Scope of integrating insect biological control with semiochemicals deployment for synergy impact

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Biological control of insect pests has made significant strides in recent years largely due to increasing awareness of the ecosystem benefits. Matching progress has been accomplished in multi-directional R&D focus in biodiversity, bio ecology, climatic stress adaptation, more efficient mass production and quality upkeep extending shelf life by diapause induction and alternative delivery systems, together culminating in improved cost-competitiveness and greater access to biocontrol technology products/methods. There has been concurrent remarkable progress in the field of semoichemicals deployment for monitoring and/or mass trapping of a wide spectrum of insect pests and vectors. The most important among semiochemicals are insect pheromones, which are chemical signals that mediate mostly intra-specific interactions and are more widely used across diverse agro-ecosystems. The sex pheromones of moths (order: Lepidoptera) are the most studied and widely used in insect pest management among tropical and temperate agri-horticultural habitats. Synthetic mimics of moth sex pheromones are being commonly used in monitoring traps, besides deploying them in large numbers for mass trapping impact. In addition, there is good scope for utilizing pheromones and other semiochemicals to improve the herbivore host insect-parasitoid relationship, so as to enhance the impact of conservation or augmentative biocontrol approaches. These include kairomones used by parasitoids to locate their hosts. Some of the recent initiatives, which seek to capture the synergy between biological control and pheromone trapping technologies impacts while deployed together are illustrated. The future thrusts and R&D that need to maximise the synergy are indicated.

O13-2. Commercial production, marketing and application of parasitoids and predators for biocontrol of crop pests: challenges and prospects

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Ready availability of the required quantities of prescribed natural enemies for timely releases is an essential prerequisite for successful implementation of biological control by augmentation. In fact, non-availability has been a major hurdle. Commercial production of biological control agents, especially the macrobials that include parasitoids and predators, is beset with several tough challenges, calling for a great deal of preplanning, innovation and commitment to tide over them in order to match the seasonal demands and production. More often than not, the success of mass production of biocontrol agents is dependent upon our ability to mass produce their host insects - actual or factitious. The paradox is that such hosts/pests, which breed so rapidly in nature and cause havoc, refuse to multiply in captivity even if we provide them with all comforts like controlled temperature and humidity and highly nutritious food. Thus, the first challenge is to develop successful mass production technologies for host insects. Against this background, although a large number of biocontrol agents have been discovered and studied, the techniques for mass production have been

standardized for barely about 15 species and the same are utilized since decades. The pros and cons of these are discussed. Marketing, storage, transport and releases of parasitoids and predators, being live, sensitive and short-lived, require special approach and care on the part of the producers, users and other stakeholders. These issues are highlighted with some suggestions to overcome them.

Invited

O13-3. Microbes as biocontrol agents for crop protection in India

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Microbes like bacteria, fungi and viruses were investigated and developed as biocontrol agents to minimize the usage of chemical pesticides for disease and insect pest management in Indian agriculture. Seventeen microbial biocontrol agents are registered in Indian Central Insecticides Board & Registration Committee for crop pest management. Potential strains of antagonists like *Trichoderma viride, T. harzianum, Pseudomonas fluorescens* and *Bacillus subtilis* were identified and commercialized against soil-borne plant pathogens like *Fusarium, Pythium, Phytophthora, Rhizoctonia* and *Sclerotium* in several crops. Several strains of entomopathogens like *Bacillus thuringiensis* (Kurstaki), Nuclearpolyhedrosis viruses and *Beauveria, Metarhizium, Lecanicillium* were registered for insect pest management. Formulations of *B. thuringiensis* used for management of lepidopteran pests in India are mostly imported and expensive. However, a few indigenous Bt strains like, DOR-Bt-1 & NBAIR-BtG4 were developed and commercialized for pest management in oil seed crops, pulses and vegetables. Nuclear polyhedrosis viruses like, HearNPV and SpliNPV are utilized for the management of *Helicoverpa armigera* and *Spodoptera litura* in vegetables and pulses. Recently, an indigenous NPV (SpfrNPV-NBAIR1) and Bt strain (NBAIR-Bt25) were identified against invasive maize pest, *Spodoptera frugiperda*. Entomopathogenic fungi like *Beauveria bassiana* and *Metarhizium anisopliae* are gaining importance for management of *Holotrichia* (sugarcane), *Oryctes rhinoceros* (coconut), *Dicladispa armigera* (Rice), *Hypothenemus hampei* (Coffee) *S. frugiperda* (Maize), *Lecanicillium lecanii* for sucking pests (aphids) in vegetables and *Isaria fumosorosea* against *Aleurodicus rugioperculatus* (coconut & oil palm). The future thrust in research is to develop aggressive virulent strains of entomopathogens and their formulations with long shelf life suitable for dry weather conditions.

O13-4. Maternal influence on diapause induction: an approach to improve long-term storage of *Trichogramma chilonis*

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We have investigated the role of the thermo-photoperiodic condition of maternal generation in diapause induction of *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) lab strain. To test the maternal effect, two lines of *T. chilonis* lab strain were generated by rearing them for one generation at: (1) 15 °C with L:D-12:12 (15F-112) and (2) 15 °C with L:D-20:4 (15F-120). The laboratory strain reared at 15 °C with L:D-12:12 for 65 generations (15F-6512) was used as the control (acclimatized strain) due to its proven diapausing capacity. The 15F-120 line failed to undergo diapause, though healthy pre-pupae were formed at the pre-storage condition (at 10 °C with L:D- 8:16 and RH-60-70%). However, 15F-112 line could successfully complete all the phases of diapause and was comparable with the control batch. Considering 50% adult emergence and minimum 3 days of longevity, 125 days of storage could be achieved. From our current study, we conclude that diapause can be induced in *T. chilonis* lab strain by providing appropriate

thermo-photoperiod to their maternal generation (for a single generation) followed by suitable diapause inducing and terminating protocols.

O13-5. Entomopathogenic nematodes: potential for exploration and use in India

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Entomopathogenic nematodes (EPN) have the potential for biological control of insect pests because they possess impressive attributes of parasitoids/predators and pathogens such as quick kill, broad host range, high virulence, chemoreceptors. They are currently used for the control of soil and cryptic pests worldwide. Due to the history of EPN success with the implementation of biological pest control programs, India has a great opportunity to develop and implement the use of EPNs. India has very diverse agroclimatic conditions, ranging from the humid, high rainfall north-eastern zone to the north-western semi-arid and arid zones. There is a tremendous opportunity for discovery of new nematode species and strains adapted to local environmental conditions and pests. There are several target pests in India that can be controlled with EPNs. Bioefficacy tests in India have been confined mostly to lab studies, the efficacy tests should be carried out in the field to see the real biocontrol potential of EPNs against target host. Since the efficacy of EPNs is based on several factors that include the nematode's behavior and soil ecology, therefore behavior and ecology of EPNs must be studied because these factors play important role in EPN successes and failures as biological control agents. Finally, mass production is a key issue to EPN commercialization and these nematodes can be mass produced both *in vivo* and *in vitro* conditions but commercialization still has to address issues such as mass production, formulation, and use.

O13-6. Mechanization in the commercial production of biological control agents

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Utilization of biological control agents for the management of pests has always been a wishful thought, but their utilization in field has been far from reality. The most important reason for this is the non-availability of biocontrol agents in sufficient quantity and at the required time. Commercial production of biological control agents has been a challenging task for the reason that it is labor intensive and therefore, it is not economically viable. Mechanization in various steps in the process of mass production of biocontrol agents not only increases the efficiency of production but reduces the professional hazards involved in the process and cut the labor cost thereby making a successful production system of biocontrol agents, a distinct possibility. Insect handling device that captures the laboratory bred insects in millions directly in the oviposition cages most efficiently; collection of eggs of *Corcyra* and separating them mechanically with a device reduces the time, drudgery and obviate the professional hazards of exposing the workers to insect scales. Sterilization (killing of embryo) of *Corcyra* eggs before exposing them for parasitization in a high throughput UVC sterilization chamber improves the efficiency and quality of sterilization. An improved oviposition cage for *Helicoverpa armigera* maintains ambient humidity and temperature for moths to mate and lay fertile eggs during the lean period ensure the regular supply of larvae for the mass production of an obligatory parasite Nuclear polyhedrosis virus, a most tenable control measure of *H. armigera*. Mechanization of extraction of these eggs reduces the cost of production.

O13-7. Prospects for predatory mirids in biological control

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Predatory mirids might be neglected as biological control agents as very few studies have been conducted to understand their life history to exploit them as biocontrol agents. In European countries and North America zoophytophagous bugs have been used as biocontrol agents to manage sucking and lepidopetran insect pests in greenhouse. In India scanty information is available on biology, rearing protocol and other parameters of predatory mirids and their uses except *Cyrtorhinus lividipennis* Reuter. *Nesidiocoris tenuis* Reuter, a zoophytophagous bug is capable to reduce *Tuta absoluta* Meyrick in India. Members of tribe *deraeocorini* and *termatophylini* of subfamily Deraeocorinae are the general predators. For the first time, rearing protocol, biology and its efficacy against some sucking and lepidopteran insect pests were studied for the predatory mirid bug, *Dortus primarius* Distant. These bugs share niche with other predators, so it is also very important to understand their interaction to enhance biological control. Therefore, keeping this in mind, ecological studies *viz*., population dynamics, intraguild competition and efficacy to control insect pests have been studied for both *N. tenuis* and *D. primarius*. These studies suggest that both mirid bugs might play a very important role in management of thrips and *T. absoluta* in protected cultivation.

O13-8. Challenges and way forward for agri-entrepreneurships in promotion of smart agriculture

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Global and Indian agri-horti-dairy markets are transforming agriculture to Smart Agriculture with quality-safety driven commodities, and technologies that utilize safer and non-recalcitrant inputs. Natural biological control agents and biological processes are gaining prominence in input market for organic farming, plant and soil heath management. Current global biopesticide consumption is 4.5% of pesticide market. USA, Canada, Mexico, Europe consume 65% of global biopesticides, while India's share is 3-4% for its 140mha of cropped area, with a production growth rate of 2.5%. Significantly, timely availability, production rate, quality, effective strains, pricing, 'one-size-fits-all' label claims, limited number of products (14) eligible for marketing under CIB & RC are important challenges in meeting the demand for biopesticides and accomplish the goal of minimized use of synthetic inputs. Paradoxically, realizing the growing gap between supply and demand, the market is thriving with spurious, contaminated and unregulated products. Biopesticides are yet to take off in India despite their enormous market potential. Smart agriculture envisages worldwide linking of knowledge, decision systems, demand-supply, innovation-agribusiness, and make agriculture a profitable proposition. Smart agriculture essentially requires agri-stratups for linking farm produce to market chain, production to demand-supply, investment to employment generation and profitability. We intend to discuss the opportunities that entail these challenges from the entrepreneurial point of view that ensures investment, employment, quality input supply, value addition to the agriproducts and enhanced profitability. India, with the increasing agritechstartup entrepreneurs is primed to tap potential opportunities with a variety of smart agricultural technologies in biological control *per se*.

Oral

O13-9. Assessment of *Trichopria drosophilae* for biological control of *Drosophila suzukii*

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We investigated biology of the pupal parasitoid *Trichopria drosophilae* to assess its suitability as a biocontrol agent against *D. suzukii*. Our field surveys revealed that adult parasitoids searched for drosophila-infested fruit in crops and semi-natural habitats during summer and autumn. In laboratory experiments, we exposed different developmental stages of *T. drosophilae* to cold temperature. Although adults could survive several days of frost, subadults are most likely the overwintering stage, according to their cold tolerance. Next, we allowed *D. suzukii* to oviposit into various wild fruits common in semi-natural habitats and added *T. drosophilae* to half of the samples upon formation of the first fly pupae. The parasitoids significantly reduced fly emergence from all fruits and parasitoid and fly weight on the respective fruits was linked. Finally, we conducted no-choice and choice assays with *T. drosophilae* on *D. suzukii* and the alternative rearing host *D. melanogaster*. We found that *D. suzukii* was a more suitable and preferred host, even when the parasitoid had been reared for multiple generations on *D. melanogaster*. However, the preference for *D. suzukii* was stronger in parasitoids had emerged from this host. We conclude that the release of laboratory reared adult *T. drosophilae* in semi-natural habitats in spring could be a promising strategy to control populations of *D. suzukii* before they infest the first crops in the growing season.

O13-10. Effect of joint predators (*Pardosa pseudoannulata* and *Verania lineata*) on *Nilaparvata lugens* in competitive condition

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Pardosa pseudoannulata (Araneae: Lycosidae) and *Veranial ineata* (Coleoptera: Coccinellidae) are two generalist predators commonly found in rice fields. There is an assumption that the presence of two predators together will increase supressing on certain pests, but there is very little literature assures that their presence together will be followed by positive interactions (joint predators) then supressing on pests significantly, including brown planthopper (BPH). The research was conducted to determine the predation of joint predators in competitive condition, as well as the suitable composition of joint predators for controlling the BPH. The research was conducted in laboratory using a completely randomized design with a combination of density of two predators in 1, 3, 5 (P1V1, P1V3, P1V5, P3V1, P3V3, P3V5, P3V5, P5V1, P5V3, P5V5). Each treatment was carried out in 5 replications. As many as 2,250 nymphs of BPH (2nd-3rd instar) were prepared as prey for all treatments. The results showed that the *P. pseudoannulata* ability to survive in competitive condition was lower than *V. lineata*. The composition of one *P.pseudoannulata* and three *V.lineata* was suitable because they could prey on 98.7% BPH on first day without followed by the death of both predators.

O13-11. Biological control success of a pasture pest: has its parasitoid lost its functional mojo?

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Sustainable and integrated pest management often involves insect parasitoids. However, the effectiveness of parasitoids biocontrol has often failed, frequently for obscure reasons. A parasitoid's success is partly due to its behavioural response to pest density, *i.e.*, its consumer functional response. For many years in New Zealand, a braconid parasitoid, *Microctonus hyperodae* successfully suppressed a severe ryegrass weevil pest, *Listronotus bonariensis*. However, there is now evidence that this has severely declined, but that the extent of decline can depend on the pasture species. Here, we tested whether the current functional responses of *M. hyperodae* to *L. bonarensis* in two of the most common New Zealand pasture grasses (*Lolium multiflorum* and *L. perenne*) reflect observed differences in field parasitism and whether this functional response has changed over time. Our analysis involved data from 1993 and 2018. We found a type I functional response in *L. multiflorum* in both years, but the slope of the relationship declined over time. There was no evidence for any type of functional response in *L. perenne*. This lack of response in *L. perenne* coincided with consistently found lower parasitism rates on this host plant than in *L. multiflorum*; both in the field and laboratory. Here, we found that apparently declining searching efficiency was correlated with the decline in parasitism. This observation supports the hypothesis that parasitism decline could be the result of the evolution of resistance based on enhanced evasive behaviour by *L. bonariensis*.

O13-12. Effect of herbivore and artificially induced plant expressions on ants and extrafloral nectaries number in cotton and castor

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Induced plant resistance attributes are expressed in response to attack and found commonly in plants. Extrafloral nectar is secreted as an indirect resistance, attracting ants, which defend plants against herbivores. We conducted studies on the effect of herbivore and artificial inductions on ants and extra floral nectaries (EFNs) number in cotton and castor in the experimental plots of Department of Entomology, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India during 2019. In herbivore induction of cotton and castor, the number of ant recruitment events was highest at 5th hour (2.60 and 4.00) in treatment (with Spodoptera). In both cotton and castor, number of EFNs were highest (23.00 and 171.05) in the treatment. Five species of ants were recorded from each of cotton and castor. In artificial induction of cotton and castor, the number of ant recruitment events was highest at 5th hour (2.85) and 2nd hour (5.54) in treatment (with scissor damage), respectively. In both cotton and castor, number of EFNs was highest (25.75 and 178.95) in the treatment. Eight and seven species of ants were recorded from each of cotton and castor, respectively.

O13-13. Algae-based technology to control plant pathogenic fungi

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Ulvans are water-soluble sulphated heteropolysaccharides, which can be obtained from cell walls of the green marine macroalgae *Ulva* spp., and are able to induce systemic resistance in plants. The aim of this report is to summarize the main results of our research group, from the discovery to the first attempts in evaluating its efficiency. A bioprospecting study carried out between 2002 and 2004 identified *Ulva fasciata* Delile as a potential source of active compounds for controlling plant diseases. Under field conditions, weekly sprays of Ulva extracts were able to control anthracnose by 50% in a highly susceptible bean cultivar. Follow-up assays revealed ulvans as the main elicitor molecules in the extracts of Ulva. In greenhouse, ulvans demonstrated to protect several crop plants such as beans, apple, and cereals against a broad range of foliar phytopathogens, including biotrophic, hemibiotrophic and necrotrophic fungi. Pretreatment of barley leaves with ulvans significantly reduced the severity of powdery mildew by 80%, and in cereals, priming effect was detected in assays with suspension-cultured cells. Resistance induced by ulvans reduced the bean anthracnose severity by 50%, lasting at least up to nine days after treatment. However, the effect on Fusarium wilt was weak and only transiently expressed. Protection levels of 65% were recorded in ulvans-treated apple plants against the Glomerella leaf spot, but the effect was weaker in not-directly treated distal tissues. Together, our findings open new horizons for using ulvans as an algae-based technology to induce plant resistance to fungal diseases.

14. Crop protection in horticulture

Organizers: H R Gautam and Satish K Sharma

Lead

O14-1. Status of Marssonina blotch of apple in India and advancements in its management

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Marssonina blotch caused by *Marssonina coronaria* (Perfect state: *Diplocarpon mali)* caused widespread defoliation of apple trees in Himachal Pradesh in mid1990's. It is still number one disease problem in most of the orchards if the fungicidal sprays are not executed properly. This fungus has been observed to perpetuate in the infected leaf litter on the orchard floor. The ascospores of this fungus are produced in the infected leaves are mature by the time of blooming in apple in the spring and they are liberated in the orchard for a quite long period. In Himachal Pradesh, the perfect state of this fungus was intercepted sparingly in some of the orchards only. Detailed studies have shown it to survive in winter in the form of acervuli which produce clouds of conidia in early summer to start primary infections. Frequent rains with a moderate temperature of 23^{o}C are helpful for disease development. Infections first appear on mature whorl leaves causing dark brown spots followed by their yellowing leaf fall down prematurely. Countless conidia and microconidia are formed in leaf lesions which cause fresh infections leading to epidemic development favourable conditions. This disease could be controlled effectively by integrating different methods like field sanitation, proper pruning and judicious use of protective fungicides. Three spray applications of kresoxim-methyl also provided more than 90 percent disease control in a directed spray programme aided by the predictive devices and were at par with the calendar based spray schedule comprising five applications of the contact fungicides used in relatively very high concentrations.

O14-2. Economically important diseases in pomegranate: Recent status and management

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Pomegranate is an important fruit crop of arid and semi-arid regions of India. Among various diseases of pomegranate, bacterial blight (*Xanthomonas axonopodis* pv. *punicae)* and wilt/decline (*Ceratocystis fimbriata* major cause along with *Meloidogyne incognita*) were, till recently the two most important diseases in India. The other predominant fruit spots are caused by *Cercopsora punicae* and *Alternaria alternata*, scab (*Sphaceloma punicae),* anthracnose (*Colletotrichum gloeosporioides)* and fruit rots by *Colletotrichum gloeosporioides, Alternaria alternata* and *Phytophthora nicotiane*. These pathogens also result in foliage infections, but are manageable. The major post harvest rots include species of *Aspergillus, Cephalosporium, Cladosporium, Curvularia, Glomerella, Paceilomyces, Penicillium, Rhizopus, Sclerotium and, Phomopsis,* however, losses are very low.

Integrated management includes avoiding rainy season crop for 2-3 years; maintaining orchard sanitation, providing recommended nutrition during rest period soon after harvest and crop season; taking 4 sprays of salicylic acid 300 ppm and $ZnSO_4$ 0.3% and $MnSO_4$ 0.6% at 1 month interval starting pre-flowering for systemic resistance and bactericidal sprays at 7-14 days interval along with required insecticides and fungicides. Integrated Disease & Insect Pest Management schedule (IDIPM) schedule has been continuously modified to make it cost effective and eco-friendly with the use of promising bio-formulations and preventive

strategies. However, there are some policy issues *viz*., sale of unregistered chemicals/bioformulations, unregistered consultants/Agridoctors and strict nursery certification that require intervention of policy makers. In addition Government support for encouraging community farming and claim for more chemicals (label claim for just 9 agro-chemicals till date) is of prime importance for improving export, which is less than 2% of the total production.

O14-3. The role of entomopathogens in integrated control of white grubs in India

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White grubs are highly polyphagous and most destructive soil pests inflicting damage to a wide variety of crops. White grubs are naturally infected by various entomopathogens which include fungi, bacteria and nematodes. Entomopathogenic fungi offer great potential and members of genera *Beauveria* and *Metarhizium* are widely used against white grubs. In India, good control of white grubs in potato, paddy, ginger and sugarcane has been achieved with different entomopathogenic fungi. In Uttarakhand, good control of *Holotrichia longipennis* was achieved with *Metarhizium anisopliae* in upland paddy. In Himachal Pradesh, the grubs of *Brahmina coriacea* grubs are highly susceptible to *Heterorhabditis indica*. In laboratory assays, *H. indica* caused 100 per cent mortality of second instar grubs. The liquid formulations of *Steinernema thermophilum* and *Steinernema glaseri* against grubs of *Holotrichia consanguinea* in groundnut at Jaipur have shown 65.71 and 42.85 per cent reduction in plant mortality with *S. thermophilum* and *S. glaseri*, respectively. Some insecticides, such as imidacloprid and clothianidin are synergistic with EPNs. Against white grubs only a few strains of bacteria have been tested and used. *Paenibacillus* (=*B.*) *popillae* was tested against different species of white grubs in India, and in Gujarat, 20-25 per cent grubs of *Holotrichia* spp. showed infection of *B. papillae* in the subsequent years following its application. Recently, *Bacillus cereus* has been isolated from atrophied pupae of *Anomala dimidiata* from Almora and its strain WGBSP-2 has been able to cause 92 and 67 per cent mortality in second instar grubs of *A. dimidiata* and *Holotrichia seticollis*, respectively.

O14-4. Diagnosis and management of diseases in coconut and arecanut: status and strategies

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Coconut and arecanut palms suffer from a number of biotic and abiotc stresses during various stages of their growth. Diseases caused by fungi namely *Phytophthora*, *Ganoderma* and *Phytoplasma* are the major melodies limiting the production of these crops. Among the various *Phytophthora* diseases, bud rot caused by *P. palmivora* is a lethal disease with sporadic occurrence ranging from 1 to 30 per cent incidence. Similarly *P. meadii* causes fruit rot and fruit shedding in arecanut. Both bud rot and fruit rot diseases are seasonal and occurs during rainy season. Timely prophylaxis with 1 % Bordeaux mixture is found to be the best option for reducing the loss due to these *Phytophthora* diseases. Basal stem rot or *Ganoderma* wilt disease of coconut and arecanut caused by *G. lucidum* is another most destructive disease of these palms. Integrated plant health management involving tolerant varieties, cultural, nutritional, biocontrol and phytosanitary measures is found to be the best option for managing this disease. Diseases caused by phytoplasma namely root (wilt) disease of coconut and yellow leaf disease of arecanut are the major threats in cultivation of these palms. Though PCR based technologies are developed for detection of phytoplasma, yet early reliable diagnosis is difficult due to its exclusive phloem confinement and non-uniform distribution in palms. Management practices involving

various agronomic and integrated pest and disease management practices are developed and demonstrated to obtain satisfactory yield even from these disease-affected palms. Root (wilt) resistant/tolerant coconut varieties are developed and recommended for planting in diseased tracts.

O14-5. SPNF a potential tool for plant health management

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Subhash Palekar Natural Farming (SPNF), discovered by a noted agriculturist Subhash Palekar, disillusioned by ill effects of green revolution, is a set of nature-friendly farming methods. In international classification, it comes under climate change resilient and 'Agro-ecology'. SPNF reduces farmer's costs, increases yield and improves soil health by avoiding synthetic inputs and use of local inputs. It includes Beejamrit and Jeevamrit, concoctions made from cow dung, cow urine, and other locally available resources to destroy seed germinating aflatoxins and multiply soil microbes, cover crops and mulching to prevent water evaporation and add soil humus and Waaphasa to improve soil aeration. Whereas, insect-pest and disease management has been suggested through sound agronomy and only where, necessary use of botanical extracts like Paudhastra, Brahmastra, Agniastra, etc. The Government of Himachal Pradesh has launched mega Project involving farm universities and line departments for conservation of natural resources, improves their vitality and enhances productivity of crops, livestock and income of farm families. The initial data generated on SPNF has shown a remarkable success in fruits and vegetables. High density apple was free from scale and mite infestations, and woolly apple aphid and powdery mildew attack remained below 5.0%. The yield of apple under SPNF (43.2 t ha^{-1}) was on par with chemically produced apples however, incurred 29 times more cost. In cauliflower and tomato, SPNF practices delayed the infestation of cabbage aphids and tomato pin worm by two weeks and the incidence was also low compared to chemically treated fields.

Invited

O14-6. Integration of soil solarization with other eco-friendly approaches for the management of soilborne diseases in horticultural crops

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Soil solarization proved more effective against soil-borne pathogens when integrated with soil amendments, fungicides and biological control agents. In strawberry, treatment combination of soil solarization with soil amendment of neem cake was found effective in reducing the plant mortality by 96.2 per cent caused by combine infection of crown rot (*Rhizoctonia solani*), southern blight (*Sclerotium rolfsii*) and wilt (*Fusarium oxysporum* f. sp. *fragariae*) accompanied with significant increase in plant growth characteristics and yield. In another study, inoculation of apple saplings with $AMUHF_1$ (*Glomus fesiculatum*) isolate of va-mycorrhiza and $AZUHF_1$ isolate of *A.chrococcum* and then their planting in solarized soil was found effective with no incidence of white root rot in comparison to 33.6 to 35.4 per cent in control. Inoculation of mango saplings with $AMUHF_4$ (*Gigaspora* sp.) isolate of va-mycorrhiza and $AZUHF_1$ isolate of *A.chrococcum* and then their planting in solarized soil was found most effective with no incidence of sapling wilt in comparison to 32.33 per cent in control. Treatment combination of soil amendment with neem cake and soil solarization was found effective in reducing the disease incidence of stem rot (*Rhizoctonia solani*) and wilt (*Fusarium oxysporum* f sp. *chrysanthemi*) of chrysanthemum (*Dendrathema grandiflorum*) accompanied with

appreciable increase in plant growth and flower characteristics. Conjoint application of native isolates of AM fungi, *A. chroococcum* and *T. viride* as soil application before transplantation of the cuttings was found most effective with 97.2 per cent reduction in disease incidence with significant increase in different plant growth and flower quality characteristics.

O14-7. Advances in forecasting of late blight of potato

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The potato is the third most important food crop in the world after rice and wheat and has been acknowledged as the 'food for the future' by Food and Agriculture Organization of the United Nations. India is the second largest producer of potato after China with a production and productivity of 53 MT and 23 t/ha, respectively. Potato is vulnerable to a magnitude of fungal, bacterial and viral pathogens. Late blight (*Phytophthora infestans*) is still the most important impediment to potato cultivation. Disease forecasting allows the prediction of probable outbreaks and decision support system; however the forecasting models are region specific and have to be validated for each local situation. In India, late blight forecasting systems have been evolved both for temperate highlands and sub-tropical plains. A forecasting model 'JHULSACAST' was developed for western Uttar Pradesh, which uses hourly temperature and RH data. Recently, Indo-Blightcast- a web-based late blight forecasting model which is applicable across the agro-ecologies and requires only daily mean temperature and RH data, has been developed. Late blight is predicted to appear within 15 days if moving cumulative effective temperature (P-days) and RH exceeded 52.5 and 525, respectively for seven consecutive days. Based on Indo-Blightcast, disease severity values (DSV) of 15 days are displayed in an array with different colour code. Based on colour/severity value, one can take decision whether to spray or not, when to spray, and which fungicide is to be sprayed. Further, stakeholders can make decisions on whether spraying of the crop would be economical or not.

O14-8. Advances in the management of white root rot of apple

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Himachal Pradesh is recognized as an "apple state" of India because its cultivation has emerged as remunerative venture that has revolutionized the socio-economic conditions of the growers. The area under apple cultivation has increased manifolds during the last few decades but the production has not increased proportionally and the productivity is quite low in comparison to advanced countries. The reason for low productivity could be many but one of the major constraints is the damages caused by fungal, bacterial and viral diseases throughout its growing period. In order to unravel the biological threats of *D. necatrix*, latest strategies of disease management have been evaluated and validated under field conditions. Amongst seven IR chemicals tested, maximum disease control in pot conditions was recorded with Salicylic acid (SA) at 300ppm (83.90%), which also provided maximum disease control of 78.14 and 74.11 per cent in virgin and sick fields, respectively and also effective in improving plant health as compared to other treatments. The induced resistance through SA persisted in seedlings for more than two years leading to permanent resistance as the plant survival in virgin and sick field was 68.89 and 59.44 per cent, respectively. The Calcium cyanamide, PGPR and AM fungi evaluated individually and in combination, revealed maximum disease control (100%) in combination treatment i.e. Calcium cyanamide + *Bacillus subtilis* + *Bacillus licheniformis* + AM fungi and Calcium cyanamide + *Bacillus subtilis* + *Bacillus licheniformis*) with maximum plant

growth parameters, soil microbial population, root colonization by AM fungi, and physicochemical properties both under pot and field conditions.

O14-9. Bio-intensive management of temperate crop pests

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Growing awareness among farmers and consumers towards the harmful effects of pesticides and a shift towards the organic/natural farming points to the promising future for bio-control based pest management. The basic approaches of biological control are the conservation, introduction and augmentation of natural enemies. Temperate cropping systems harbour a rich diversity of bio-control agents which contribute significantly in the natural control of pests. Over 130 species of bio-control agents have been reported to naturally suppress major insect pests in temperate region. Among them, coccinellids, chrysopids, syrphids, anthocorids, braconids, eulophids, aphelinids, phytosiids, etc. are the important ones. *Chilocorus infernalis*, *Aphytis* spp. and *Encarsia perniciosi* have successfully suppressed Sanjose scale, *Quadraspidiotus perniciosus* in apple. Similarly, apple woolly aphid, *Eriosoma lanigerum* has been effectively suppressed by *Aphelinus mali*. Root and stem grubs in apple have been managed by the application of entomopathogenic fungi and nematodes. Bio-intensive IPM packages comprising of trap crops, trchogrammatids, chrysopids, azadirachtin, Bt, NPV, pheromone traps, etc., have been utilized effectively against pests of many crops. Predatory mite, *Neoseiulus longisinosus* is effective against phytophagous mites in various crops. In conclusion, the bio-control has a great potential in pest management in temperate crops. There is a need to select right candidate(s) for applied bio-control, conserve the existing natural enemies for natural control and develop pesticide tolerant strains for their compatible use with chemical pesticides.

O14-10. Virus and Phytoplasma diseases of temperate fruit crops and biotechnological approaches for their management

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Biotic factors (primarily, fungal, bacterial, viral and related pathogens) are a cause of concern in commercial temperate fruit production. Among these pathogens, viruses and phytoplasmas being graft transmissible pathogens (GTPs) have direct impact on temperate fruits resulting in diseases with adverse effects in different parts of the world. Losses resulting from these pathogens in temperate fruit crops remain largely unattended over a short period of time as the influence of the diseases caused by these pathogens on fruit productivity is usually evident over a period of time. Early detection of viruses and phytoplasmas in the propagative material is a pre-requisite for effectively managing the spread of these GTPs in a sustainable temperate fruit production system. In the present context, biotechnological strategies appear to be more realistic for managing diseases caused by viruses and related pathogens. Transgenic plants developed have shown promising resistance to viral infection and the RNA silencing pathway appears to be the most specialized molecular strategy for combating infections. Techniques that induce viral RNA silencing without altering the plant genome are even more useful as these methods override risks associated with genetic manipulations. Increasing knowledge in bioinformatics, genomics, proteomics and transcriptomics, concepts of changes in mRNA, proteins and cellulites are expected to further refine our understading of host-pathogen interaction to a new level. These strategies not only increase the efficiency of understanding the mechanism of infection

and devising environmental friendly biotechnological approaches against virus and phytplasma diseases of temperate fruits but also open new channels for the development of many innovative strategies for future.

O14-11. Plant pathogen interaction and weather components of disease progress for modelling apple scab epidemics in integrated systems

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Apple scab is generally controlled by calendar-based fungicide applications regardless of the presence of ascospores of the causal fungus, *Venturia inaequalis* (Cke.) Wint. (anamorph *Spilocea pomi* Fr.), in the orchard. Yield losses during epidemic years in 1996, 2008 and 2013 in the Gangotri valley of Distt. Uttarkashi went up to 70 per cent. The main reason for the heavy infection appeared to be the high inoculums level from the previous season. In orchards managed according to advisory information, a significant increase of yield was obtained relative to the common management policy. The environmental conditions varied from location to location, and Mills infection periods ranging from 19–47 were recorded from April to September every year revealed that number of infection periods varied from year to year depending upon the weather conditions. The number of cumulative degree-days for 50 and 95 per cent ascospore discharge was approximately 426 and 826, respectively for orchards situated at 1900-2200 masl and > 1272 for orchards situated at >2200 m asl. The PAD values were 50 times higher in the poorly managed orchards than in the integrated managed orchards. The PAD-calculated orchards were classified into well-managed (PAD <600), moderately managed (PAD 1000-5000) and poorly managed (PAD >5000) groups. PAD involves the elimination of unnecessary early-season sprays in orchards where the inoculums is below a specified level. Warnings are issued mainly via a call in telephone, Agriculture Govt. department, and broadcasted through radio stations. The possibility of an integrated approach to control the diseases menaces would be discussed.

O14-12. Global improvements in cultivation of different edible fungi, commercialization and marketing scenario

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Low in calories and fat and cholesterol-free, mushrooms contain a high amount of proteins, fiber and over a dozen minerals and vitamins. Hawksworth estimated that there are 1.5 million fungi. While recent estimates predicted as many as 5.1 million species of fungi existing on earth. It is estimated that 1,60,000 species are macrofungi, out of which 16,000 (15%) species are mushrooms. A total of 3,000 species from 231 genera are reported as prime edible mushrooms and 200 are experimentally grown. Presently about 100 mushrooms are economically cultivated and around 60 commercially cultivated while only 10 mushrooms are produced on an industrial scale. Few mushrooms like *Agaricus bisporus, Lentinula edodes, Auricularia spp, Pleurotus spp, Flammulina velutipes, Volvariella volvacea* contribute about 90% of the world mushroom production. World mushroom industry has seen a Cumulative Annual Growth Rate (CAGR) of 10.56% during 1961 to 2018. However there is a rapid increase in in mushroom production but the relative contribution of button mushroom has declined from 73% in 1975 to 15% in 2013 mainly due to rapid increase in production of wood rot fungi like *Lentinula edodes, Auricularia, Pleurotus* species, etc cultivated in Asian countries in general and China in particular. These species have started making inroads in western countries but even today *Agaricus bisporus* is prime contributor to European and American mushroom industry (contributing 80

to 100%. The global mushroom industry has expanded rapidly in the last two decades by the addition of newer types of mushrooms for commercial cultivation. However, mushroom as a vegetable is yet to find regular place among the Indian consumers. Despite of favourable agro-climate, abundance of agro wastes, relatively low-cost labour and a rich fungal biodiversity, India has witnessed a lukewarm response in its growth. At present, the total mushroom production in India is approximately 0.18 million tons. Mainly, five mushroom species viz; *Agaricus, Pleurotus, Volvariella, Calocybe* and *Lentinula* are cultivated in India. From 2010-2018, the mushroom industry in India has registered an average growth rate of 4.3% per annum. Out of the total mushroom produced, white button mushroom share is 73% followed by oyster mushroom (16%), paddy straw mushroom (7%) and milky mushroom (3%). Compared to other vegetables; per capita consumption of mushrooms in India is meagre and data indicates it is less than 100 grams per year. In the year 2018, Indian mushroom industry generated revenue of Rs. 7282.26 lacs by exporting 1054 quintals of white button mushroom in canned and frozen form. Major bottleneck in the growth of mushroom industry is the availability of spawn and the awareness amongst the masses about the nutritional and medicinal benefits of mushrooms. This communication discusses the opportunities and challenges for development of mushroom entrepreneurship in India.

O14-13. Hot water seed treatment: A successful approach to combat seed borne diseases in vegetable crops

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Treatment of seeds with hot water is a classical thermo-physical method of plant protection. Under the present investigations, carried out in the department of Seed Science and Technology, YSPUHF, Nauni, Solan (HP), hot water seed treatment has also been successfully applied to control seed-borne diseases in bell pepper (*Capsicum annuum* L.). The hot water seed treatments comprised of different temperature ranges (47-49, 50-52 and 53-55 °C) for different time durations (30, 45 and 60 min.) were applied to work out an effective temperature range and time duration of the treatment. The hot water treatment at a temperature of 50-52°C for 30 minutes was found significantly better as compared to others w.r.t. the percent seed germination. The effect of this treatment (50-52°C for 30 min) was also observed on seedling growth parameters like total emergence %, seedling height, seedling dry weight and disease incidence in bell pepper cv. Solan Bharpur under nursery conditions. The seeds treated with hot water showed significant increase in seedling emergence (89.48 %) as compared to untreated seed (75.23%). Similar trend was observed w.r.t. seedling height, and seedling dry weight. The nursery raised from the hot water treated seeds had significantly lower incidence of damping off (2.34%) and viruses (0.0%) as compared to that of untreated seed (15.46%) and 4.1 %, respectively. Even after transplanting, the treated ones showed a significant less incidence of seed borne diseases like anthracnose, cercospora spot and viruses as compared to untreated ones under field conditions.

15. Predicting population dynamics of insect pests under climate warming

Organizers: Chun-Sen M A and Gang M A

Lead

O15-1. Interest of gradient studies to predict the consequences of climate change on conservation biological control

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Intensive agriculture and climate change have profoundly altered biodiversity, leading to the deterioration of ecosystem services such as biological control of crop pests by their natural enemies. The main objective of our study, part of the European Biodiversa WOODNET project, is to understand the spatial and temporal factors influencing the potential of biocontrol by evaluating the relative proportions of pests and natural enemies in cereal fields. Five taxa containing both crop pests (aphids and slugs) and natural enemies (spiders, carabids and parasitoids) were sampled in winter wheat crops in 2017 and 2018 in three regions (Brittany (France), Haut-de-France (France) and Wallonia (Belgium)). The spatial scale was studied at the landscape level*via* a gradient of landscape complexity and at the local level*via* the study of two types of borders (hedges and grass strips). The biocontrol potential was greater and earlier in Brittany than in the two other regions, and this is linked to the warmer winters in this area. Complex landscapes were favourable to all taxa compared to open landscapes. In addition, natural enemies were more abundant in the middle of the crops, contrary to pests, more abundant in the borders. Finally, the grassed strips appeared to be more favourable for potential of biocontrol than hedges. Our results suggest the importance of taking into account the regional scale in order to predict the consequences of climate change on the biocontrol service.

O15-2. Overwintering strategies of arthropods under climate change: implications for conservation biological control

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With climate warming, an alteration of the response of insects to seasonal changes is expected. Since the 1980s in Western France, the winter guild of aphids in cereal fields has been reproducing parthenogenetically during the winter, inducing an increasing risk of virus transmission. However, climate warming is also acting on their natural enemies and the winter guild of aphid parasitoids (Hymenoptera: Braconidae) is more and more active (no more diapause) during the winter months since 2010, which suggests that a modification of aphid parasitoid overwintering strategies has taken place within the guild. Since 2015-2016, ground predators (Staphylinidae, Carabidae and Araneae) were sampled using pitfall traps in the cereal fields, and were also observed in activity during the winter. These agro-ecosystems may also benefit from a change in plant phenology, such as flowering plants often used in conservation biological control programs. We investigated the consequences of flowering plants during winter to assess if they may constitute favourable habitats, which promote the presence of biological control agents and increase their pressure on aphid pest populations in adjacent cereal crops. Higher aphid parasitism has been observed close to flowering cultivated plants and the density of activity of ground predators was higher within sown flowering strips. The results suggested that the

winter period should constitute the target period for conservation biological control programs under changing environmental conditions.

Invited

O15-3. Outbreaks of maize wallaby ear symptom on forage maize under climate change

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Maize wallaby ear symptom (MWES) is a kind of stunted growth of maize caused by the maize orange leafhopper, *Cicadulinabipunctata*. Since the 1980s, MWES has been gradually expanding its range in East Asia and caused serious yield loss. A multiple linear regression analysis using 10-years occurrence data of *C. bipunctata* in temperate Japan found a positive contribution of temperature to *C. bipunctata* occurrence in summer, indicating that the recent outbreaks and range expansion of *C. bipunctata* are caused by global warming. To predict future risk of MWES occurrence, range expansion and population growth of *C. bipunctata* in a 1 km ×1 km fine scale of entire Japan were predicted, using future climate data calculated from Atmosphere-Ocean Coupled General Circulation Models. This prediction showed a gradual range expansion of *C. bipunctata* from south to north until 2100. Occurrence of *C. bipunctata*is predicted to increase as global warming advances, indicating that MWES will occur severelyin wider range of temperate region than present. As countermeasures to the future outbreaks of MWES in Japan, improvement of MWES-tolerant cultivars of forage maize and prevention of expansion of *C. bipunctata* into new areas are proposed. This study showed that changes in damage by agricultural pest along with climate change can be predicted based on ecological characteristics of target pest and future climate scenarios although the validity of the prediction should be carefully considered.

O15-4. Differential wing polyphenism adaptation across life stages under extreme high temperatures in corn leaf aphid

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Polyphenism, a common phenomenon in nature, is an important form of adaptation in a diverse environment. Corn leaf aphid, *Rhopalosiphummaidis*, (Hemiptera: Aphididae), exhibits wing polyphenism in response to poor habitat quality. In this study, we focused on the effects of crowding and thermal cues on morph determination of the aphid. Five life stages of aphid (1st to 4th nymphs and maternal adults) with increased population densities, were tested under two kinds of temperature patterns, *i.e.*, A) a constant temperature of 22 °C with 2 h exposure to high temperature in the range of 35 to 39 °C and B) different constant temperatures in the range of 22-30 °C with 2 h exposure to high temperature of 39 °C. Crowding was found to directly impact winged induction. The 1st, 2nd nymphsandprogenyof maternal adults were more sensitive for winged morphs induction under high density. In addition, temperature played a significant role in wing production, with the temperature setting of 26/39 °C in pattern B inducing higher winged morphs and survival than other temperature settings. Therefore, we hypothesize that warmer climate with brief high temperature is more favorable for survival and winged morphs production, but cool weather and transient extreme high temperature (>39 °C) is detrimental for the corn leaf aphid. Our results provide a new perspective on understanding the interactions between changes in extreme high temperatures and insect

densities that differentially affect wing polymorphism for further demographic and distribution rates of species across temporal and spatial scales.

O15-5. Elevated temperature reduces wheat grain yield by increasing pests and changing soil microbes

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Climate warming is known to affect species' phenology, abundance, and species interactions. Understanding how crop plants, and associated community members, such as pest insects, natural enemies and soil microbes together respond to warming to determine crop yields is critical for current and future food security. We conducted a 2-year field experiment to study effect of elevated temperature on winter wheat growth and grain quality, insect pests, natural enemies, ground arthropods, weeds, and soil microbes.Elevated temperature shortened the period of wheat growth, decreased grain yield, and reduced grain quality by decreasing wet gluten, protein, total soluble sugars, and starch and by increasing fiber. Elevated temperature also increased aphids' abundance, and changed the fungal community according to the Principal component analysis (PCA)and Chao1 index rather than the bacterial community. Furthermore, elevated temperature decreased the Arbuscular mycorrhizal fungi (AMF) colonization rates, which result in decline of the wheat growth. Structural equation modeling indicated that a direct negative effect of warming on wheat yield was augmented by indirect negative effects *via* increased aphid abundance, weeds abundance, and decreased AMF colonization. Climate change could affect crop production and quality both directly and indirectly by modifying interactions with above- and below-ground organisms. Future studies on the effects of climate change on crops should consider the responses of above- and below-ground biotic community members and their interactions with crop plants.

O15-6. Responses of a migratory planthopper to global warming

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Responses of brown planthopper (BPH), *Nilaparvata lugens* (Stål), a major rice insect pest occurring principally in autumn in temperate regions, to global warming were investigated. (1) Overwintering boundaries are projected to shift northwardunder Special Report on Emissions Scenarios (SRES)relative to the baseline period, 1961-1990; these shifts are more pronounced in SRES A2 and A1B. The intermittent overwintering area will increase by 11, 24 and 44 %, and the constant overwintering area, by 66, 206 and 477 %, during the 2020s, 2050s and 2080s, respectively. BPHvoltinism will increase by <0.5, 0.5-1.0 and 1.0-1.4 generations in northern, central and southern China, respectively, in 2021-2050. (2) Modelling temperature effects on BPH performance using constant serial temperatures indicate that 34°C inhibited egg hatching, low and high temperatures cause high mortality in young and old nymphs, respectively. The optimal temperatures for BPH performance are between 27°C and 31°C. (3) Investigation of temperature effects on mate location shows that 20 °C and 32°C inhibit the production of courtship signals by both genders; male responsivity to female callingis relatively high at 28°C and more males locate females at 28 °C than at 20 °C. With the progress of global warming,especially temperature increase in autumn in the temperate regions under SRES,

the current results altogether indicate that, BPH will overwinter in a much larger region and will produce more generations, achieve higher performance and realized fecundity. As a result, BPH will exert an even greater threat to rice production in the future.

O15-7. Succession effects of a transient exposure to extreme temperature on eggs of Asian corn borer

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One of many extremes resulted from the global change is the frequent appearance of extraordinarily daily high temperature. A transient high temperature, particularly early in embryonic stage, could profoundly affect insect performance across all subsequent life stages. In this study we investigated the impact of a transient exposure to extremely high temperature on egg of *Ostrinia furnacalis* for biological parameters across subsequent life stages. Eggs were heat-shocked to 5 temperatures from 37 ℃ to 45 ℃ for 90 min, and then transferred to control of 25 ℃. Effects of heat shock on egg hatching rate were significantly different among treatments. No larvae hatched out at treatment of 45 ℃. The development times had no difference at egg stage, but a significant prolong at treatments of 41 and 43 ℃ at larval and pupal stages. Pupal masses were significantly increasing at treatment of 39 ℃ for male. There were no significant differences for fecundity and sex ratio among treatments. The phenomenon of protandry appeared at treatments of 39 and 41 ℃, but faded away at treatment of 43 ℃. Our findings indicate a critical point may exist between 39 and 41 ℃ and provide useful information for predicting population dynamics under variable temperatures.

O15-8. Heat waves occurred in different life-stages contribute differently in survival and reproduction of a global pest, the diamondback moth

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Climate change lead to a substantial increase in the frequency and duration of hot events. Ambient temperatures often fluctuate with hot days in summer, and organisms with relatively short generation times might experience hot days at certain developmental stages. Because of inter-annual variation in the timing and duration of hot days, heat events may affect a single or multiple life-stages. This raises the question of how the timing and duration of hot days during the life cycle affect survival and reproduction of organisms. We used a global insect pest, *Plutella xylostella* as our model. We found that hot events occurred at different life-stages caused different demographic performances. Elder instar larvae often survive better than other stages. Heat events at early life stages could carry over to depress subsequent survivals and reproduction; heat stress closer to adulthood reduced more reproduction. Even a single hot day during adult stage could decrease egg hatching. When hot events persist to multiple life stages, the combined effects of heat at different life-stages are not always additive and not independent of each other. Both the stage specific heat effects and interdependent effects between stages suggest that we need to determine the likely time and duration of occurrence of heat events to identify what life-stages (or age structure) will be affected. All these findings emphasize the importance of incorporating the temporal patterns of heat events to describe the dynamics of natural populations and how they will respond to future climate change.

O15-9. Resolving biological impacts of multiple heat waves on insect population dynamics

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Global climate change has led to a substantial increase in the probability of heat waves. How the combination of extreme heat events and mild recovery will be transferred into the biological effects of multiple heat waves on insects still remains a big challenge. We examined how changes in the intensity, frequency, duration and timing of extreme heat events would impact life history traits and demographic parameters on pest insects. We found that theincreases in intensity, frequency and duration of extreme heat events had detrimental effects on insects' key fitness components including developmental rate, survival, reproduction and lifespan as well as demographic parameters such as intrinsic rate of increase. Importantly, the extent of such impacts depended on the temporal dynamics of extreme heat events and mild recovery. Even if with the same ratio of hot versus normal periods, the timing and distribution of extreme heat events could have different impacts on insects' performances and demographic parameters. The effects of heat waves were driven by a delicate balance of damage during hot periods versus repair during normal periods. Our findings thus emphasize the importance of accounting for the temporal distribution of extreme temperature events for predicting their consequences of populations of insect pests.

O15-10. Aphid behavioral thermoregulation in a warming world: linking insects' behavior to their population dynamics

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Behavioral thermoregulation is critical for ectotherms to buffer against thermal extremes especially in the context of climate change. Many insect species including butterflies and dragonflies can adopt thermoregulatory behaviors to avoid extreme temperatures. Small insects like sap-sucking aphids also can escape from thermal extremes such as heat stress *via* either walking away or dropping-off form their feeding site to seek for relative cooler places when the ambient temperature becomes stressful. However, such thermoregulatory behaviors are expected to incur a trade-off between heat escape and food availability. Both walking away and dropping-off from the host plant may disrupt the aphids' feeding behavior and force the aphids to spend much energy and time to finding new suitable microhabitats. Such behaviors may lead to a series of ecological consequences such as microhabitat selection, death from starvation, delayed development, insufficient nutrition intake and decreased reproduction at the individual level. Importantly, the thermoregulatory behaviors may also result in a substantial decrease in aphid abundance at the population level. Therefore, the increased duration and frequency of aphids' thermoregulatory behaviors caused by climate warming may have important implications for their population dynamics.

16. Pesticide resistance management

Organizers: Ashutosh Bhaik and G Ravi

Lead

O16-1. Zorvec™ - a novel OSBPI fungicide and strategies to manage resistance risk

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Zorvec™(Oxathiapiprolin) is a novel fungicide and the first member of a new class of piperidinylthiazoleisoxazoline fungicides. Zorvec™ exhibits exceptional activity against plant diseases caused by oomycete pathogens. It acts *via* inhibition of a novel fungal target-an oxysterol binding protein-resulting in excellent preventative, curative and residual efficacy against key diseases of grapes, potatoes and vegetables. Fungicide resistance action committee (FRAC) has categorized this group (group 49) to be having moderate to high resistance risk. Detailed recommendations have been suggested by experts to deliver effective disease management and better management of resistance over time.

O16-2. Insecticide resistance BPH population: A major concern in Asian rice farming

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Rice brown planthopper, *Nilaparvata lugens* (Stal) (BPH) (Hemiptera: Delphacidae), is a destructive pest in most of the rice growing regions in the Asian countries. Insecticide resistant BPH population is becoming a major concern in rice farming in East Asian, Southeast Asian, and South Asian regions. Number of reports on resistance and possible cross-resistances for existing molecules like phenyl pyrazoles, neonicotinoids, buprofezin, isoprocarb and pymetrozine make the insecticide resistance in BPH a critical issue both in farmers and industrial point of view. The intrinsic long distance migratory behaviour of BPH resulted in evolving resistance and cross resistance along the migratory routes in countries like India, China, Vietnam, Thailand and Japan. There are new class of molecules like Triflumezopyram and Benzpyrimoxan effective on insecticide resistant biotypes of BPH and they are to be endorsed with due etiquette. The battle between the farmer and the BPH is still continuing in many parts of the world and winning the battle is possible only if a mission mode approach through committed participation by policy makers, extension officials, farmers and pesticide stakeholders. A nationwide policy with multi-institutional approach for insecticide resistance management (IRM) sensitization linked to a region specific ready reckoner to guide on sensible use insecticides is needed. Proper extension methods to encourage farmers to grow resistant and tolerant varieties, integration of innovative cultivation practices like agro ecosystem analysis (AESA) and ecological engineering (EE), building awareness on pest bio-ecology and monitoring are also essential for the management of insecticide resistant BPH population in rice crop.

Invited

O16-3. Pesticide resistance in horticultural crops: management strategies and way forward

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Modern commercial horticulture includes use of pesticides as an integral part to minimise the biotic stresses caused by insects, mites, nematodes, pathogens and weeds. Frequent and indiscriminate use of pesticides led to selection pressure in pest populations leading to development of resistance. Ever since the first documentation of insecticide resistance in San jose scale, *Quadrispidiotus perniciosus* to sulphur-lime in 1914, presently more than 600 species are reported to have developed resistance to various pesticides. Significant yield loss due to major pests in vegetables and protected ornamentals is a main concern coupled with insecticide resistance, particularly in sucking pests like mites and thrips. Diamondback moth, *Plutella xylostella*, chilli thrips, *Scirtothrips dorsalis*, whitefly, *Bemisia tabaci* and two spotted spider mite, *Tetranychus urticae* are other major pests developed resistance to several pesticides. Plant oils like neem and pongamia as synergists increase the efficacy of insecticides like dimethoate and imidacloprid for managing resistant populations of thrips and aphids on horticultural crops. Rotation of chemicals with different modes of action delays the development of resistance. Effective resistance management demands interdisciplinary approach with scientists from different fields like basic ecology to molecular biology for understanding various evolutionary aspects of pesticide resistance development. IRM should exploit using synergists, integrating bio-intensive strategies within IPM for effective management of resistant pests. Ultimately, focus should be on development and integration of pesticide resistance management tactics as an effective component in Holistic crop management using Good Agricultural Practices. Various pesticide resistance management strategies applicable for horticultural crops are discussed in this paper.

O16-4. Evaluation of resistance in *Cyperus difformis* biotypes to ALS inhibiting herbicide in rice

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Rice (*Oryza sativa* L.) is the main staple food for a large part of the world population. The intensification of rice cropping systems in the same area promotes heavy infestation of weeds. Generally, weeds represent a major obstacle for rice production, causing as high as 96% yield reductions or sometimes complete crop loss when left uncontrolled. The continuous use of acetolactate synthase (ALS) inhibiting herbicides in rice associated with other field management disparity can cause herbicide resistance in one of the important sedges *i.e.*, *Cyperus difformis* L. in major rice-growing states like Chhattisgarh and Kerala. The biotypes of *C. difformis* were collected after interviewing farmers, using ALS inhibiting herbicides for quite long times. In all, 53 biotypes of *C. difformis* were collected from different rice growing districts of Chhattisgarh and Kerala. These were evaluated in pots (17 cm x 17 cm dimension) against bispyribac sodium 10% SC (ALS inhibitor) at different doses (0, 12.5, 25, 50, 100, 200 g/ha, field dose is 25 g/ha) and Rinskor 2.5% EC at 31.25 g/ha applied at 2 to 5 leaf stage of weed during 2018 and 2019 at ICAR-Directorate of Weed Research, Jabalpur, India. Experiments were arranged in a completely randomized design and replicated thrice. On the basis of whole-plant bio-assay and molecular aspects, 16 biotypes in 1X, 11 biotypes in 2X, 6 biotypes in 4X and 4 biotypes were found to be resistant against 8X level of bispyribac sodium. However, none of the biotypes could survive in Rinskor applied pots at tested dose.

O16-5. Insecticide resistance in whitefly: what next ??

Insecticide resistance in whitefly: what next??

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The whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae), is one of the world's top 100 invasive organisms causing extensive economic damage in over 60 crop plants as a pest and or as a vector of viral diseases. With the wider adoption of Bt cotton technology in India during 2002, the insecticide usage on cotton had started declining. However, there has been a surge in demand for insecticides from 2374 MT in 2006 to 6372 MT in 2011, on account of increase in area under sucking pest susceptible Bt cotton hybrids and due to increase in levels of resistance to insecticides by insect pests such as whiteflies. Resistance to insecticides in whitefly, *B. tabaci* is a global phenomenon and to date, it has shown resistance to more than 40 active ingredients of insecticides, including compounds of novel chemistry in several countries, *viz*., Brazil, Burkina Faso, China, Colombia, Cyprus, Egypt, Germany, Greece, Guatemala, India, Iran, Israel, Italy, Malaysia, Nicaragua, Pakistan, Spain, Sudan, Turkey, and USA. The prevalence of biotypes/genetic groups in whitefly as many as 42 as on date has compounded the problem of insecticide resistance as certain biotypes as B and Q in certain geographical regions and Asia II-1 in Asia have shown higher propensity for insecticide resistance. Extensive information is available on the insecticide resistance status of B and Q biotypes across the world, while, a comprehensive study from our lab has documented the widespread and strong occurrence of resistance to insecticides in Asia I & Asia II-1 genetic groups of *B. tabaci* across diverse ecological zones of India. There is a need for massive Institutional and industrial collaboration to monitor the insecticide resistance at real time in India, as do the insecticide monitoring networks in Australia, USA, Greece and other countries. Extensive studies on molecular basis of insecticide resistance are also the need of the hour as the biotypes of whitefly prevalent in India are unique. Improved awareness on efficacy of novel chemistries and judicious use of dose and quantum of chemicals go a long way in improving the shelf life of novel insecticide chemicals.

O16-6. Molecular ecology of key stored grain insect pests across India and their implications for the management of resistance to phosphine

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Tribolium castaneum and *Rhyzopertha dominica* are considered as the most serious insect pests of stored grains in India and other parts of the world. Fumigation with phosphine gas is the most common and effective method for the management of these stored grain pests. However, prolonged use of phosphine gas has resulted in the development of heritable resistance. Developing an effective pest management strategy is crucial and that depends on better understanding of genetic diversity and structuring of that diversity geographically. Thus, the present study was focused to assess the genetic diversity and phylogeographic structuring of *T. castaneum* and *R. dominica* in different geographical regions of India using the mitochondrial Cytochrom oxidase subunit I gene. The results showed that the genetic diversity was moderate in *T. castaneum*, with only 12 haplotypes (including three very common haplotypes) from the 142 specimens sequenced across the nation and AMOVA analyses demonstrated that the most of the variation within the populations (85.1%) could be attributed to within region differences, but a small (14.9%) and significant ($P < 0.01$), component was attributed to among region difference. Genetic diversity was lower in *R. dominica*,

with no discrete COI haplotypes identified from 96 specimens. The very low level of genetic diversity in *R. dominica* suggests selection may be occurring on the mitochondrial genome, potentially driven by an endosymbiont such as Wolbachia. The contrasting genetic patterns, across species, emphasize the importance of understanding the resistance mechanism among the species for developing insecticide resistance management practices that are both species specific.

O16-7. Draft genome of eggplant shoot and fruit Borer, *Leucinodes orbonalis* (Lepidoptera: Crambidae): Mining and mapping of genes involved in insecticide resistance

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Eggplant, *Solanum melongena* L. also known as aubergine or brinjal, is a most popular vegetable after potato in India, China and Bangladesh. The major limiting factor in realizing the yield potential of eggplant is the damage caused by shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Crambidae). Lack of resistant genetic resources in eggplant coupled with indiscriminate use of various insecticides led to the evolution of multiple insecticide resistance in *L. orbonalis* and subsequent field control failure in many Asian countries. However, the precise role of various genes in insecticide resistance and chemoreception in this almost a monophagous pest is not known. Through whole genome (Illumina HiSeq 2500 &PacBio RSII) sequencing, the genomic DNA was sequenced and assembled into 14900 scaffolds of size 855.62 MB with N50 value of 108kb. Repeat regions were also identified which accounts for 35.38% of the total genome. Further, we identified 22000 protein coding genes with an average gene length of 1330.94 bp. It is the first draft genome information for *L. orbonalis* with complete annotation and detection of gene families and genes involved in pesticide degradation.

O16-8. Indication of potential development of insecticide resistance in the field population of South American tomato leaf miner, *Tuta absoluta*

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The tomato borer, *Tuta absoluta*, is an important pest native to South America that was first detected in Spain in 2006 and in India during 2014. *T. absoluta* larvae destroy tomato plants by producing large galleries in tomato leaves and burrowing stalks, apical buds, green and ripe fruits. This larva causes major economic losses on tomato industry. In order to manage this pest, insecticides are being commonly used in tomato fields. However, intensive use of synthetic insecticides has led to development of resistance, due to its high reproductive capacity and short generation life cycle. In this context, experiments were conducted in the laboratory to assess the resistance levels of *T. absoluta* field populations to Indoxacarb, Flubendiamide, Emamectin benzoate, Spinosad, Spinetoram and Chlorantraniliprole. IRAC leaf-dip bioassay method was used to determine the LC and resistance ratio of insecticide. Mixed function oxidase and glutathione S-transferase activities were determined by conducting biochemical assays. *T. absoluta* field population has shown reduced susceptibility (1.34 folds resistance) to flubendiamide compared to susceptible population with LC50 for field 9.40 ppm and lab 6.97ppm. There was a significant increase in cytochrome P450 monooxygenases level in resistance population shows probable involvement of the enzyme in flubendiamide

resistance mechanism. This is an indicative trend of development of resistance to frequently used insecticides like flubendiamide against *T. absoluta*. The present study thus warrants immediate adaptation of Insecticide Resistance Management (IRM) strategies to avoid future losses to tomato crop by resistant population of the pest.

O16-9. *Bt* resistance and management of cotton bollworm in texas cotton

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Cotton bollworm (*Helicoverpa zea*) is one of the most serious insect pests of cotton in the US. Transgenic cotton expressing Cry and Vip toxins derived from a soil bacterium, *Bacillus thuringiensis* (Bt), has been widely used to control this pest. However, several field populations of bollworm across the US have evolved resistance to Bt toxins reducing overall benefits of Bt technology. Laboratory diet bioassay results indicate that >90% of bollworm field populations that were studied are resistant to at least one of the Cry toxins (Cry1AC/Cry1F/Cry2Ab). Increasing cases of Bt resistance and field failures are proving to be problematic across cotton growing regions as farmers are having to spray for bollworms even after investing into Bt technology. With the field evolved resistance to Bt becoming widespread, it is not uncommon to spray Bt fields for bollworms. Field evolved resistance to Bt toxins has practical implications in the pest management as it increases the cost of production and exert more selection pressure on the remaining Bt toxins (Vip) and foliar insecticides (e.g. diamides). This presentation aims at providing the current status update on the bollworm resistance to Bt in Texas cotton. In addition, it will also discuss field performance of various Bt traits and chemical insecticides used to manage cotton bollworm.

17. Plant-pest/pathogen interactions in the context of chemical ecology

Organizer: Laura Cortada

Lead

O17-1. Semiochemicals in pest management: highlights from above- and below-ground

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Semiochemicals are widely used globally in the control of agricultural pests as an alternative to synthetic chemical pesticides, which are known to impact negatively on non-target beneficial organisms including pollinators and natural enemies of pests. In the last three decades, research on semiochemicals of pests and beneficial organisms has accelerated rapidly in sub-Saharan Africa (SSA), mostly conducted at the International Centre of Insect Physiology and Ecology (icipe), Nairobi, Kenya. This presentation will highlight advances made in chemical ecology research at icipe to identify and exploit semiochemicals for the management of some key above- and below-ground pests and beneficial organisms.

Invited

O17-2. Chemical ecology interactions on cyst nematodes: current status and potential for biocontrol

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Cyst nematodes are sedentary endoparasitic plant pests known to cause significant economic losses in crop production worldwide. Most of the losses are attributed to species belonging to the genera *Globodera* and *Heterodera* specifically, potato cyst nematodes (PCNs) *Globodera pallida* and *G. rostochiensis*, the soybean cyst nematode (SCN) *Heterodera glycines*, the sugar beet cyst nematode *H. schachtii* and cereal cyst nematodes (CCNs) *Heterodera avenae* and *H. filipjevi*. Current management strategies for cyst nematodes include the use of synthetic chemical nematicides, resistant cultivars, biological control agents and cultural control methods. Nevertheless, the effectiveness of all these methods can be at times limited by the protective nature of the cysts and their longevity in the soil, the genetic diversity of the nematodes and its hosts and the ban of broad-spectrum chemical fumigants due to health and environmental concerns. To improve the existing or to develop novel, more effective, sustainable and environmentally benign management strategies, is paramount to understand the chemical ecology interactions and the factors influencing the plant-nematode communication strategies at different stages of the nematode lifecycle. Hence our research reviews on the existing knowledge available regarding the chemical interactions of cyst nematodes and its environment with a special focus on the cysts' hatching and host finding phases, while highlighting the unexploited chemical ecology strategies that could be developed further to design sustainable and durable management strategies for cyst nematodes.

O17-3. African nightshade for capturing plant parasitic nematodes

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Potato cyst nematode (PCN) (*Globodera rostochiensis* and *G. pallida*) is a quarantine pest of potato in more than 100 countries. In East Africa potato cyst nematodes (PCN) were first detected in Kenya (2015) and recently in Rwanda (2018). PCN is now widespread, affecting most of the main potato growing regions in the highlands of Kenya. Knowledge is lacking on how to tackle this pest under the prevailing climatic and agroecological conditions in the region. This paper presents preliminary findings from a collaborative field trial between *icipe* and KALRO (Kenya Agricultural and Livestock Research Organization) Tigoni. A field study was conducted for three seasons and the main objective was to evaluate traditional vegetables as trap crops for PCN in a rotational program with potato. Treatments comprising seven different plant species were compared; *Amaranthus dubius*, *Solanum scabrum*, *Solanum vilosum*, three potato varieties (Dutch Robjin, Mayan Gold and Shangi), and weed free fallow. Data were collected on the initial and final density data of PCN cysts in soil from each treatment to compute reproductive indices. Our results show that the PCN population under *Solanum scabrum* was reduced by 50% after one season and by about 80% after the three seasons. The presentation will discuss implications for management of PCN in the region.

O17-4. Exploiting phytochemicals for developing sustainable crop protection strategies to withstand climate change

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A novel approach for integrated insect pest, weed and soil fertility management, was developed through exploitation of chemical ecology to address agricultural constraints facing millions of resource poor African farmers. The technology, widely known as 'Push-Pull' was developed by selecting appropriate plants that naturally emit semiochemicals and influence plant-plant and insect-plant interactions. Plants highly attractive for egg laying by cereal stemborer pests were selected and deployed as trap crops. Of these, *Pennisetum purpureum* (Schumach) produced significantly higher levels of volatile cues used by gravid stemborer females to locate host plants, than maize or sorghum. Despite its attractiveness to stemborer moths, *P. purpureum* supported minimal survival of the pests' immature stages. Plants that repelled stem borer moths notably, *Melinis minutiflora* P. Beauv., and forage legumes in the genus *Desmodium*, were selected as intercrops, which also attracted natural enemies of the pests through emission of (E)-β-ocimene and (E)-4,8-dimethyl-1,3,7-nonatriene. *Desmodium* intercrop also suppressed parasitic weed, *Striga hermonthica* (Del.) Benth., through an allelopathic mechanism. *Desmodium* root exudates contain novel flavonoid compounds which stimulate suicidal germination of *S. hermonthica* seeds and dramatically inhibit its attachment to host roots. We identified and selected new drought and temperature tolerant trap (*Brachiaria* cv mulato) and intercrop plants (desmodium, e.g. *D. intortum*) suitable for drier agro-ecologies and developed a climate-smart push-pull. The climate-smart push-pull also has appropriate chemistry for controlling fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Opportunities for semiochemical delivery by companion

plants, including plant-plant signalling and early herbivory alert, are being explored for developing future smart IPM strategies.

O17-5. Root-knot nematodes: chemical ecology of parasite-host plant interactions

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Root-knot nematodes (RKNs) are economically important belowground pests that parasitize numerous crop species and present a risk to food security. The global crop losses attributed to RKN infestation is estimated at over USD 100 billion annually. Crop production losses of 40-100% have been observed in Africa although the economic impact is yet to be established. RKN infestation persists despite cultural practices and the most effective nematicides have serious negative impacts on the environment, humans, and other non-target organisms. This necessitates the use of other complementary approaches in their control among them being the use of semiochemicals. The success of RKN is attributed to a suite of sophisticated strategies for exploiting the developmental process and defense mechanisms of plants. This presentation will highlight scientific advances in elucidating the role of RKN-induced plant chemical defenses in the chemotaxis of *Meloidogyne javanica*, a key RKN of tomato. Using behavior-guided chemical analysis, we show that RKN infection alters the volatiles of the host roots which in turn influences host plant recognition ability of the infective RKN-juveniles present in the soil. We found qualitative and quantitative differences in the volatile profiles with 2-7-fold increase in the amounts of terpenes emitted in infected plants, compared to the uninfected ones. We will discuss the behavioural significance of the identified compounds in nematode responses and their potential for future control of RKN.

O17-6. Disruption of the potato plant-potato cyst nematode chemical interaction using the "Wrap & Plant" technology

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Potato production in Kenya is threatened by the occurrence of the widespread potato cyst nematode (PCN), which causes yield losses of more than 80%. Recent attempts to assess novel management options for PCN in the country demonstrated the effectiveness of the "Wrap & Plant" technology (W&P) to increase yields under heavy PCN infestations. This innovation consists on a field deployable biodegradable matrix produced from banana fibre (banana paper) that is impregnated with abamectin (nematicide). Farms where potato seeds were wrapped with the abamectin-treated and the untreated banana paper (paper control) increased yields by 4-fold and 3-fold, respectively, and experienced a decline of 83% and 43% of the PCN inoculum in the soil. Our study sought to elucidate the underlying chemical interactions between the pests and its host plant in the presence of the W&P technology, from a PCN-management perspective. We hypothesised that banana paper acts as a physical and/or chemical barrier, hampering plant-nematode communication. Behavioural

experiments indicated that the treated and untreated banana paper reduced PCN hatching by 60% and 80%, respectively, and that the paper inhibits the chemotaxis response of the PCN juveniles. Chemical analysis by liquid chromatography, coupled to triple quadrupole mass spectrometry of the potato root exudates exposed and unexposed to banana paper, revealed that the paper matrix adsorbs specific hatching factors (solanoeclepin A, α-chaconine, o α-solanine) required by the nematode for host identification. This research provides new insights on how PCN could be managed at the rhizosphere level by disrupting the chemical signalling with its hosts.

O17-7. Stem borer egg induced indirect defense in maize: behavioral, chemical and genetic exploration

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Plants have evolved intricate defence strategies against herbivore attack which include production of herbivore induced plant volatiles (HIPVs) to attract natural enemies antagonistic to the herbivores. Emission of HIPVs that attract natural enemies, known as indirect plant defense, early on at the egg-laying stage of herbivore attack could provide timely biological control of pests and deter subsequent oviposition. Our study showed that egg deposition by stemborer moths (*Chilo partellus*) on certain maize genotypes causes emission of HIPVs that attract parasitic wasps. However, the herbivore egg induced indirect defense traits were more common in maize landraces than in improved inbred lines and hybrids. In the landraces, not only egg parasitoids (*Trichogramma bournieri*) were attracted but also larval parasitoids (*Cotesia sesamiae*), implying a sophisticated defence strategy whereby parasitoids are recruited in anticipation of egg hatching. The effect was systemic and caused by an elicitor, which could be extracted from egg materials associated with attachment to leaves. The chemical analyses revealed strong induction of bioactive compounds such as (*E*)-caryophyllene, (*E*)-4,8-dimethyl-1,3,7-nonatriene and (*E,E*)-4,8,-trimethyl-1,3,7-tridecatetraene from maize landrace volatiles exposed to *C. partellus* egg deposition. Our recent data from a genome wide association study (GWAS) on diverse maize genotypes (146) identified 101 marker-trait associations (MTAs), some of which were adjacent to genes involved in the jasmonic acid (JA) defence pathway, terpene biosynthesis, benzoxazinone synthesis and known maize resistance genes. Strategies for exploiting egg induced indirect plant defense traits to enhance crop resistance against insect attack for sustainable crop production are discussed.

O17-8. Chemo-ecological basis of insect-plant interactions under changing climate change: A case study with the herbivores of mango and tomato

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Climate change has drastically influenced the ecology of insect pests aiding them to expand their inland-range. Elevated temperature (eTemp) and/or CO2 (eCO2) are mainly considered to be the consequences of climate change. Further, frequent episodes of moisture stress (low as well as high) also affecting the host plants vis-à-vis their associated herbivores. These factors have profound effect on plants impacting their

metabolism thereby changing their volatile emissions. On the other side, the insect responses that are optimally tuned to specific volatile patterns of host plants may go 'out of tune' thereby effecting insect-plant interactions. Our study explores the preferences of herbivores viz., fruit flies, Bactrocera dorsalis, stone weevil, Sternochetus mangiferae, hoppers, Ideoscopus nitidulas, etc associated with mango and American serpentine leaf miner, Liriomyzatrifolii, gram caterpillar,Helicoverpaarmigera, tobacco caterpillar,Spodoptera litura associated with tomato plants through olfactometer and cage assays to evaluate gravid female preferences. Our study clearly established significant differences in the adult oviposition choice among these herbivores indicating that the host plants grown under eCO2/ moisture stress may have profound effect on host location by herbivores and it will be species specific. The paper presents the impact of these climate change variables on host plants vis a vis host location by insect in greater details.

O17-9. Chemical ecology providing management solutions for fall armyworm in Africa

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Fall armyworm (FAW), *Spodoptera frugiperda* (JE Smith), an economically important pest native to tropical and subtropical America has recently invaded Africa, causing substantial damage to maize and other crops. Understanding the interactions involving plants, herbivores and their natural enemies is important in designing effective and successful integrated pest management (IPM) strategies where such interactions could be manipulated through habitat management approaches. One of the most successful of such approaches is the 'push-pull' cropping system based on stimulo-deterrent principle, where the target crop is intercropped with herbivore repellent plants (push) while attractive plants (pull) are planted around this intercrop. We evaluated the impacts of this technology, originally developed for control of cereal stemborer, on FAW. Results indicated significant reduction of pest infestation levels, and damage to maize with the technology. Additional studies elucidated the chemical ecology of pest - plant -natural enemy interactions, with results indicating effectiveness of the 'push' chemistry of desmodium on FAW moths and improved activity of an egg-larval parasitoid commonly found in maize fields in western Kenya. Additional factors responsible for the technology's success in control of FAW in the region, its mechanisms and implications for extension to other cropping systems and regions will be discussed.

18. A greener IPM: Development of ecologically-based management of pests, weeds and diseases in cereal grain crops

Organizer: Buyung Hadi

Lead

O18-1. Envisioning rice IPM in tropical Asia

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Rice cultivation constitutes the majority of arable land in tropical Asia and rice pest management practices in the region have consequences beyond productivity into environmental and public health domains. IRRI, together with other organizations such as FAO and various NARES partners, have been actively involved in developing and deploying Integrated Pest Management (IPM) in the region. Well-timed and selective pesticide use is a part of IPM but the approach includes many other tactics that inherently reduce dependence on pesticide use, such as the use of resistant varieties and natural enemy conservation. Despite the efforts and investments, over-reliance on pesticide continues to be the dominant rice pest management regime in the region. This stubborn fact necessitates fresh thinking on how rice IPM should be validated and mainstreamed in the region. Through "Developing Ecologically-based Participatory IPM strategy for rice in Cambodia (EPIC)", a USAID-funded project in Cambodia, IRRI partners with Cambodian General Directorate of Agriculture, Cambodian Agricultural Research and Development Institute, Royal University of Agriculture and the University of Battambang to conduct a number of studies validating IPM tactics against multiple biotic stresses. The studies also attempt to tease out the intricacies of policy and stakeholder interactions to formulate a scaling strategy. A wide range of tactics were tested including resistant variety, microbials and botanicals, trap barrier system and integrated use of mechanized seeder (line sowing, low seed rate) and well-timed herbicide applications. These tactics were shown to be at least as efficacious as the current farmers' practice of pesticide reliance. Finally, we submit a theoretical framework on Rice IPM that will put the focus of pest management on a series of preventive actions and leaving pesticide use as a rarely-used as-needed option.

Invited

O18-2. Ecologically based IPM in Cambodia without a farmer field school: is there potential to scale out?

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The Integrated Pest Management - Farmer Field Schools (IPM-FFS) is a proven approach to teach pest monitoring and reduction of pesticide use. It is however expensive and difficult to sustain or scale out. Can learning and spread of IPM happen without FFS? This study examines a method to introduce an ecologically-based IPM package with a focus on adaptive learning networks that support scaling of the technologies. Learning outcomes were examined by comparing practices from 1) research trials (N=56) in 2017, 2)

'adapted IPM' practices in 2018-19, documented in farmer diaries (N=72), and 3) practices of randomly selected farmers (N=324) in 2018-19 surveyed from the same sites. We also tracked the learning activities implemented in eight sites in Cambodia in 2016-2019, and implemented thematic analysis on end-of season reflections by farmers. Farmers were able to integrate a range of IPM practices, with limited uptake for those not directly involved in the trials. The approach entailed learning about the technologies and integrating different practices at community level, as well as learning by a broader network about supportive policies and marketing of IPM products. Themes such as access to biological control options, technical constraints on the tools used, costs, marketability of pest resistant varieties were emphasized by farmers. These have implications for the spread of IPM in Cambodia.

O18-3. RiceXpert app: role in the adoption of rice IPM practices in India

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With the advent of new ICTs such as space technology, remote sensing, drones, big data analytics, artificial intelligence and smartphones, the agricultural scenario is changing worldwide. Of late, the mobile apps have emerged as handy tools in providing farm advisories. With the aim to bridge the information gaps between farmers and scientists, an inexpensive tool, riceXpert app has been developed to reach the latest rice technologies in real-time basis. Since, identification of pests and diseases is a tricky issue, the farmers can get them easily identified through this app. Besides, the farmers can also send the image, text message or recorded voice to the expert for further clarification and get quick solution through SMS. The riceXpert app also gives farmers a personalized pest solution platform based on the type of insect pests, diseases, crop stage, area and sprayer type. Presently, more than 24,000 users have registered riceXpert app covering India (73%), Philippines (9%) and other counties (18%) and more than 1500 queries have been received from India. Analysis of category-wise queries received through this app revealed that rice disease showed highest number of queries followed by insect pests which showed that use of riceXpert apps is emerging as a potential for improving the livelihoods of the rice farmers. Although, this is still not been adopted fully by all farmers, but they have keen interest to learn and use riceXpert app thus enabling them to take in time decisions to manage the pests and adopting green IPM in rice farming.

O18-4. Mating disruption: a foundation to manage stemborers in rice

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Mating disruption is a species-specific, non-lethal form of pest control that can reduce crop damage to levels comparable to conventional insecticide practices, while having the additional benefit of being less susceptible to resistance evolution. The mechanisms of mating disruption are diverse, but it primarily functions by severely reducing the number of males that are able to find and mate with virgin females, thus lowering the frequency of fertile eggs and damaging larvae being deposited on the target crop. Mating disruption technology has been most popularly adopted in pome fruit & nut tree agricultural systems, but it has also had immense success in the control of stem borer in Spanish rice production. The traditionally high cost of synthesizing the sex pheromone have likely been a barrier to the adoption of this technology in low-cost, large hectarage row crops like rice. Recent advancements in the syntheses of these pheromones brings tremendous opportunity in managing stemborers of rice with mating disruption, thus reducing our dependency on insecticides. Mating disruption as a foundation to manage stemborers in rice and how it complements insecticide usage is important to understand to bring IPM & IRM principles to action. Mating

disruption as a viable and economically-feasible pest control method in row crop agricultural systems would be discussed.

O18-5. Efficacy of two weed management recommendations for direct wet-seeded rice production in Cambodia

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Faced with increasing costs and scarce labor in agriculture, Cambodian rice farmers have turned to direct seeding to establish their crop. Weeds become a major constraint when appropriate control tactics, correct timing of application and necessary complement of agronomic practices are not implemented. Farmers often resort to increased reliance on herbicides, which are not sustainable. There is a need for an integrated weed management package which is suitable for the ecological conditions faced by Cambodian rice farmers. We tested two integrated weed management recommendations which include good agricultural practices for crop establishment as a base, then use of appropriate herbicides, application at correct timing, and hand weeding when necessary. The two treatments were tested against several controls: 1) farmer's practice (FP), 2) conventional practice (CP) which is the average of farmers in the village, and 3) modified FP with use of appropriate herbicide only. The experiments were in randomized complete block design, with 3 replicates in a province. These were implemented in three provinces, Battambang, Prey Veng and Kampong Thom, for two seasons in 2017. The two treatments tested were not significantly different to the controls in terms of weed count and effect of the treatments. In Battambang however, where there is higher weed pressure, the two treatments showed significantly improved results on weed control. There was also higher grain yield with proper use of herbicide. This implies potential for improving herbicide use efficiency because the current practices of farmers use more toxic chemicals or excess amounts of herbicides.

O18-6. Towards an integrative approach of ecological engineering in Cambodian rice fields

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With the intensification of rice production, landscape heterogeneity decreased due land transformation. High external inputs of environmentally polluting chemicals go hand in hand with intensified rice production to reduce potential yield loss by insect pests. Although, it is well known that outbreaks of insect pests can be induced by insecticides, farmers still use them abundantly. That calls for an urgent need for sustainable farming practices. In our study, we implement a novel approach of ecological engineering in Cambodian rice agroecosystems to reduce the use of pesticides. Growing additional nutritious crops beside rice fields to promote ecosystem services like biological control by beneficial arthropods. Over two cropping seasons, we identified and compared arthropod communities among ecological engineered rice fields and fields farmed with conventional methods. We found significantly higher numbers of beneficial insects in ecological engineered rice fields than in conventional ones, despite no differences in rice yield among fields. Our results show that the withholding of pesticides do not negatively affect rice yield. Furthermore, additional crops surrounding the rice fields have manifold benefits including higher landscape heterogeneity, additional yield

and higher abundance of natural enemies of insect pests in rice agroecosystems. Proper implementation of ecological engineering can be a promising solution towards sustainable rice production in Cambodia.

O18-7. Strategies for sustainable management of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in sorghum

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Fall armyworm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is a Polyphagous pest; it feeds almost 80 recorded host plants in 26 families but prefers graminaceous plants including ICRISAT's mandate crops Sorghum, Pearl millet and Finger millet. FAW poses threat to the food security of more than 300 million people in Africa, leading to an estimated loss of $4.8 billion. In India, 36% yield losses have been attributed to this pest as per the preliminary reports. FAW has the ability to develop resistance to commonly used insecticides. In this view, we studied different approaches for management of FAW. The results revealed that, among > 200 lines of sorghum were evaluated for resistance to FAW under unprotected conditions. The lines, IS 18551, IS 2205, ICSV 705, ICSV 25333, ICSV 93046, 104B, CSV 24SS exhibited lower damage as compared to the susceptible check Swarna. The seeds treated with Benevia (Cyantraniliprole) exhibited least damage (%) followed by Thiodicarb as compared to control. Among the insecticides tested, Thiodicarb, Emamectin benzoate and Delegate were found to be very effective against FAW while Pongamia oil was found to be most effective among the bio-pesticides followed by BCIR 300.The maximum number of catches in prevailing weather conditions, were recorded during 46th and 45th standard weeks for maize and sorghum respectively.

O18-8. Microencapsulation for an effective, sustained and safe release of the of antagonistic microbes and their metabolites for the management of blast disease of rice

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Rice is one of the most important food crops cultivated globally in an area of 166 mha, with a production of 745.17 mt and 43.86 mha in India with a production of 104.80 mt. Blast disease in rice is caused by the fungus *Magnporthe grisea.* It is the most important and devastating disease of rice, causing symptoms in leaf, neck nodes and panicle, collar and nodal regions of the rice plants. Bio control is accepted to be the most effective alternative to the use of hazardous chemicals for the management of plant diseases. However, the most important constraint in the successful use of bioagents is their formulation, which often does not retain the viability of the spores for the intended period, not easy to handle and store and not effective under field conditions. In this context, microencapsulation is proposed to be a better method of formulating the bioagents and their metabolites in most effective way to ensure precise delivery of the antagonists in the target area. Microencapsulation is the technique of coating the viable spores of the microbe or the potential metabolites using a soluble, biodegradable and safe to the environment materials like biopolymers, alginate, hydrocarbon sources etc., in the size of micro metric scale. The coated materials shall be released upon contact with the predetermined triggers like the pH, contact with the root surface etc., present in the target area. Microencapsulation increases the efficiency of the microbes/metabolites by protecting them from the harsh environment and the local competition by the native micro flora present in the microsphere.

O18-9. Effects of agronomic practices on blast (*Pyricularia grisea*) and yield parameters of finger millet (*Eleusine coracana* (l.) Gaertn) in southern Guinea savanna zone of Nigeria

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Finger millet is rich in proteins, sulphur, calcium, iron, low glycemic index and high fibre content. Despite its importance, it has yields of 400 kg ha^{-1} compared to 2,500 kg ha^{-1}. Trial was conducted in 2015 and 2016 at the Research farm of Federal University Wukari (Latitude 7o 50' - 8o 30'N and Longitude 9o 68' - 9o 89' E.) to investigate the response of finger millet and blast to sowing method, plant population and fertilizer. The treatments consisted of three planting methods (Transplanting direct seeding and broadcasting), two plant population (1 plant per stand and 2 plants per stand) and three N - fertilizer rates (0, 30 and 60 kg ha^{-1}). The treatments were laid out in factorial manner using RCBD with three replications. The results indicated that the leaf, neck and finger blast increased with increasing N – levels. However, 30 kg N ha^{-1} was found optimum for maintaining low disease without sacrificing the yield. The highest numbers of effective tillers (5.06), head and 1000 kernel weight (4.80 3.5 g) were recorded at the highest rate of 60 N kg ha^{-1} compared to 0 N kg ha^{-1}. Furthermore, plant population of 2 plants per stand, transplanting and fertilization of 60 N kg ha^{-1} gave the highest grain yield (1130 – 2, 140 kg ha^{-1}), compare to the lowest yield from broadcasting, 1 plant per stand and fertilizer rate of 0 kg ha^{-1}.

19. Beneficial microbes for plant protection – current performance and future expectations

Organizers: Nora Altier and Trevor Jackson

Lead

O19-1. Impact of modes of action of biological control agents against plant diseases

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Fungi or bacteria applied for biological control of plant pathogens act through different modes of action such as inducing resistance without direct interaction with the pathogen, nutrient competition modulating the growth conditions for the pathogen or hyperparasitism and antibiosis interfering directly with the pathogen. Interactions are highly regulated metabolic events based on signalling compounds, enzymes and other interfering metabolites. The potential to produce such compounds in vitro does not necessarily correlate with the in situ antagonism. Understanding the mode of action is crucial to optimize biological disease control. The choice of a certain mode of action has not only impact on the biocontrol activity but also on possible risks for humans or the environment and risks for resistance development against the biocontrol agent. In vitro screening assays can be designed to find isolates with a specific mode of action. However, since most antagonists combine a range of different modes of action, well-designed bioassays should be preferred to quantify the overall effects of biocontrol strains on plants or in soil. Risks assessments for registration of biocontrol strains are often conducted for specific metabolites similar to assessments of single molecule fungicides applied in stable formulations to the entire crop. However, the nature of often combined modes of action of biocontrol strains requires a rethinking of such risk assessments because metabolites are usually produced temporarily in situ during interaction with the pathogen or the plant at very low quantities. Such metabolites are ubiquitous in nature and not relevant for risk assessments.

Invited

O19-2. Progress and uses of biocontrol in Chile

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Although its complex geography, the agriculture is one of the major economic activity in Chile. Thus, the country is the major fresh fruit producer in the South hemisphere, besides other commodities such as wine, horticulture crops and seed production. The biological control in Chile has a long tradition, since the first introduction of a natural enemy in 1903 to control an olive pest. At the beginning the emphasis was on pasture and cereals through classical biological control, but later the breakout of the fruit industry increases the necessity for augmentative and effective biological control agents. Farmers base their management in chemicals pesticides, but the growing restriction for chemicals and the public concern about pesticides, encourage the farmers to use microbial control. The incorporation of Chile into the OCDE increase the pressure for pesticide reduction. The use of entomopathogenic (EP) fungi and nematodes (EPN) are more common today, and research has showed that the use of EP is an effective alternative to manage mealybugs, weevils, and other pests in fruit orchards. The last period considers the research and commercial initiatives made by private and government institutions, in order to work with predators and parasitoids, entomopathogenic fungi and nematodes, bacteria and fungi for plant pathogens. New development in mass

production, formulations such as granules, gels and clays are available for field applications today. The most recent research is the uses of microbial endophytes for pest and disease control, improving the options for biologicals in agriculture and forestry.

O19-3. Beneficial microbes for agriculture in Uruguay: strategies and successful case studies

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Biotechnologies based on microbial resources have enabled the development of biological products to improve plant protection and plant nutrition, while addressing environmental sustainability. These technologies also contribute to the achievement of high-end market requirements for low agrochemical use. The Platform of Microbial Products for Agriculture at INIA Las Brujas has emphasized the role of microorganisms in the biocontrol of plant pests and diseases, and in nitrogen and phosphorus plant nutrition. The long-term strategy is based on five pillars: strengthening of research facilities and collaborative team work; recruiting and training of human resources; supporting research and technology ventures with the public and private sectors; fostering legal framework for registration and intellectual property protection of products; and promoting education and extension for farmer adoption. Main research areas include: (1) biological control, (2) biological nitrogen fixation, (3) microbial mediated phosphorus availability for plants, and (4) microbial bioproduction and formulation. In addition, supporting research addresses metagenomic approach for assessment of microbiome composition and diversity. Two case studies of product development based on strains of entomopathogenic fungi and Plant Growth Promoting *Rhizobacteria* (PGPR) will be presented. First, the process of strain characterization, selection and massive production will be described for the development of a bioinsecticide based on *Beauveria bassiana* to manage the eucalypt bronze bug *Thaumastocoris peregrinus* (Heteroptera: Thaumastocoridae). Second, the development of a novel Phosphorous-biofertilizer based on selected strains of *Bacillus* spp. with PGPR characteristics will be outlined, as an example of a successful co-innovation business model.

O19-4. Impacts of soil borne disease on plant yield and farm profit in dairying soils of New Zealand

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Soil-borne organisms that cause diseases on pasture plants impose substantial constraints on production in New Zealand dairy systems. Regional measures of disease pressure were obtained by comparing white clover, perennial ryegrass and plantain growth in 30 farm soils with (non-pasteurised) or without (pasteurised) their normal complement of microbial and nematode pathogens. Pasteurising soils from the North Island of New Zealand led to significant average increases in clover and ryegrass (35% and 19%, respectively) shoot dry matter. For the South Island there was no increase in plant yield with pasteurisation on a regional basis, but increases in either clover or ryegrass were significant at three individual farm sites. Across all regions, high disease pressure and soil quality were identified as driving factors, accounting for 34% of the variation in both clover and ryegrass growth. A positive linear relationship was found between disease pressure and Heterodera cyst nematode abundance, accounting for 33% and 17% of the variation in clover and ryegrass growth change, respectively. By determining the extent and consistency of these

constraints, this study demonstrated that root pathogens are most prevalent and damaging in the Northern region of New Zealand and are estimated to cost $900 per ha per year in farm profitability. Harnessing the natural, defensive activities of a soil's biological community may present opportunities for sustainable disease control in these agricultural systems.

O19-5. Delivery of the entomopathogenic fungus *Metarhizium* spp. in seed coatings for plant growth promotion and plant protection against pests and diseases

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Entomopathogenic fungi belonging to the genera *Metarhizium* and *Beauveria* are well known for their natural ability to infect and kill insects. Recently it was established that these fungi are also able to associate with plant roots. Potential benefits for the plant from this fungal association include: nutrient acquisition, plant growth promotion, elicitation of induced resistance and plant protection against insect pests and plant pathogens. After maize seeds coated with conidia from *Metarhizium* spp. were sown, conidia germinated, and hyphae from the fungus colonized the rhizosphere and even grew endophytically within maize roots. The entomopathogenic fungal association with roots had a cost for the plants in terms of nutrients which was reflected in reduced maize growth. Conversely, in the presence of either larvae of *Costelytragiveni* (Coleoptera: Scarabaeidae) or the plant pathogen *Fusariumgraminearum* (Nectriaceae), maize plants from some fungal seed coating treatments had more dry weight than untreated plants. Furthermore, biocontrol properties resulted in up to 67% mycosis of larvae and a reduction in Fusarium rot root symptoms of between 24 to 44%. Finally, isolates of *M. anisopliae* were also able to increase levels of the phytohormones salicylic and jasmonic acid in roots, which could be indicative of an induced resistance response in maize. Entomopathogenic fungi delivered in maize seed coatings represent an alternative biocontrol strategy targeting soil-dwelling pests and diseases.

O19-6. Biological control of *Helicobasidium purpureum* (*Rhizoctonia crocorum*) causing violet root-rot of carrot and dwarf-bean

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Violet root-rot caused by *Helicobasidium purpureum* (*Rhizoctoniacrocorum*) causes significant losses for New Zealand carrot growers, and as fungicide use has not mitigated these losses, biological control was investigated. In glasshouse experiments, isolates of *Trichoderma atroviride*, *T. hamatum, T. polysporum*, and *T. harzianum* were applied as a seed-coating, and carrot seeds sown into H. purpureum infected soil. Several isolates enhanced seedling emergence and reduced disease severity compared to bare seed. Based on these glasshouse results, one isolate of *T. atroviride* (LU132), was then assessed for its ability to control *H. purpureum* in carrot (cv. Express Hybrid) and dwarf bean (cv. Top Crop Dwarf) in a field known to be infested with *H. purpureum* inoculum. LU132 significantly increased carrot seedling emergence (by 14%) and reduced disease severity (by 40%). In dwarf bean, LU132 also significantly increased seedling emergence (by 18%) and reduced disease severity, and increased the yield of green beans (by 43%) and final seed yield (by 52%). As the isolate LU132 also provides control of other soil-borne pathogens (*Rhizoctonia*

solani, *Sclerotinia sclerotiorum*, *Pythiumu ltimum*, *Botrytis cinerea*, *Fusarium* spp.) it is being developed as a generic bio-inoculant seed treatment for soil-borne pathogens of fresh vegetables and vegetable seed crops.

O19-7. Overcoming constraints to adoption of beneficial microbes for insect control and plant growth promotion

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The potential for use of beneficial microbes for insect control and plant growth promotion has been recognised for more than 100 years. While there has been recognition of benefits and growth in the sector, microbial control agents and biofertilisers remain as minor components in the international plant protection market despite a socio/political environment favouring environmentally acceptable alternatives to residual chemicals. The reasons for limited uptake need to be examined. Variable efficacy or slow speed of action of biocontrol microbes are reasons sometimes given for slow uptake but biologicals often give better results than agrochemicals if use is properly timed. Efficacy will depend on the relationship between pest, pathogen and environment but the ecology of these interactions is often not well understood leading to poor results. Economics of production of many agents has been challenging as small scale of production and low margins have limited the success of beneficial microbe producers. One of the greatest challenges has been commercialisation. While regulation is intended to build confidence in microbial products, complex regulatory requirements have often been a brake to product availability. Success requires close collaboration between all actors in the development chain, from scientists through to farmer users. Some examples of successes and failures in microbial product development will be given and options to overcome constraints to development discussed.

Oral

O19-8. Mass multiplication and predatory potential of the apefly, *Spalgis epius* (westwood) (Lepidoptera: Lycaenidae), a candidate biocontrol agent of mealybugs

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Spalgis epius has been recorded as a potential predator of various species of mealybug crop pests worldwide. Gravid females of *S. epius* deposited eggs on the mealybug-infested pumpkins inside the different sized nylon cages with or without a bush/tree. *Spalgis epius* eggs were maintained on mealybug-infested pumpkins in the laboratory and developmental stages of the predator were reared. *Spalgis epius* with a lifecycle completed in 21.2 days. About 56 larvae could be reared on a single mealybug-infested pumpkin. Assessed daily prey consumption by different larval instars of *S. epius* reared on mealybug *Maconellicoccus hirsutus* in the laboratory. The 1st to 4th instar larvae of *S. epius* consumed, respectively, a mean of 181.3, 679.1, 1770.4 and 4333.0 eggs or 19.1, 67.7, 153.0 and 639.0 nymphs or 2.72, 6.26, 13.8 and 32.1 adults of *M. hirsutus*. When an *S. epius* larva was fed on *M. hirsutus* eggs, nymphs and adults separately, it consumed a mean of 6952.6 eggs, 878.8 nymphs or 53.9 adults during its entire development. A single larva of *S. epius* consumed 2358.3 eggs, 151.2 nymphs and 34.3 adults of *M. hirsutus* during its entire development when the prey stages were offered altogether. The study revealed that *S. epius* is a voracious predator of mealybugs and thus could be utilized as a potential biological control agent.

O19-9. Application of microbial cultures to sustain soil health and crop productivity under changing climatic conditions

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Sugarcane is long duration crop and it extracts large amount of nutrients from the soil. Generally, plant nutrients requirement is done through application chemical fertilizers. Due to non-judicious application chemical fertilizers soil physical, chemical and microbial properties adversely affected. Besides this, it also pollutes our environment. Keeping challenges in mind, we have isolated, characterized and identified diverse group of beneficial bacterial and fungi. These beneficial microbes molecularly identified and their nucleotide submitted to GenBank NCBI. Potential microbial culture screened in glass house and mini plot experiments. Due to significant results in glass house and mini plot experiments, the field experiment was carried out at research farm of ICAR-Indian Institute of Sugarcane Research, Lucknow. Different treatment combinations were made with recommended dose of fertilizers. Observations were recorded on germination percentage, tillering, plant physiological, plant growth and juice quality parameters. It was recorded that the application of microbial culture 25% doze of chemical fertilizers can be reduced while increasing 10 – 15% cane yield compared to the treatment. The increased sugar percentage was also recorded. The application of microbial culture is cost effective, sustainable and eco-friendly.

O19-10. Effects of plant growth promoting bacteria on the plant parasitic nematode *Meloidogyne javanica*

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Plant growth promoting (PGP) bacteria can colonise living plant tissues and maintain a mutualistic relationship with the host plant. There are many benefits involved with such relationships including increased plant growth and biocontrol against plant pathogens. Currently, there are various practices and strategies employed to manage plant parasitic nematodes (PPN) in crops but the application of nematicides still dominates. The use of such chemicals is now heavily regulated due to their hazardous effects on the environment, human health and lack of efficacy, while PPN can develop resistance. Therefore, demand for improved, alternative strategies is increasing. Exploiting the potential biocontrol properties of PGP bacteria in plants is a recent development. This presentation will highlight (1) the attraction of the plant parasitic nematode *Meloidogyne javanica* to PGP bacterial strains and their antibiotic component 2,4-DAPG and (2) the tritrophic interactions between beneficial bacterial strains, *M. javanica* and tomato plants, regarding plant growth promotion and nematode biocontrol. Nematodes were repelled by the antibiotic. Various bacterial treatments as well as that with 2,4-DAPG had positive effects on tomato plant growth even during nematode infection. At the same time, low levels of nematode infection were initially observed in plants (at 20 days post infection) but these increased with time (at 50 and 70 days post infection). An induced systemic resistance response was observed in plants treated with bacterial strain Pseudomonas L321. The potential of these bacterial agents as alternatives to *M. javanica* management will be discussed.

20. Integrated management of the cactus cochineal, *Dactylopius opuntiae* (Hemiptera: Dactylopiidae)

Organizers: Mustapha El Bouhssini & Rangaswamy Muniappan

Lead

O20-1. Conflict between cactus grown for food and biocontrol of invasive cactus in Africa

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The cactus *Opuntia ficus indica* (L.) Mill. (Cactaceae) is grown for food and fodder in Northern Africa and the Middle East. In Israel, it is called "Sabra" and is considered a part of the country's national identity. There are other cacti such as *Opuntia stricta* Haworth (Cactaceae) that are considered invasive and biological control programs have been instituted by introducing the cochineal insect *Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopidae). This introduced cochineal has invaded the areas of the cultivated cactus, *O. ficus indica* and is causing economic distress. To protect this cultivated cactus from *D. opuntiae*, Israel has imported a lady beetle, *Hyperaspis trifurcata* (Coleoptera: Coccinellidae) and released them in the fields. There is an urgent need for scientists involved in biological control of invasive cacti and scientists involved in biological control of the cochineal insect to communicate and address the needs of the affected countries to prevent counterproductive activities.

Invited

O20-2. First resistant cactus ecotypes to the wild Cochineal identified in Morocco

Mohamed Sbaghi[1], Rachid Bouharroud[1], Mustapha EL-Bouhssini [2] and Mohamed Boujghagh[1]

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Since its first detection in Doukkala region in 2014, the wild cochineal *Dactylopius opuntiae* has devastated large cactus plantations in several regions of Morocco, inflicting heavy economic losses for the whole value chain. As part of the control strategy of *D. opuntiae* set by the Ministry of Agriculture, Marine Fisheries, Rural Development and Water and Forest in Morocco, a joint team of scientists from the National Institute of Agricultural Research (INRA) and the International Center for Agricultural Research in the Dry Areas (ICARDA) screened 249 ecotypes of cactus for resistance to this pest. These genotypes are of different cactus species from the collection maintained at INRA, Morocco. The screening was carried out in the field under natural and artificial infestations. Eight ecotypes were found very resistant to the cochineal. These eight resistant ecotypes have been registered in the national cactus catalog under the names of *Marjana*, *Belara*, *Karama*, *Ghalia*, *Angad*, *Cherratia*, *Melk Zhar* and *Aakria.* Also, a timber park with these resistant ecotypes to *D. opuntiae* was established. The use of these resistant cactus ecotypes through Pillar II of the Green Morocco Plan would re-establish cactus plantations in places where the pest has wiped out this crop and contribute greatly to the overall control strategy of the cochineal.

O20-3. Biological control of the cactus cochineal *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) in Morocco

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The Opuntia cochineal *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) is a devastating pest causing heavy damage to cactus prickly pear (*Opuntia sp*). Since this pest was accidently introduced in Morocco only in 2014, the biocontrol agents associated with this pest were unknown. The research work undertaken in Morocco since 2016, which is part of a national emergency plan of the country, included host plant resistance, the biology of this pest in Moroccan conditions, biopesticides and biological control. The Australian ladybird beetle also named the mealybug destroyer *Cryptolaemus montrouzeiri* (Coleoptera: Coccinellidae), known as a voracious predator of mealybugs and scale insects, was the first tried for the control *D. opuntiae* in Morocco. In fact, it's predatory potential in field, semi-field and laboratory conditions was confirmed on this pest and safe period was more than 3 months. On the other hand, native predators were observed having significant and variable predatory potential on *D. opuntiae*. The species which have showed feeding habits on *D. opuntiae* were: *Hyperaspis campestris, Scymnus interruptus, Scymnus loewii, Nephus redtenbacheri, Scymnus guttulatus, Hippodamia convergens, Exochomus nigripennis, Chilocorus bipustulatus* and *Chilocorus politus*. The predatory potential of these species on *D. opuntiae* and their likely control strategy will be discussed.

O20-4. Field and Laboratory evaluations of different botanical insecticides for the control of *Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopiidae) on cactus pear in Morocco

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The prickly-pear cactus Opuntia ficus-indica L. is a very important crop in Morocco, used as source of food, animal feed and income for rural populations. However, currently the crop is suffering from the damage of the wild cochineal Dactylopius opuntiae. This study was conducted to evaluate the effectiveness of five botanicals extracts, two biopesticides and a detergent for controlling nymphs and females D. opuntiae. Under laboratory conditions, *the detergent black soap with different doses* reduced effectively the adult females *and the crawlers of D. opuntiae. The highest mortality (100%) among females and nymphs was obtained for the tested doses 60g, 100g and 150g/L, 48h after treatments. The contact toxicity of the* botanical extracts showed that the highest percentage mortality (100%) of nymphs was observed with Capsicum annuum at 10%, followed by both botanical extracts C. annuum at 5% and Urtica dioica at 10% with 92% mortality, respectively. Under field conditions, the mixture formulation of the black soap 60g /l with Capsicum annum at 200g /l, caused the highest percentage mortality of adult females (87.31%) seven days after spray, and 84.9% on nymphs three days after treatment. The results of these experiments also showed the high efficacy of the black soap at 60g/l, when it's used in double application over a three-day spray interval. This causes morality of 100% and 82.50% on nymphs and adult females, respectively. These findings showed that the use of black soap at 60g/l in double application or in mixture with Capsicum annum at 200g /l could be an excellent candidate to control the cochineal as a safe alternative for chemical insecticides.

O20-5. The implications of biological control of cochineal insects for the control of invasive alien cactaceae

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Some cochineal species (*Dactylopius* sp.) are considered both agricultural pests of cactus crops as well as beneficial agents for the biological control of invasive alien Cactaceae. Classical biocontrol of cochineal has thus far been limited to the release of the beetle *Cryptolaemus montrouzieri* (Coccinellidae) for the control of *Dactylopius opuntiae*, but recently other natural enemies are being considered. Many *Dactylopius* species are utilised to control invasive alien cactus species, which are known to have negative impacts on biodiversity, pasture production, and human and animal health. These *Dactylopius* species, including *D. ceylonicus, D. aurantiaca, D. opuntiae* and *D. tomentosus*, have successfully reduced invasions of several alien cactus species to the point that they are no longer problematic, with considerable benefits to livelihoods and biodiversity. Cochineal natural enemies that are being considered for release are not known to be host specific and as such will also feed on beneficial cochineal species utilised as biocontrol agents. This has potentially serious implications for invasive species management since physical and chemical control is costly and largely ineffective, especially for resource-poor communities. Without effective control many cactus species will proliferate around the world to the detriment of biodiversity and livelihoods. It is imperative that an amicable solution be found to resolve the issue of cochineal as a cactus pest and its use as an effective cactus biocontrol agent taking cognisance of the fact that an intervention that may benefit one sector may have considerable negative impacts on others, negating development prospects at a landscape level.

O20-6. Natural enemies of cactus cochineals and holistic pest management

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Opuntia cactus plants and carmine cochineal insects are considered useful and invasive natural resources, a singular biointeraction case arising even at the same time and place. The association of these cactus plants (mostly *Opuntia ficus-indica*) and the cochineal insects (scales of genus *Dactylopius*) is ecologically equilibrated in Mesoamerica (native area), but beyond this region, recurrently ends in catastrophic panoramas, as happened in Madagascar, Brazil, Ethiopia, and still is going on. Biological control through Integral Pest Management (IPM) seems to be the option to face this situation, and since there are no parasitoids known from *Dactylopius*, predators come to scene. There are several natural enemies in Mesoamerica controlling cochineals, but nevertheless is necessary to implement some studies to know their efficiency in non-native areas (attending also controversies), and even selecting biocontrol agents in base to the theory of new association. Holistic Pest Management (HPM) goes beyond Integral Pest Management (IPM) by integrating ideas, concepts, philosophies, and experiences; placing growers in central focus, instead the plagues (as occurs with IPM), allowing producers surpass their significative problems, and then they will have resources and interest to attend the causes and control of a given plague, getting competitive levels of profitability. Autonomous control of cochineals on *Opuntia* plantations with Good Agricultural Practice (GAP), currently allows in Mesoamerica to have this biointeraction below the economic threshold. The main request to fulfill this concept is having the plants as a formal cultivation, since in neglected plantations or naturalized plant populations it seems useless.

O20-7. The Cochineal (*Dactylopius coccus* Costa), a threat to cactus pear production in northern Ethiopia

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Cactus pear (*Opuntia ficus indica*) is an important source of income, food, livestock feed, seasonal employment, and serves as live fence in northern Ethiopia. With the intention of diversifying income and benefits, the cochineal insect (*Dactylopius coccus costa*) was introduced to Ethiopia in 2003. But soon after exporting of dried cochineal began in 2009, due to strong opposition from the local farming communities, the cochineal production and exporting was officially terminated in 2010. Nevertheless, the dried cochineal export business survived until to date through smuggling via Djibouti. On the other hand, the insect continued to multiply incessantly and severely destroyed more than 72000 hectares of private and communal cactus pear vegetation acutely affecting the livelihood of millions. Chemical insecticide sprayings and destruction of infested vegetation through cutting and burning/ burying failed to stop further spread and invasion. And the threat of invasion to the remaining and highly productive cactus pear areas in northern Tigray is alarmingly high. Unless, the situation is urgently reversed, there is a possibility that cactus pear production in Northern Ethiopia would become a history. Laboratory and field studies have identified two *O. stricta* and two *O. ficus indica* varieties completely resistant to the insect. The search for natural enemies has not yet been successful; so far two batches of *Cryptolaemus montrouzieri* from Israel and Netherlands were tested. There is a need to further test other potential natural enemies and study the factors contributing to the aggressive spread and multiplication of the insect in Ethiopia.

21. Molecular pathology and entomology

Organizers: Joerg Romeis and C P Srivastava

Invited

O21-1. Molecular and morphometric characterization of intraspecific variations within Indian populations of *Helicoverpa armigera* (Hübner)

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Helicoverpa armigera (Hübner) is a highly polyphagous pest that inflicts serious damage to a wide spectrum of crop plants in India. It also exhibits differential response to various selection pressures like insecticides, pheromones and parasitoids in different agro-climatic zones of the country. Thus, we conducted biometric studies on different geographic populations of *H. armigera*, along with their molecular characterization using mitochondrial cytochrome oxidase I (COX-1) gene and SSR markers. Populations differed significantly for most of the morphometric traits studied at immature and adult stages. Significant differences were also observed among the populations with respect to occurrence of larval body colour patterns, adult eye colour and wing colouration and spot patterns. Several polymorphic sites were observed in the COX-1 gene sequences of the studied populations, showing both transitional and transversional substitutions but divergence existing was not high enough to delineate them as separate species. The genetic similarity coefficient based on SSR markers widely varied within a range of 0.063 to 0.964 with lowest evident between Kanpur and Coimbatore populations. The cluster analysis of *H. armigera* populations based on morphometric traits and microsatellite markers showed similar pattern of population differentiation into two major clades. Inter-location breeding studies on different populations revealed that all crosses were fertile with maximum fecundity and per cent egg hatch recorded in the Ludhiana (Male) × Varanasi (Female) pairing. Differences based on biometric and genetic analysis in the present study clearly indicates the possibility of existence of subspecies within *H. armigera* populations of India.

O21-2. Multi-pathogen molecular interaction of bread wheat: miRNAome study

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The serious threat raised by fungal pathogens on bread wheat could keep the global food security in danger. Plant micro RNAs (miRNAs) are well known for their vital role in growth, development and stress responses through post-transcriptional gene silencing mechanism. miRNAs are class of endogenous small non-coding RNAs which are 18-24nt in length. A vast number of miRNAs have been identified to be induced upon fungal infection. Most of them are contributed for re-programing of host defence response. Our study focuses on identification and differential expression of novel and conserved miRNAs in resistant and susceptible hosts of wheat that contributes to defence responses upon multiple fungal diseases. To elucidate the common miRNA mediated gene regulatory pathways of wheat acting upon biotrophic and hemibiotrophic fungal infection, we have identified miRNAs and their target genes for Powdery mildew, leaf rust and blast infected samples. Though we could find several miRNAs expressed common to multiple hosts, their targets and regulatory pathways significantly differs. To our surprise, we could find that batches of miRNAs from

different miRNA families found to regulate single gene hosts which is like the trend of co-functional miRNAs in animals. Moreover, we have also identified the comparative miRNAome of resistant and susceptible hosts of wheat upon multiple rust infection. This study provided valuable information on miRNA mediated gene regulation in wheat-fungal interaction, which could be useful in disease management.

O21-3. Identification of odorant response (o) genes in entomopathogenic nematode *Heterorhabditis bacteriophora*

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Entomopathogenic nematodes (EPNs) are widely used bio-control agents for insect-pest of crops. They exhibit a complex host-seeking behavior, and use universal host cue CO2, as well as host- and insect-damaged plant-derived odorants to locate their hosts. The odorant response (odr) genes, expressed in the olfactory epithelium are expected to play an important role in insect-host recognition. However, no information on the odr genes is available for the EPNs. Here we investigated odr genes in the EPN *Heterorhabditis bacteriophora*. Seven odr genes could be identified by in-silico analysis in *H. bacteriophora* out of which six were successfully amplified and cloned. Four genes (Hb-odr-2, Hb-odr-3, Hb-odr-4 and Hb-odr-10) could be validated by re-sequencing. Further bioinformatic analysis confirmed presence of various protein domains respective to *C. elegans* odr orthologs. The phylogenetic analysis of these genes revealed that Hb-odr genes have evolved according to their taxonomic clades. The developmental stage-specific expression profile showed that odr-2, odr-3 and odr-10 were highly up regulated at the IJ stage, whereas odr-10 was significantly up regulated in J4 and adult stages as well. Kinetic expression profile of the odr genes showed significant down regulation at 60 m after exposure to Galleria hemolymph. Only odr-3 was found as up regulated at earlier time points as well. The in-situ expression analysis showed that odr-2 and odr-3 genes express at nerve ring and anterior esophageal region of the IJs, respectively. To the best of our knowledge, this study is the first comprehensive investigation of odorant response genes in EPNs.

O21-4. Identifying novel target genes in burrowing nematode (*Radopholus similis* Thorne) –a transcriptome-based approach

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Burrowing nematode (*Radopholus similis*) is a migratory endo-parasite causing yield loss in >350 agricultural and horticultural crops. In place of toxic nematicides, still being the best option for nematode control, we need novel and more specific control measures that are safe to the environment and human health. Prediction and functional annotation of the *R. similis* transcriptome using several bioinformatics tools revealed the presence of ~1118 excretory/secretory proteins. Among them, nine genes which showed homology to other plant pathogens but had no similarity to free living organisms were cloned and characterized through intensive data mining. Inter-Pro-Scan analysis indicated the presence of key functional domains and conserved motifs which suggest their role in parasitism and survival. They are abhydrolase domain-containing protein (Rs-AB), immunodominant hypodermal antigen Ac16 (Rs-Ac16), astacin-like metalloendopeptidase (Rs-AsLM), carbonate dehydratase, eukaryotic-type (Rs-CDh), EGF-like domain protein (Rs-ElDP), vacuolar protein sorting-associated protein 45 (Rs-VpSA), Glycoside hydrolase, superfamily domain-containing protein (Rs-GH), pectate lyase (Rs-PL) and reticulocalbin-2 (Rs-ReCa2). Structural motif characterization and phylogentic analysis with corresponding genes in other nematodes indicate the structural diversity of the conserved motifs present in these proteins. These genes are reported for

the first time in *R. similis* and Rs-AB, Rs-AsLM, Rs-CDh, Rs-ElDP, Rs-VpSA, Rs-GH and Rs-ReCa2 for the first time from any plant parasitic nematode.

O21-5. Identification of differentially expressed miRNAs between Bollgard II- resistant and susceptible strains of *Pectinophora gossypiella*

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The pink bollworm, *Pectinophora gossypiella* (Saunders) (PBW), has developed a strong resistance to the transgenic Bt cotton expressing Cry1Ac and Cry2Ab (Bollgard II), the most widely commercialized Cry toxins for Bt cotton worldwide. It is important to understand the mechanism of resistance for management of Pink bollworm, but information on the post-transcriptional regulation of Bt resistance in this target insect is limited. In the present study, total RNA was extracted from the PBW midgut tissue of Bt susceptible (PBW-BtS) and Bollgard II resistant (PBW-BtR) strains and three biological replicates of each strain were sequenced using Illumina small RNA sequencing technology. A total of 16,799,0497 high-quality clean reads were obtained from the six PBW libraries. The number of identified known miRNAs were 59, 59 and 71 for PBW-BtS and 74, 67 and 66 for PBW-BtR. Using miRDeep2 software, we identified 8,15 and 13 novel miRNAs for PBW-BtS and 12,13,12 miRNAs for PBW-BtR. Among them, 30 known and 8 novel miRNAs were identified as differentially expressed between PBW-BtS and PBW-BtR using edgeR software. Different miRNAs were found to targets putative Bt receptor genes such as Cadherin, Aminopeptodase and ABC transporters. KEGG enrichment analysis revealed ABC transporters pathway and glycosylphosphatidylinositol-anchor biosynthetic process as most enriched pathways in PBW-BtR in comparison to PBW-BtS.

O21-6. Molecular diagnostics of the bacterial blotch pathogens of button mushrooms

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Mushroom cultivation in Europe is severely affected by bacterial blotch outbreaks. *Pseudomonas gingeri* and *P. tolaasii* are the most prevalent causative agents, among others. Once the pathogens are introduced in the farm, mesophilic growing conditions result in widespread secondary infections. Hence, efficient and timely detection of the blotch pathogens is essential. Knowledge on pathogen population dynamics is also critical for the development of disease indicators and localized control strategies. In this study, blotch pathogens were isolated from mushroom farms in Netherlands, Belgium and United Kingdom. The whole genomes from 108 pathogenic and non-pathogenic isolates were sequenced to explore the genetic diversity in Western Europe. Phylogenetic characterization allowed identification of unknown blotch pathogens via MLSA, ANI and in-silico DDH. Triplex real-time Taqman-PCR assays were developed against three bacterial blotch pathogens, *P. gingeri*, *P. tolaasii* and an unknown *Pseudomonas*. An extraction control, *Xanthomonas campestris*, accounted for DNA loss. The assays also quantified the total Pseudomonad population in the sample. The ratio of pathogenic to beneficial *Pseudomonas* is speculated to be an indicator for blotch outbreaks. For each pathogen, two assays were developed on different loci, for primary detection and a secondary verification of the results. The assays are highly specific and sensitive. They tested negative against 126 related Pseudomonas strains, other plant pathogenic bacteria and antagonists. Their limits of detection are 10^1 copies

in gblocks, 10^3 cfu/mL in water and 10^4 cfu/g in soil samples. Supplemented with metadata on disease indicators, these assays have the potential to be developed as warning systems.

O21-7. A root-induced, small, secreted, cysteine-rich effector-like protein from *Trichoderma virens*

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Trichoderma virens forms intimate symbiosis-like relationship with roots, an interaction being beneficial for both plant and the fungus. *Trichoderma virens* secretes a plethora of proteins while interacting with roots, some are known to be involved in induction of resistance response against plant pathogens, while a few may be involved in repression of defence at initial stage for facilitating root colonization (Mendoza-Mendoza et al. 2018). We have expressed a small, secreted, cysteine-rich protein (SSCP) that is induced in the presence of maize roots (Lamdan et al. 2015), *in E. coli* and assessed the effect of this protein in plant defence using a maize- *Cochliobolus heterostrophus* system developed in our lab. Application of this protein to maize (Co 6) roots followed by inoculation of leaves with the pathogen resulted in bigger lesion size than mock control. It therefore appears that *T. virens* deploys this protein for suppression of plant defence during penetration of roots.

O21-8. A PCR based technique for molecular detection of white-tip nematode (*Aphelenchoides besseyi* Christie, 1942) infection in rice seeds

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Aphelenchoides besseyi Christie, 1942 is a seed-borne ectoparasitic nematode that causes the 'white-tip' disease of rice. This nematode is of quarantine significance and finds place in regulatory pest lists of several countries. Currently, the most practical and effective management strategy available for this nematode is early detection and disinfestations of seed material. In conventional method, presence of this nematode in seeds can be detected by soaking the seeds in water for reviving the nematodes from the anhydrobiotic state and observing the water under stereo microscope. Microscopic examination and accurate identification of extracted nematodes based on morphological features requires a trained specialist and nematodes may often escape detection when they are low in numbers. Therefore, attempts were made to develop a PCR-based diagnostic assay for rapid and accurate detection of white-tip nematode *Aphelenchoides besseyi* infection in rice seeds. This method employs nematode specific primers AbF2 and AbR2 that amplify a 180-bp fragment of ribosomal DNA of the nematode. These primers were found to be highly species specific in in silico analyses. Further, these primers did not amplify DNA from other plant parasitic nematodes infecting rice in the laboratory tests. The PCR assay was found to be sensitive, detecting the presence of nematode in seeds even with a low nematode load of five to ten nematodes per seed.

O21-9. Development of rolling circle amplification actuated loop mediated isothermal amplification (rca-lamp): a new tool for rapid and ultra sensitive diagnosis of cotton leaf curl viral disease

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Cotton leaf curl disease ranks top among all endemic diseases transmitted by Whitefly (*Bemicia tabaci*) causes severe economic losses to the cotton growers of Indian subcontinent. For its effective management, robust tools for detection are a prerequisite and it is important to diagnose the virus titre in early stage of infection and in the disease transmitting vector. Considering the limitations in current PCR-based techniques we have standardized the protocol for the diagnosis of Cotton leaf curl virus (CLCuV) from leaves and in its transmitting vector whitefly by using Loop Mediated Isothermal Amplification (LAMP) in a rapid, sensitive and specific manner. In fact, this is the first report of use of LAMP tool for rapid diagnosis of CLCuV in cotton and its transmitting vector Whitefly. Further, the colorimetric detection for diagnostic simplicity of amplified LAMP product by using different dye lead to enhanced applicability of this technique in the field of diagnostics. Failure to detect the virus titre in the infected leaf by PCR and LAMP may be due to low concentration of the virus which is insufficient for amplification using PCR and LAMP. Through the combination RCA with LAMP, the amplification efficiency and the detection sensitivity has been improved. This confirms that RCA-PCR and RCA-LAMP can be an option for ultra sensitive detection of Cotton leaf curl virus where the virus titre is very low. This advance diagnostic protocol can be effectively utilized in laboratory research of quarantine matters and field diagnosis of CLCuV, an important viral pathogen of cotton.

O21-10. Searching root of Indian population of *Tuta absoluta* (Meyrick) with coi gene sequence based meta-geographic study

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Tuta absoluta (Lepidoptera: Gelechiidae) is an insect pest and causes economic damage to solanaceous crops. It is thought to be native of Central America and limited to South America before first report from Spain during 2007. Since 2007, this pest has been reported from many countries of Africa, Europe and Asia. In India, invasion of *T. absoluta* was first reported from Maharashtra during 2014 and presently it has been reported from almost every state of India. *T. absoluta* is an alien species invaded India in recent past, knowledge on its source/origin is now imperative for the future bio-security measures and management. In this study, meta-geographic population genetics of *T. absoluta* based on 259 (5'-3' region) and 36 (3'- 5' region) COI gene sequences of 11 and 15 countries distributed in 5 and 3 continents, respectively were collected from GenBank. Out of 259 COI gene sequences, 255 COI gene sequences from 11 countries including India were found 100 percent similar forming predominant haplotype H1 with 6 haplotypes in whole dataset. Analysis of 36 COI gene sequences (563 bp) formed 7 haplotypes in which predominant haplotype formed from the sequences of *T. absoluta* from South America, Europe and Africa suggesting its entry into Europe from South America during 2007 or even before the actual date of detection and further expanded throughout Europe and African. Indian population of *T. absoluta* was genetically like the European and African populations, suggesting that the same population invaded Europe, Africa, and India in the past.

O21-11. Population genetic studies of pink bollworm *Pectinophora gossypiella* (Saunders) using mitochondrial cytochrome C oxidase I (COI) gene

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Commercialization of genetically modified insect resistance cotton in India brought bollworm complex under control successfully for more than a decade. However, success of Bt Cotton was under threat due to resistance development by pink bollworm, *Pectinophora gossypiella* to Bollgard II cotton expressing dual toxin Cry1Ac + Cry2Ab in 2018 in several cotton growing regions of India. To know level of susceptibility to changing environmental conditions studies on population genetic structure, distribution and genetic diversity in pink bollworm are crucial. The present study was carried out in 16 different cotton growing regions of India using partial mitochondrial *Cytochrome C Oxidase I (COI)* gene. The average haplotype diversity (Hd), nucleotide diversity (π) were 0.628 and 0.0017 respectively which exhibited low genetic variation among the populations. Zone wise data reveal that diversity values were very low in central India than South and North India. Haplotype network constructed using median-joining method showed a total of 13 haplotypes formed among which Hap2 is most predominant and widely distributed among all locations. Negative Tajima's D value indicates excess of low frequency polymorphism among the populations. Low genetic variation in the pink bollworm populations in India despite of geographical differentiation suggested selection pressure of BGII lead to genetic bottleneck.

O21-12. Silencing of JHEH gene through RNAi in *Spodoptera litura* (Noctuidae: Lepidoptetra) and their effect on larval growth and development

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Juvenile hormone epoxide hydrolase (JHEH) is a key enzyme in degradation pathways of JH in insects. It converts JH to JH diol and hydrolyses JH acid to JH acid diol thus its titer regulates the entire process of insect development. RNA interference (RNAi) is a potential tool for pest control. In this study, silencing of the JHEH through dsRNA ingestion was conducted during the larval stage of *Spodoptera litura*, an economically important polyphagous pest. Here, we have cloned a partial Sljheh cDNA (412 kb) from *S. litura* and synthesized dsRNA in vitro. Feeding bioassay was conducted with Sljheh dsRNA through diet overlay method. Bioassay result showed that 27.8% and 6.6% of mortality in 1st and 4th instar larvae respectively. However, larval duration was significantly increased in fourth instar larvae followed by a significant number of them became malformed during larval pupal inter molt. We have further assessed expression of slJHEH gene at three time point (viz. 24, 48, and 72 h) which coincided with the moulting process and dsRNA ingestion actively down regulated mRNA level by a factor of 0.3, 0.21 and 0.5 respectively in 4th instar larvae. dsRNA treatment inhibited slJHEH gene transcription without affecting expression of actin as assessed by quantitative real-time PCR. In addition, it has been observed that gene silencing was directly influenced by the concentration of dsRNA and requires higher concentration for greater success. Thus, slJHEH gene offers a potential insecticide target for sprayed or plant mediated RNAi for damaging pest like *S. litura*.

O21-13. Multilocus gene characterization of 'candidatus *Phytoplasma australasia'* (16sr ii-d) related strain associated with peanut witches' broom disease in India

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Peanut (*Arachis hypogaea*) belonging to the family fabaceae, is a leguminous oilseed crop predominantly cultivated for vegetable oils in India. Symptoms of severe witches' broom were observed on peanut Kadiri region of Andhra Pradesh in India, during Kharif 2018-19. There was 2-3% incidence of peanut witches' broom (PnWB) disease in different fields. The association of phytoplasma with PnWB disease samples were confirmed by amplifying of ~1.8kb and ~1.25kb DNA products of 16S rRNA gene using nested polymerase chain reaction with phytoplasma specific primers, P1/P7 and R16F2n/R16R2 respectively. Further amplification of DNA associated with PnWB was also confirmed with phytoplasma specific primers for secA, tuf, and SAP11 genes. Sequence analysis of the amplified products of 16SrRNA, secA, tuf and SAP11 genes of PnWB phytoplasma strain through pairwise sequence comparison and phylogenetic analysis revealed the association of 16SrII-D with PnWB isolates. In silico RFLP analysis of ~1.25 kb product of 16SrDNA gene sequence of PnWB phytoplasma strain using iPhyClassifier online tool further classified PnWB isolates into 16SrII-D subgroup. *Parthenium hysterophorus* and *Cleome viscosa* plants with witches' broom and little leaf symptoms collected from the same peanut fields were also, identified to be associated with similar strains of phytoplasma (16SrII-D) as with PnWB. This is the first report of the association of 16SrII-D subgroup with PnWB disease in India.

O21-14. The relationship between genome size, morphological parameters and diet breadth in insect species

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Genome size estimation is the first step involved in the complete genome sequencing project. Knowledge on genome size is also useful in research work related to genetics, molecular biology, and systematics. Though there are many methods of genome estimation, the Propidium Iodide (PI) based flow cytometry is simple and gives an accurate estimation. In the present investigation, the diploid genome size of four insect species viz., cotton leafhopper, *Amrasca biguttula biguttula* (392.47 Mb) (Cicadellidae: Hemiptera), bean pod borer, *Maruca vitrata* (1489.63 Mb) (Crambidae: Lepidoptera), tomato pinworm, *Tuta absoluta* (1128.61Mb) (Gelechiidae: Lepidoptera) and eggplant shoot and fruit borer, *Leucinodes orbonalis* (944.52Mb) (Crambidae: Lepidoptera) were estimated using Chicken RBC (2.33pg) as a reference standard. The relationship of genome size with the insect morphological traits and host plant range showed no evident correlation between them. Hence, the main mechanisms contributing to genome size variations are polyploidy and accumulation of DNA sequence repeats rather than the insects' morphological features or host plant range. The causes of expansion and shrinkage of genome size will require a closer look on their genetic make-up that includes the number and length of repeats comprising transposons and microsatellites and the size of introns between the coding regions.

22. Conventional and omic approaches to integrate host plant resistance in IPM

Organizers: Thomas E Hunt and Joe Louis

Lead

O22-1. Sorghum resistance mechanisms to sugarcane aphid

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Sorghum is one the world's most important monocot crops grown for food, feed, and/or fuel. Simultaneously, sorghum is highly susceptible to insect pests that cause dramatic decreases in yields. Even though there is extensive natural variation for resistance against insect pests in sorghum, much of it remains undiscovered and under-utilized. The underlying mechanisms of sorghum resistance or susceptibility and novel sources of resistance to sugarcane aphids will be discussed.

Invited

O22-2. Molecular mechanism of plant resistance to gall-midge pests

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Gall midges manipulate host plants extensively by inducing the formation of galls or converting a whole plant into a gall. Plant manipulation is achieved by secreting a large number of effector proteins into host cells from gall midges. As high as 10% genes in a gall midge genome are predicted encoding effector proteins. By molecular and cytological analyses, we found that the critical process to determine whether a plant becomes resistant or susceptible to gall midge attack is determined by its ability to prevent gall midge effectors from entry into plant cells. Rapid strengthening of cell wall and instant hypersensitive reaction are critical to prevent insect effector from entry and spread into host tissues.

O22-3. Identification of effector proteins from generalist herbivore, *Spodoptera litura* and finding their targets in plants

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The common cutworm, *Spodoptera litura* is a leaf and fruit feeding generalist insect pest of the order Lepidoptera and among the most destructive pests in agriculture. Plant defense mechanisms against this prolific feeder are not well understood. The identity of insect elicitors that activate defense and effectors released by *S. litura* to modulate/attenuate defenses is largely unknown. The current study aims to identify genes encoding effector proteins in salivary glands of *S. litura* by bioinformatics based analysis. Head and salivary glands of *S. litura* were used for de-novo transcriptome analysis and effector prediction. 1328 proteins from the head and 641 from salivary gland were identified as secretory proteins. Out of which, 808

from the head and 267 from salivary gland proteins were predicted to be potential effector proteins, and some of their orthologues play important roles in plant-pathogen interactions. This study provides the first insight of potential effectors from *S. litura* salivary glands, which might be crucial in broad host specificity of the herbivore.

O22-4. Tolerant plants: sustainable tools in pest insect management

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Tolerance is a genetic trait of the plant that makes it capable of overcoming an arthropod infestation as well as recovering after tissue destruction in relation to a susceptible plant. Unlike antibiosis and antixenosis, tolerance is an adaptive response of the plant and involves several plant compensation factors. Since it does not affect arthropod biology or behavior, the tolerant plant is interesting for IPM programs, especially where biological control agents are used due to the lower use of insecticides. In addition, tolerant genotypes increase the level of economic damage, thus reducing the number of pesticide applications in the fields and exerting less selection pressure on the pest. Since tolerance offers a moderate level of resistance (polygenic), this category is more durable than antibiotic or antixenosis (monogenic), which, although promoting high level of resistance, becomes inefficient with the emergence of new biotypes. Brazilian and American soybean genotypes have been identified as tolerant in studies involving sucking insects. IAC-100 and IAC-782318 showed high levels of tolerance to the soybean stink bug complex (*Euschistus heros*, *Piezidorus guildinii* and *Nezara viridula*) in Brazil. In addition, American soybean KS-4202, known to be tolerant to *Aphis glycines*, also expressed this trait when infested by the silverleaf whitefly *Bemisia tabaci* biotype B in Brazil.

O22-5. Areawide suppression effect of Bt maize, enhanced by biological control for European corn borer in the U.S.: The benefits continue

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Genetically engineered (GE) crops expressing insecticidal proteins from *Bacillus thuringiensis* (Bt) for insect control have experienced high adoption rates in both industrial and developing countries, with ~470M acres planted globally in 2017 by >17M farmers (ISAAA, 2018). Despite the success with increased yields and reduced pesticide use, at least 15 insect species have evolved resistance to one or more Bt proteins. The resistance challenge has generated renewed interest in revisiting how GE crops should best be incorporated into Integrated Pest Management (IPM) programs. Parallel to the evolution of resistance, the IPM concept is being re-defined by several researchers to allow for an increased emphasis on a risk-based framework to support reduced economic volatility, an increased awareness of the role of farmer communication networks, and at the same time promote ecosystem services and environmental sustainability. In this presentation, the Bt maize, European corn borer (ECB, *Ostrinia nubilalis*) system will be discussed with regard to on-going success in the central and eastern U.S. corn production areas. The compatibility of Bt maize (conferring antibiosis), along with conventional host plant resistance (tolerance via stalk strength), coupled with naturally occurring biological control, continue to contribute to the long-term sustainability of the Bt-maize IPM system. Data for the microsporidium, *Nosema pyrausta*, and a generalist predator, *Orius insidiosus* will be reviewed. Cultural practices such maintaining non-Bt refuge acres for Bt resistance management (including

economic incentives), will also be discussed as components of IPM that have likely contributed to the long-term success of Bt maize for *O. nubilalis.*

O22-6. Host plant-aphid interactions: It's about host resistance and aphid virulence.

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Diuraphis noxia (Kurdjumov), a specialist cereal aphid afflicting wheat and barley yield in dry-land production regions. Unlike in areas where *D. noxia* is endemic and can reproduce through facultative parthenogenesis, in areas where it is invasive, it reproduces only asexually. Despite the lack of sexual recombination, new *D. noxia* biotypes with varying levels of virulence continue to develop and overcome previously resistant host plants, posing multiple threats to global food security. Host plant resistance, the most environmentally sound measure of pest resistance is defined by the response to aphid feeding (i.e., antibiosis, antixenosis or tolerance), with most *Dn* genes following the gene-for-gene relationship. With the availability of the draft genome of *D. noxia* and confounding evidence of genomic plasticity, we set out to determine the extent of DNA methylation in the genome of *D. noxia* in order to determine if epigenetic regulation contributes to changes in virulence. To this end, the global levels of methylation as well as the methylation profiles of the different biotypes were investigated. The global and specific methylation results suggest an inversely proportional relationship between virulence levels and DNA methylation, and that methylation may be associated with increased virulence. Also, bacteria associated with the aphid may be a contributing factor. This study, being the first of its kind for *D. noxia*, has provided the groundwork for future research into methylation of this insect, and adds to a growing body of knowledge on hemipterans.

O22-7. RNA interference and artificial miRNA based Strategies for engineering insect resistance in tomato (*Solanumlycopersicum*)

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Tomato yield is significantly affected by a notorious insect pest, *Helicoverpa armigera* and conventional approaches, including the use of agro-chemicals, breeding methods and Bt technology to prevent crop damage have met with certain limitations. Recently, RNA interference (RNAi) have gained relevance for crop protection against pests. We have been exploring RNAi-based strategies for engineering tomato for resistance against *H. armigera*. RNAi approach is essentially involves the expression of dsRNA in transgenic plants to silence a vital gene of the target pest for resistance. In this study, we have targeted a vital chitinase (*CHI*) gene of *H. armigera* for insect resistance. The developed RNAi lines of tomato expressing dsRNA of *H. armigera CHI* gene were used for insect bioassays on tomato leaves and fruits, and such lines have exhibited insect resistance. In addition, we are also using the artificial miRNA (amiRNA) technology to develop tomato resistant to *H. armigera* by knocking down the ecdysone receptor (*EcR*) gene of the pest, which plays a pivotal role during insect growth and metamorphogenesis. The feeding bioassays with *E. coli* expressing amiRNA-*HaEcR* showed decreased target gene transcripts and also affected the insect growth and reproduction when compared to controls. Also, the amiRNA-*HaEcR* construct was used for tomato transformation by *Agrobacterium tumefaciens,* and the confirmed amiRNA tomato transgenic lines showed the expression of the intended amiRNA and resistance against *H. armigera*. These studies suggest that RNAi and amiRNA strategies can be effectively used to target insect pest genes for developing pest resistant transgenic crop plants.

O22-8. Using sweet corn sentinel plots to monitor pest resistance to Bt corn traits

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A network of sweet corn sentinel plots was started in 2017 to provide an in-field diagnostic screen to detect early shifts in lepidopteran pest susceptibility to Bt toxins. In 2019, the network expanded to 32 sites in 16 states and four Canadian provinces. Each site consisted of plots of Bt and non-Bt sweet corn planted side-by-side, so that the attractive silking period coincided with the highest level of moth activity. Plots included: Attribute 'BC0805' expressing Cry1Ab, Attribute II 'Remedy' expressing Cry1Ab and Vip3Aa, and their non-Bt isoline 'Providence' (Syngenta US); and Performance Series 'Obsession II' expressing Cry1A.105+Cry2Ab2, and its non-Bt isoline 'Obsession I' (Seminis). Ears were examined at fresh market maturity to record the live instar stage, amount of kernel area consumed, and location of damage by species. For *H. zea*, the percentage of 4th, 5th and 6th instars was computed. Results support previous findings that *H. zea* populations have developed field-evolved resistance to Cry1Ab and pyramided Cry1A.105+Cry2Ab2 toxins. Results provide evidence of increasing resistance to these toxins during the past three years, and unexpected injury in Vip3Aa sweet corn starting in 2018. The sweet corn sentinel approach may be a more efficient and less variable method to monitor resistance by measuring relative changes in control efficacy between isogenic pairs of non-Bt and Bt plots. The side-by-side planting lowers the risk of 'false positives' compared to sampling for unexpected injury in Bt-only fields, and sentinel plots would not be subject to intervening management strategies should an action threshold be reached.

O22-9. Soybean tolerance to the soybean aphid, *Aphis glycines*

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Soybean aphid (*Aphis glycines* Matsumura) is arguably the most important insect pest of soybean [*Glycine max* (L.) Merr.] in the United States. Plant resistance offers effective, economical, and sustainable management of soybean aphid. Tolerance to the soybean aphid has been identified in the soybean KS4202, and although the resistance mechanisms are not fully understood, evidence suggests that enhanced detoxification of reactive oxygen species (ROS) is an active system under high aphid infestation. We will present the path to confirming tolerance in KS4202, the work elucidated the underlying mechanisms of tolerance, ways to assist breeding soybean with these traits, and possible options for deployment and use of soybean tolerance to soybean aphid.

O22-10. Involvement of lncRNAs in mediating canola resistance to clubroot disease

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Clubroot disease, caused by the fungus-like protist *Plasmodiophora brassicae*, is a threat to Brassica crop production world-wide including canola (*Brassica napus* L.) production in Canada. Yield loss due to this disease can be up to 100%. Canola cultivars resistant to clubroot are available; however, evolution of new pathotypes of this pathogen necessitates continued research on the canola-clubroot pathosystem to extend our knowledge on molecular basis of the resistance and for identification of the candidate genes controlling this resistance. Canola lines carrying clubroot resistance, introgressed from rutabaga (*Brassica napus var. napobrassica*), have been developed by the University of Alberta's canola breeding program, and the resistance genes has been mapped on chromosome A08. We have identified several long non-coding RNAs (lncRNAs) that are differentially expressed in the resistant and susceptible lines in response to challenge by this pathogen using the strand-specific lncRNA-Seq approach. Some of the lncRNAs as well as their target genes are located on chromosome A08. Further research is underway in our laboratories to delineate the role of lncRNAs in mediating resistance to clubroot disease. Our investigations will offer additional clues regarding the molecular mechanisms underlying resistance to *P. brassicae* and may result in the development of novel strategies to protect canola from clubroot.

23. Breeding for disease/pest resistance (HPR 1)

Organizers: P M Gaur and N Gangarao

Lead

O23-1. Breeding for resistance to diseases and insect pests in grain legumes

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Grain legumes are source of high-quality food and feed and their integration in the cropping systems provide multiple benefits for agriculture sustainability. They are being considered important to ensure food and nutritional security in the face of climate change. Diseases and insect pests are the main constraints in the quantity and quality of yield. This presentation focuses on chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* L.), which are mandate crops of ICRISAT and globally grown on 21.6 million ha, largely in the developing countries of Asia and Africa. The production and productivity of chickpea is severely constrained by diseases such as Fusarium wilt (FW, *Fusarium oxysporum* f sp *ciceris*), dry root rot (DRR, *Rhizoctonia bataticola*), Ascochyta blight (AB, *Ascochyta rabiei*) and Botrytis gray mold (BGM, *Botrytis cinerea*). In pigeonpea, Fusarium wilt (FW, *Fusarium udum*) and sterility mosaic disease (SMD) caused by pigeonpea sterility mosaic virus (PPSMV) are the most important diseases, while Phytophthora blight (PB, *Phytophthora cajani*) is an emerging important disease. Pod borer [*Helicoverpa armigera* (Hubner)] is the most important insect-pest of both the legumes. In addition, spotted pod borer [(*Maruca vitrata* (Geyer)] is also important in pigeonpea. Several varieties with high resistance to FW and AB have been developed in chickpea and FW and SMD in pigeonpea. Only moderate level of resistance is available for resistance to the remaining diseases and pod borers in the germplasm of cultivated species. Comparatively, higher levels of resistance have been observed for some of these diseases and pod borers in wild species and are being exploited in breeding programs. Transgenic resistance using insecticidal genes has been developed to achieve high level of resistance to pod borer in both the legumes. Numerous genes/quantitative trait loci (QTL) conferring resistance to key diseases have been mapped and markers linked to some of these have been validated. Use of novel sources of resistance and novel breeding techniques (marker-assisted selection, speed breeding) are being used to accelerate development of improved varieties with enhanced resistance to diseases and insect pests. Availability of such varieties will improve yield stability and production of these grain legumes and contribute to food and nutritional security and sustainable food production.

O23-2. Utilizing crop wild relatives (CWR) for improving biotic stress tolerance in ICRISAT mandate crops

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Biotic stresses such as diseases and insect-pests cause huge yield losses to most of the crops worldwide. Under changing climatic conditions, new insect-pests and diseases are emerging as serious threats to crop production and productivity. High levels of resistance for these stresses is not available in cultivated genepool, which necessitates the exploitation of new and diverse sources of variations. Crop Wild Relatives (CWR) possess many useful and novel genes including high levels

of resistance for biotic stresses, and can be utilized for creating new variability for further use in breeding programs. Though large number of wild species are conserved in genebanks, their frequent utilization in breeding programs is limited due to various cross-incompatibility barriers and linkage drag. To enhance utilization of CWR for cultivar improvement, pre-breeding provides a unique opportunity to the breeders through the creation of new genepool having high frequency of useful genes/alleles introgressed from CWR and with acceptable agronomic background. Pre-breeding populations have been developed using CWR as donors and popular cultivars as recipients for improving and diversifying resistance/tolerance to major diseases (botrytis grey mold, ascochyta blight and dry root rot in chickpea, phytophthora blight in pigeonpea, early- and late-leaf spots and stem rot in groundnut and blast in pearl millet) and insect-pests (pod borer and pod fly in pigeonpea and *Spodoptera* in groundnut) in ICRISAT mandate crops. Promising introgression lines with improved resistance/tolerance for these stresses have been identified and are being shared with breeders to develop improved cultivars with a broad genetic base.

O23-3. Wild jute, *Corchorus aestuans* accession wcin-179: A unique source of resistance against hairy caterpillar, *Spilosoma obliqua* Walker

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Jute (*Corchorus olitorius* and *C. capsularis*) is one of the important best fibre crops, especially in India and Bangladesh. The lignocellulosic fibre derived from plant has diverse industrial uses besides it's a greener crop being an efficient CO_2 sequester. More than 30 species of insects and mites infest jute crop which cause yield loss up to 31-34%. Host plant resistance (HPR) has special significance for jute as the growers have a marginal approach towards HPR- centric integrated pest management (IPM) is the best solution for emerging insect pest problem in jute. Source of resistance against hairy caterpillar, *Spilosoma obliqua* and its mechanism in cultivated and wild jute species have been determined. The wild accession (*C. aestuans*, WCIN 179) is resistant as evidenced through a significant adverse effect on pest biology with prolonged larval duration, less larval weight, decreased larval survival, pupal weight, pupation and adult emergence. The accession has higher phenol, reduced sugar and protein etc. The adult insect has 71% and 52% less preference for oviposition and feeding preference respectively. GC- EAD study of VOCs substantiated by conferring the presence of benzene-1 ethyl-3 methyl, dodecane and tridecane conferring possible deterrence for oviposition and feeding. The uniqueness and novelty of *C. aestuans* (WCIN-179) by unique biochemical and VOC profile made resistant against *S. obliqua*. As *C. aestuans* is crossable with the cultivated species, *C. olitorius* it is quite practical that this accession can further be used for insect resistance breeding program in tossa jute.

O23-4. Identification of sources of resistance in castor parental lines to leafhopper (*Empoasca flavescens*)

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Castor (*Ricinus communis* L.) is an important industrial oilseed crop. It is mainly grown in the tropical and sub-tropical climate of India, China and Brazil. Leafhopper, *Empoasca flavescens* F. (Cicadellidae: Homoptera) is an important sucking pest of castor in India and can cause 20-80% yield loss during both kharif and rabi seasons. The development of high yielding castor hybrids resistant to leafhopper requires

information on the reaction of parental lines of castor against leafhopper. The present study was undertaken to screen the parental lines of castor for resistance to leafhopper. Field experiments were conducted during rabi 2017-18 and 2018-19 to screen 107 parental lines against leafhopper using infester row technique. Among the parental lines screened, 28 lines were found highly resistant to leafhopper and did not exhibit any hopper burn (Hopper burn grade 0 on 0-4 scale). Six selected promising parental lines (ICS-186, ICS-190, ICS-200, ICS-210, ICS-216 and ICS-217) were further screened during rabi 2018-19 at four locations (Palem, Yethapur, SK Nagar and Hyderabad). The line, ICS-200 with low leafhopper infestation (6.4 to 10.8 leafhoppers/3 leaves/plant) was resistant to leafhopper (hopper burn grade of 0 to 1 on 0-4 scale) at all the four locations, while susceptible check (DCS-107) recorded high pest infestation (19.8 to 70.0 leafhoppers/3 leaves/plant) with hopper burn grade 3 to 4 on 0-4 scale. The lines viz., ICS-186, ICS-190 and ICS-217 were also found as resistant to leafhopper at the three locations. The parental lines with resistant reaction may be utilized in castor improvement programme to develop leafhopper resistant hybrids.

O23-5. Mini Pink- a promising small cardamom accession against shoot and capsule borer – *Conogethes punctiferalis* Guen.

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Shoot and capsule borer, *Conogethes punctiferalis* is one of the most important pests of small cardamom. An experiment was conducted at Cardamom Research Station, Pampadumpara to identify varieties/accessions resistant to shoot and capsule borer and to investigate the biochemical basis of resistance. Seven cardamom accessions namely Minipink, Pink base, PV2, Compound panicle, Hybrid 9, Brinth 12 and Green gold were selected for the study. Field screening trials revealed that lowest shoot borer infestation was in Minipink (4.67 %) and highest in green gold (40.25%). In vitro screening trials showed that Minipink and Pink base were devoid of infestation and cent per cent infestation was in Green gold. Biochemical analysis revealed that total phenol content was the highest in the resistant accession Mini pink (4.0 mg g^{-1} plant tissue) and the lowest was in Green gold. All the defense enzymes viz., peroxidase, polyphenol oxidase and phenyl alanine ammonia lyase showed elevated activity in minipink (5.433 activity g^{-1} min^{-1}, 8.733 activity g^{-1} min^{-1}, 51.773 activity g^{-1} min^{-1}) and the lowest was recorded in Green gold (0.833 activity g^{-1} min^{-1}, 0.183 activity g^{-1} min^{-1}, 13.776 activity g^{-1} min^{-1}) . Present investigation proved that the enhanced levels of biochemicals and defense enzymes play a key role in imparting resistance in cardamom against shoot and capsule borer.

O23-6. Influence of slicon supply on plant growth and the resistance of bell pepper to thrips (*Scirtothrips dorsalis*)

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Silica (Si), being a major inorganic constituent in higher plants and it is one of the important beneficial nutrient elements for plant growth and the scientific studies on the benefits of Si to crops have helped to establish Si fertilization. Silicon has important roles in plant physiological processes and plant resistance to pests. The objective of this research was to investigate the effect of foliar application of silicon at different concentration (0.1%, 0.2% and 0.4% Si) with zinc (0.2%) and boron (0.1%) on plant growth, and nutrient accumulation and resistance of bell pepper to thrips (a serious insect-pest) at ICAR-Indian Institute of Horticultural Research, Bengaluru, India. Silicon as potassium silicate and ortho-silicic acid was provided to

foliage by spraying at 15 days intervals from 30 days after transplanting. Foliar application of silicon irrespective of doses recorded significantly higher plant height and biomass production. Significantly higher yield was obtained due to foliar application of 0.4% silicon over the control. The mortality of this thrips and mean number of lesions on bell pepper was evaluated on weekly basis. Silicon treatment significantly reduced the mean of number of thrips and of lesions on bell pepper. The mortality of *Scirtothrips dorsalis* was higher (42%) with silicon treatment irrespective of doses than non-sprayed treatment, showing increase in resistance of bell pepper to this pest. Silicon supply significantly increased phenolic compounds and peroxidase enzymes. After silicon treatment, SEM images showed a greater number of ladders like silica structures and flexural rigidity increased with increasing silica content in leaf.

O23-7. Heterosis in *Capsicum annuum* L. F_1 hybrids for anthracnose diseases resistance

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To improve chilli pepper variety for anthracnose resistance and good agronomic traits, the information of heterosis for anthracnose severity and yield performance are necessary. In the present work, ten F1 hybrids were produced by half diallel crosses along with their five different individual gene of anthracnose resistance in *Capsicum annuum* L. The ten F1 hybrids, 5 pure-line parents, commercial variety, susceptible and resistance check tested using Randomized complete block design with three replications in the field condition. Yield performance evaluated: Yield per plant (YP), Dry yield per plant (DP), Number of fruits per plant (NFP), Weight per fruit (WPF) Fruit length (FL), Fruit width (FW), Plant height (PH) and Wide canopy (PW) and analysis followed by Griffing's method 2, model 1 were used for determining their combining ability and heterosis. The ripe fruit of chilli pepper were inoculated with *Colletotrichum capsici* by using microinjection method in the laboratory and tested using complete randomized design with three replications. The results indicated that the 102 shown High General combing ability (GCA) and low values with anthracnose severity. Thus, suitable for selected for parent. Specific combining ability (SCA) value of yield performance was the high F1 hybrids of 102/105 and 102/103 and the lowest of anthracnose disease severity. Therefore, the F1 hybrid for selected for the good F1 hybrids are 102/105 and 102/103.

O23-8. Evaluation of the tolerance of seven citrus rootstocks to *Phytophthora gummosis* under saline conditions

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The combination of biotic and abiotic stresses in semiarid regions results in severe losses in citrus production. Neglecting the interactions that may occur between these factors would lead to the over or under prediction of the performance of rootstock species under natural conditions and therefore to their erroneous ranking. In this study, seven citrus rootstocks, including two new *Poncirus trifoliata* hybrids, were evaluated for tolerance to *Phytophthora gummosis* after a short exposure to salt stress. The inoculation was made at stem level with a pathogenic isolate of *Phytophthora citrophthora* collected at the experimental field of INRA in Kenitra, Morocco. This study highlighted a significant influence of salinity on the length of stem necrosis caused by

Phytophthora attacks. Interestingly, the seedlings of the new *Poncirus trifoliata* hybrids, F6 and F18, expressed a high level of tolerance to gummosis under saline conditions similar to that observed in the 'Gou Tou' sour orange (*Citrus aurantium* L.) and Sunki mandarin (*Citrus sunki* Hort. Ex. Tan.) checks, whereas pomelo (*Citrus grandis*) and citrumelo cv. 'Winter Haven' (*Citrus paradisi* Macf. x *Poncirus trifoliata* L. Raf.) were ranked as sensitive. The length of stem necrosis waspositively correlated with the accumulation of chloride in the leaves but was independent of stem water content. This finding supports the hypothesis that the fungal infection is favoured by the specific effects of salts rather than their osmotic effects.

O23-9. Characterization of the race structure of *Leptosphaeria maculans* in Germany and searching for sources of quantitative resistance in *Brassica napus* against the pathogen

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Leptosphaeria maculans (LM), the causal agent of the blackleg disease, is one of the most important pathogens of oilseed rape (OSR). This study aimed at monitoring the race structure of LM populations in different German regions and searching for quantitative resistance against the pathogen in winter oilseed rape. To this end, 354 doubled haploid lines, produced by crossing six parents with potential quantitative resistance and one susceptible parent, were phenotyped under field and greenhouse conditions. In the field, the plants were inoculated with infested stubbles from the previous season while in the greenhouse different inoculation methods were tested. The results showed that inoculating the plants in the greenhouse with a LM-mycelial agar plug on an injured stem gave the most reproducible and reliable results. To evaluate disease severity, the percentage of the cankered area of stem base cross-section was determined at growth stage (BBCH) 80-83 in the field and at 49 dpi in the greenhouse. The results showed significant variation among the DH lines, where the cankered area was 20-25% in some resistant lines compared to the susceptible DH lines where the cankered area reached 80-100%. LM population was investigated in four regions in Germany. Twenty LM races were detected. The most dominant races in the explored regions belong to either the race Avrlm7/Avrlep1/Avrlep2 or the race Avrlm7/Avrlep1. Rlm7 and LepR1 represented the most effective major R genes in the studied regions.

O23-10. Identification of new resistant sources against sheath blight of rice from *Oryza rufipogon*

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Wild relatives of rice (*Oryza sativa*) are important sources for rice improvement under both biotic and abiotic stress. Sheath blight caused by *Rhizoctonia solani* [Teleomorph-*Thanatephorus cucumeris* (Frank) Donk.] is major rice (*Oryza sativa* L.) disease and cause significant losses up to 69% under favourable environmental conditions worldwide. Four hundred five accessions of *Oryza rufipogon* were screened to identify resistance against sheath blight during the year 2015. There was not a single accession which showed complete resistance. Out of 405, 22 were found to be moderately resistant which were further evaluated during the

years 2016 and 2017. Finally, 19 accessions were identified as promising one and showed continuously moderately resistant reaction for three years. Correlation study revealed that the different disease variables such as lesion height, relative lesion height and disease score measured were significantly ($P<0.05$) correlated. All the genotypes and genotype*experiment interaction had a significant ($P < 0.001$) effect on all the disease variables. Cluster analysis showed that all the accessions were clustered into 4 groups during the year 2015. These groups showed a moderately resistant, moderately susceptible and susceptible reaction. The results of the present study showed the promising accessions viz., IRGC80600, IRGC80762, IRGC104404A, CR100036 and CR100436 can be utilized in the sheath blight resistance breeding programme.

O23-11. Grafting on resistant root stocks - a promising strategy in the management of bacterial wilt in brinjal and tomato

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The cultivation of solanaceous vegetables like brinjal and tomato is severely affected by Bacterial Wilt (BW). The causal agent *Ralstonia solanacearum* is a soil-borne bacterium, highly diverse and can survive for many years without a host. Most of the commercially grown varieties are susceptible to the disease. Our study reports three promising resistant rootstocks and their use in the management of BW in brinjal and tomato. Highly susceptible brinjal cultivars grafted on *Solanum torvum* did not wilt in various field trials. However, the non-grafted seedlings were completely affected by wilt. Along with this, BW resistant rootstocks obtained from the World Vegetable Centre, Taiwan were also evaluated and were found to show different levels of resistance during glasshouse evaluation. One of the lines S4 and a BW resistant variety, Surya were evaluated as rootstocks and recorded a reduced incidence of BW (10 to 40 %) in brinjal during glass house evaluation while in seedlings wilt incidence was 80 to 100%. Tomato seedlings grafted on *S. torvum*, Surya and S4 also recorded very low BW incidence (0 to 15%) under glass house evaluation while seedlings recorded 80 to 100% wilt. Reduced wilt incidence (23 to 40%) was observed in grafts of greenhouse-grown tomato hybrid (GS600) made on *S. torvum* while the seedlings were severely affected (80 to 100%) in a two-year evaluation period. Grafting of susceptible brinjal and tomato on resistant rootstock could be a promising strategy in BW management.

O23-12. Pigeonpea breeding for *Fusarium* wilt resistance and pest tolerance in Eastern and Southern Africa by using local genetic diversity

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Pigeonpea provides multiple benefits to cropping and farming systems through biological nitrogen fixation, nutrient recycling, climate resilience and sustainable intensification. It plays a significant role in food and nutritional security, feed and fuel wood supply and income generation. It is grown by about 6 million smallholder subsistence farmers in Eastern and Southern Africa (ESA). Pigeonpea production in ESA is steadily increasing over the last 15 years in Malawi, Tanzania, Kenya, and Mozambique. Eastern and Southern Africa (ESA) is the secondary centre of genetic diversity and through several germplasm collection missions ICRISAT able to capture regional genetic diversity. ICRISAT-Nairobi is regularly collecting local

diversity existing in the region and till date about 1500 diverse accessions were collected. Local genetic diversity captured in ESA has unique traits for local agro-ecological adaptation, farmer and consumer preferred grain traits, tolerance to drought and region-specific diseases. ESA regional germplasm also contributed to global genetic diversity maintained ICRISAT-Patancheru in several ways. A strong region-specific genetic enhancement program is in operation with major emphasis on high grain yield, inter-cropping compatibility, photo-period insensitivity, grain quality, resistance and/or tolerance to Fusarium wilt and Helicoverpa pod borer and resilience to climate change. Initially, ESA region used to receive the elite lines from ICRISAT-Asia program and most of them succumbed to Fusarium pathotypes and soon realized the importance of utilizing local genetic diversity. Similarly, most of the cultivated germplasm is susceptible to insects but regional germplasm contributed to develop genotypes that are insect-cum-drought tolerant, high yielding and big seeded.

O23-13. Bottom-up effect of different genotypes of Kachri, *Cucumis melo* var. callosus against melon fruit fly

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The studies were conducted to identify and categorize sources of resistance in kachri genotypes against *Bactrocera cucurbitae* from the arid region of India. The genotype IC-350933 and IC-370479 were found highly resistant; IC-351005, IC-351088, IC-258153 and DKS 2011/01 were resistant and IC-351258 and DKS 2011/12 were highly susceptible to the melon fruit fly. The phenols (r=-0.90), tannin (r=-0.89), total alkaloids (r=-0.80) and flavonoid (r=-0.96) contents showed significant negative correlation with percent fruit infestation. The percent fruit infestation had a significant negative correlation with length of ovary pubescence (r=-0.95), rind hardness (r=-0.94) and rind thickness (r=-0.91). Flavinoid and tannin contents showed variation in fruit fly infestation and in larval density per fruit (91.2 and 92.1%, respectively). Maximum variation in fruit infestation and larval density was explained by the length of ovary pubescence (89.5 and 84.8%, respectively) followed by rind hardness (4.3 and 3.3%, respectively). Based on Kaiser Normalization method, two principal components (PCs) were extracted explaining the cumulative variation of 88.19% in melon fruit fly infestation. PC1 showed 71.56 % of the variation while PC2 showed 16.62 % of the variation. Kachri genotypic variability can improve plant fitness via bottom-up effects on fruit fly infestation. Growers can adopt potential resistance genotypes (IC-350933 & IC-370479) of kachri with minimal financial investment for obtaining higher yield. Hence, a benefit of diversity for yield potential is recognized and thus, genotypes diversity is used for sustainable management tactic.

O23-14. Evaluation of maize genotypes for late wilt disease (*Machrophomina phaseolina*) in Telangana State

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Late wilt is prevalent in Kharif and Rabi in Telangana and occurs in maize at maturity stages. The spread of the disease is steadily increasing because of intensive maize cultivation and harvesting of maize from the same land year in and out. 100 maize genotypes along with checks were evaluated in Kharif 2018 and 124 maize hybrids along with checks were evaluated in rabi 2018 under artificial inoculation in field at ARS, Karimnagar. Twenty parental genotypes viz; IB94, JCS060, IB44, IB33, E1598462, 52193, IB154-1, EC618234,52265, IB100, IB144, 52256, IB37, HK1323, IB149, IB47, 52204, IB69, IB146 and IB117 were

observed in disease rating scale 1 in kharif 2018. The 1-9 disease rating scale was used based on the infected nodes. These can be used as promising parental lines for the development of late wilt tolerant hybrids. In rabi 2018, 124 hybrids were evaluated, among which 31 (4845XJCY, 4845XWLSF73, CP808, EC672848XBGS337, 4845XSarhad, WLSF73XEC672848, WNC416XBML7, WNC416XPFSR14-2, MySynBXJCY, MySynBXPFSR14-2, SyngentaS6668, P3396, TMMH804, SyngentaNK6240,WNC416XEC672848, PFSR14-2XBGS337, WLSF73X4845, BLS42050-1XS049, BLS42050-1XEC672848, BML7XBGS337, BGS337XBML7, INDAM1122, S049XWLSF73, HybridcornTX369, KBumper, BML7XBLS42050-1, CLQRCYXPFSR14-2, MySynBX619098, MySynBXACC524093, WNC416XEC440608 and WLSF73XSarhad hybrids were found in disease rating scale 1. These entries will be useful to the farmers to reduce the economic loss by the disease with higher yield. Other entries were moderately resistance to susceptible to late wilt disease in rabi and kharif seasons.The lines with disease rating scale 1 are identified as promising sources of resistance against late wilt disease and can be used to develop disease resistant and high yielding varieties in Maize.

O23-15. Screening of *Abelmoschus* gene pools against root-knot nematode, *Meloidogyne incognita* for identification of sources of resistance

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Root-knot nematode (*Meloidogyne incognita*) is an important endoparasite affecting plant growth and yield of several crops. This nematode is polyphagous and has a wide host range with okra as a major economically important host. Among the nematode management approaches, plant resistance is the most economical and environment friendly sustainable strategy. In this regard, *Abelmoschus* gene pools comprising of okra (*Abelmoschus esculentus*) (137 accs.), *Abelmoschus* wild species (15 accs./Four spp.) and inter-specific derivatives (49 accs.) were screened under greenhouse conditions. Reaction of these genotypes was recorded based on the gall index (root-galls/ plant) on 1-5 scale. In the preliminary screening, all 137 accs. of okra were found susceptible and among the *Abelmoschus* wild species, *A. tetraphyllus* (IC470742, IC141006) and *A. angulosus* (IC203863) exhibited moderately resistant reaction (11-30 galls/ plant), all accessions belonging to *A. enbeepeegeearensis* and *A. mizonagensis* were found susceptible. With regards to inter-specific derivatives, five accessions (C2741gr-5, C2741gr-6, C2741gr-19, C2741mizo-8, C2106 mizo-20) exhibited resistant reaction (3 - 10 galls/ plant) and four other accs. (C350mizo-1(1), C350mizo-13(5), C350miz-22(1), C2741mizo-7) showed moderately resistant reaction (11-30 galls/plant). On advanced screening of the above promising accessions, all exhibited susceptibility except *A. angulosus* (IC470742) and A. *tetraphyllus* (IC203863) belonging to tertiary gene pool showing moderately resistant reaction. It can be deduced from the experiment that, sources of resistance may be found only in tertiary gene pool and screening of all species with sizable accessions from this group may result in identification of resistant sources for possible utilization in resistant breeding programmes.

O23-16. Screening of cowpea genotypes, *Vigna unguiculata* for tolerance to cowpea weevil, *Callosobruchus maculatus* (Coleoptra: Chrysomelidae)

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The experiments were conducted during winter seasons 2014-2015 on 100 cow pea genotypes obtained from Gene Bank Unit of the Agricultural Research corporation (ARC) including three local cultivars as local check (Dahab Elgoz, Aein Elgazal and Hiadoub). The results obtained from this study clearly explained that from the evaluated cow pea genotypes ,four showed 0.0% damage (neither holes nor eggs were found on their capsules) namely 4394, 4362, 3461 and 4381, these four entries can be used for more studies as source of resistant against this store insect pest and solve the problem of grain yield losses attributed to this insect pest, four entries showed high % damage ranging between 90-100% and this were very susceptible to insect attack and damage, 21 genotypes their damage range is 21-30%, 17 entries the damage reached 11-20%,14 of tested lines show the lowest % damage (0-10%) and the data presented in table 1 explained the degrees % damage of the reminder cow pea genotypes to weevil attack. During this study *Anisopteromalus calandrae* (Howard) (Hymenoptera: Pteromalidae) as a parasite was found.

24. Spread, monitoring and management of *Tuta absoluta*

Organizer: R Muniappan

Lead

O24-1. Role of IPM innovation lab in management of *Tuta absoluta*

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The IPM Innovation Lab, a USAID funded program, has been involved in tracking the spread and managing the South American tomato leafminer, *Tuta absoluta* since it invaded Senegal in 2013. Since then, the program has conducted over 20 national, regional, and international workshops/symposia around the world to create awareness as well as to manage the pest. It has also set up a Working Group under the umbrella of the International Association for Plant Protection Sciences. The primary approach taken to tackle this pest includes use of non-chemical solutions such as pheromone lures and traps, netting, and bio- and botanical pesticides. The IPM Innovation Lab has also prepared PERSUAPs (Pesticide Evaluation Report and Safe Use Action Plan) for USAID. Currently, *T. absoluta* has invaded Europe, Africa, Central Asia, and within South Asia, India, Nepal, Bangladesh, and Myanmar.

Invited

O24-2. Modeling the multi-pathway spread of agricultural pests using network science

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Movement of humans and their goods is widely accepted as the primary driver of invasive species invasions. Models based on network dynamics can account for these pathways and simulate the spatiotemporal spread of the pest. This can help policy makers make informed decisions in monitoring, prevention and mitigation efforts. Unlike pest risk maps based primarily on ecological suitability, these models can provide causal explanations to the observed spread and enable counterfactual analysis. However, modelers face a number of challenges in realizing such systems: data scarcity, complexity of the phenomenon, and need for multi-domain expertise, to name a few. We have developed robust data-driven models to study the role of natural and anthropogenic drivers of invasive species spread, with application to *T. absoluta*. The spread is modeled as a diffusion process over a time-varying network. This talk will present our recent work demonstrating the role of this new modeling approach in analyzing the spread, the role of tomato trade, various intervention measures and economic impact.

O24-3. Screening of native *Bacillus thuringiensis* isolates and Cry1I against Tomato leafminer *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

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Relatively recent invasive, the South American tomato leaf miner, *Tuta absoluta* (Meyrick 1917) has arrived in India in the year 2014 and since has become one of the main constraint limiting tomato cultivation. Prior to this, it had caused serious havoc in tomato production system in Africa, warranting immediate action. Even though tomato is the preferred crop, it also infests other plants belonging to Solanaceae such as potato, eggplant etc. Integrated pest management (IPM) has been the key approach in successfully managing this pestilence in different countries. In this regard, biocontrol agents such as parasitoid, predator, insect pathogens such as Bt, NPV and entomopathogenic fungi are vital components of IPM in managing *T. absoluta*. Even though effectiveness of different local isolates and crystal proteins of Bt has been tested, it is important find novel isolates and crystal proteins of Bt to ensure continued susceptibility. In this study, we evaluated the efficacy of native *Bt* isolates and the purified Bt crystal protein, Cry1I (stock concentration of 200ng/cm^2) against different larval instars of *T. absoluta* in the laboratory. The bioassay revealed high susceptibility of *T. absoluta* for both the isolates and the Cry1I. In this regard, it is advantageous to have Cry1I, as it is both lepiodpteran and coleopteran active enabling enlarged spectrum of activity as spray and for developing transgenic plants for the management of *T. absoluta*.

O24-3. Invasion risk of South American tomato pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India: predictions based on MaxEnt ecological niche modelling

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South American tomato pinworm *Tuta absoluta* (Meyrick) is a recent invasion in India, causing widespread infestations in tomato crop in the States of central peninsula, especially Maharashtra and Karnataka. Hitherto, this pest was not reported to occur in India and thus presumed to be of exotic origin. The present study attempted to delineate the potential habitat suitability of geographical areas for spread and distribution of *T. Absoluta* in India. We have modelled the potential habitat distribution of *T. absoluta* using algorithm in Maxent, a maximum entropy modelling program. The climate niche for *T. absoluta* was developed based on the relationship between presence only data for 64 places and a reference climate data for the year 2000. This established relationship was then used to predict the changes in potential distribution under future climatic conditions by 2050. The future climate data from SRES A1b emission scenario at a resolution of 10 arc minutes were used for analysing climate change impacts. The predictions from Maxent were mapped in DIVA GIS, an open source computer aided tool for mapping and analysing spatial data. The established model in Maxent gave a reasonable estimate of *T. absoluta* range with better discrimination of suitable and unsuitable areas for its occurrence under current and future climatic conditions. This was evident from the highest value of AUC i.e. 0.968 and 0.874 for training and test data, respectively. A Jacknife test for variable importance indicated that Bio3 (isothermality) with highest gain value was the most important abiotic factor influencing the potential habitat distribution of *T. absoluta*. The modelled habitat distribution of *T. absoluta*

will be a useful guide for researchers and plant protection workers to frame appropriate management strategies against this invading pest insect to cope with the future climate change conditions.

O24-4. Evaluation of biorational based IPM packages for the management of tomato leafminer, *Tuta absoluta* at farmers' fields in Bangladesh

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An experiment was conducted at farmers' fields of Chaklarhat, Panchagarh during February to June 2019 to find out most effective biorational based IPM package(s) against tomato leaf miner, *Tuta absoluta*. A total of four packages, viz, Package1 = Foliar spray of Bacillus thuringiensis (Biocure) @ 2g/L of water +Mass trapping through installation of Delta sex pheromone trap+ Application of *Metarrhizium anisolpiae* biopesticide in soil @ 5g/L of water, Package2= Application of *M. anisopliae* biopesticide in soil @ 5g/L of water + Foliar spray of Azadirachtin (Bio-Neem plus 1EC @ 1ml/L of water) + Mass trapping through installation of Delta sex pheromone trap, Package3= Farmers' practice (Spraying with Chlorantraniliprole, Coragen 20SC @ 0.5ml/L of water) and Package4 = untreated control were evaluated following Dispersed randomized complete block design with 5 replications. Results revealed that IPM package, Application of *M. anisopliae* biopesticide in soil @ 5g/L of water + Foliar spray of Azadirachtin (Bio-Neem plus 1EC @ 1ml/L of water) + Mass trapping through installation of Delta sex pheromone trap performed best in reducing *T. absoluta* infestation, increasing marketable yield and highest marginal benefit cost ratio.

O24-5. Nanomatrix for delivery of South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) pheromone

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The alien invasive South American tomato moth, *Tuta absoluta* (Meyrick) (Gelechiidae: Lepidoptera) is a key pest of tomato, *Solanum lycopersicum* in India and among the many borers that cause economic damage to tomato. The female released sex pheromone of *T. absoluta* comprises of (3E, 8Z, 11Z)-3, 8, 11-tetradecatrien-l-yl acetate and (3E, 8Z)-3, 8- tetradecadien-l-yl acetate (9:1). The pheromones loaded in rubber septa have a high release rate of pheromones and warrant frequent replacement that adds to the cost. Nanoporous materials are a novel carrier/dispenser for the volatile signaling molecules with controlled spatiotemporal release rates. The nanomatrix characterized by field scanning electron microscopy (FESEM) and X-ray diffraction (XRD) confirmed the ordered structure of the pores on the matrix. Thermal gravity analysis (TGA) revealed that the dissipation of pheromones from the nanomatrix was in a controlled manner. The combining ability of pheromones in the nanomatrix was confirmed by Fourier transform infrared (FT-IR) measurements. Entrapped pheromones in the nanomatrix revealed controlled release of pheromones as compared to release from rubber septa. The physiological response in olfactory receptor neurons and behavior of the male moths to the pheromones released from nanomatrix was ascertained. A field test of pheromones loaded in the nanomatirx captured more moths than unbaited traps. In terms of longevity of pheromone lures, the commercial lure containing 3 mg of pheromones was exhausted in 20–30 days, whilst pheromones loaded into the nanomatrix was effective for 45–60 days. The possibility of using *T. absoluta* pheromones for mating disruption is discussed.

O24-6. dsRNA mediated silencing of Vacuolar-type H + -ATPase B gene of the South American tomato leafminer, *Tuta absoluta* (Lepidoptera; Gelechiidae)

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The South American tomato leaf miner (*Tuta absoluta*) Meyrick, is one of the invasive and most devastating pest native to South America. It is initially a leaf miner and later infests fruits and thus has become one of the limiting factors in tomato cultivation in India and in different parts of the globe. Even though IPM has been successful in the management of *T. absoluta*, additional, novel tools are required for the sustaining the same. In this RNA interference (RNAi) has been demonstrated to be a useful tool for managing different species of insect pests and it is highly species-specific. In this present study, we have evaluated the potential of cognate double stranded RNA (dsRNA) for v-ATPase gene of *T. absoluta*. Custom designed, off target minimized dsRNA (500bp) were prepared by cloning and sequencing the target gene from the larva of *T. absoluta*. Different concentrations (2, 4, 6, 8, 10 µg/cm$^{2)}$ of the dsRNA was administered by smearing on to tomato leaf for different time interval (24h, 48h and 72 hours). Bioassay results showed that dsRNA at 10µg/cm^2 (72h of post treatment) resulted in 60% mortality as compared to control. Effectiveness of dsRNA was further confirmed by qRT-PCR analysis which showed reduced expression of the target gene. Thus RNAi could be a useful novel tool paving way for non-chemical management of *T. absoluta*.

O24-7. Integrated management of *Tuta absoluta* in India

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Tuta absoluta (Lepidoptera: Gelechiidae), an invasive pest has recently been invading several countries in the world causing up to 100 per cent losses to tomato crop both under greenhouse conditions and open conditions. It was reported from India during 2014 and spread to several states within a short span of time. The leaf-mining habit of this pest makes chemical or biological control alone more difficult to manage. Total rely on use of insecticide sprays, yet times their indiscriminate use results in resistance development by *T. absoluta* and pesticide residues in the produce. This necessitates need for the development of IPM package for its management. Keeping all these factors into consideration, an alternative to the presently followed chemical based management, light trap based IPM was developed for the management of this pest. Light traps have been reported to attract nocturnal moths' population and are advantageous over pheromone traps as they attract both male and female moths. Various IPM components evaluated were light sources (colour), pheromones traps, effective chemicals from different modes of action groups against adults and immature stages of the pest, entomopathogens, different species of egg parasitoids *etc*. at ICAR-Indian Institute of Horticultural Research, Bengaluru, India located at 13° 8' 18.8088" N, 77° 28' 40.4040" E. Various colours of light sources (wave lengths of visible light) were evaluated for their relative efficacy in attracting the *Tuta* adults. The efficacy of mass trapping was assessed by recording the trapped adult moths for five nights. Iincandescent yellow bulbs 60 W were found most effective in attracting the *Tuta* moths. Up to 46 per cent of catches were females in different light traps evaluated. Use of these light traps as a component of IPM significantly reduced the leaf and fruit damage in tomato, when the *T. absoluta* population density was low/moderate. Of the various IPM modules evaluated, in green house, use of incandescent bulb 60 W@ one bulb/150 m^2 plus 1 pheromone trap/300 m^2 plus need based spray of spinosad 45 SC @ 0.25 ml/l or flubendiamide 480 SC @ 0.20 ml/l in rotation at 2-3 weeks interval was found most effective. Coinciding with the peak emergence of *Tuta* adults, deltamethrin 2.5 EC @ 1 ml/l

was sprayed for reducing adult moth population. Greenhouses, in which IPM practices were followed; fruit damage by *T. absoluta* was reduced to 5-6 per cent as against 35-56 per cent in control. Similarly, number of live mines/plants ranged from 2.6-6.5 in IPM plots as against 9.2-12.8 in control. Number of eggs laid by *Tuta* were also significantly lower in IPM plots (0-2 eggs/leaf) when compared to non-IPM plots (up to 30 eggs/leaf). Light trap based IPM followed was found effective and eco-friendly approach for the management of *T. absoluta* under greenhouse conditions. Similarly for open cultivated tomato, efficacy of effective IPM components *viz*., egg parasitoid, *Trichogramma pretiosum*, use of incandescent bulb for attracting adults, pheromones, entomopathogens like *Metarhizium anisopliae* and insecticides, long term strategy of possibility of host plant resistance against *Tuta* is also discussed in this paper.

O24-8. Management of the South American tomato leafminer, *Tuta absoluta* on tomato in Nepal

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Since the first detection of *Tuta absoluta* (Lepidoptera: Gelechiidae) in Nepal in 2016, potential production of tomato has been constrained, resulting in reduced yield. Since tomato is the country's most valuable vegetable crop, this pest is considered a serious threat to production. Studies have shown that chemical pesticides fail to control *T. absoluta* in many parts of the world. Integrated pest management (IPM) practices for effective management of this pest is needed. This study highlights the results of the approaches made to manage this pest and proposes IPM recommendations as an affordable management option for tomatoes grown under plastic tunnel houses and in open fields to prevent losses of tomato production in Nepal. The pest exclusion nets were successful in reducing 90% of pest populations, 89% leaf damage, and 91% fruit damage, with a promising 23.58 more mt/ha yield as compared to open field cultivation. The results on etiveness of colored traps with lures showed that the white-colored delta traps attracted more moths, followed by green, yellow, and orange traps, respectively. Traps placed at ground level caught the most moths, followed by traps placed at one foot, two feet, three feet, and above three feet, respectively.

O24-9. Effective management of *Tuta absoluta,* tomato pinworm with semiochemicals

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Tomato is one of the important vegetable grown in India with 8.8 lakh ha area with a production of 18.2 M mt. Similarly, potato is another important solanaceous vegetable grown in 19.9 lakh ha with a production of 40.3 M mt (NHB, 2014). The Tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the global major destructive invasive pests and was first reported on Tomato and Potato in India by Indian Institute of Horticultural Research (IIHR), Bengaluru, Karnataka during 2014. The pest has disseminated from South America to several parts of Europe, entire Africa and has now spread to India. Larvae creates blotch like mines on leaves, feeds on stems, buds, calyces, young fruit, or ripe fruit and by the invasion of secondary pathogens which enter through the wounds made by the pest. It can cause up to 90% loss of yield and fruit quality under greenhouses and field conditions. High reproductive potential, multivoltine, swift dispersal and resistance to insecticides (Desneux et al., 2010) entails this pest as a major threat to tomato crop across the world. This has instigated to deploy the use of sustainable semiochemical based Tomato pinworm

pest management solution to produce resilient tomato crop. Efficacy of SPLAT TUTA was conducted in different agro-climatic regions across India as a part of DBT-BIRAC program in collaboration with ICAR Institutes and Agriculture Universities like National Bureau of Agricultural Insect Resources (NBAIR), IIHR, IARI, UAS Raichur and AVRDC, Hyderabad. SPLAT-*Tuta* was applied @ 500 g per acre in four different splits starting from 3 to 5 days after transplanting and later at 35-40, 65-70 and 95-100 days after transplanting. Efficacy is measured in terms of moth catch per trap, leaf infestation and fruit yield. Preliminary results suggest that the damage in SPLAT treated farms was less than 2-8 % shoot damage without any insecticide treatments on target pest, compared to more than 70% vegetative infestation and 20–40 % fruits damage under control farmer practice. NBAIR evaluated SPLAT Tuta absoluta efficacy in Krishnagiri district, Tamilnadu (TN) and Kolar district of Karnataka. The mean moth catch per trap in SPLAT-TUTA treated plots was below 8-10 and 25-50, while in control plot it varied between 34-74 and 324-500 in TN and Karnataka respectively. Mean per cent leaf damage in SPLAT treated plot was 1.1 to 4% whereas control plots ranged between 10-12.5%. Similarly, average per cent fruit damage differed significantly with < 9-10% in SPLAT-Tuta treated plots on the contrary in control it was above 36% and 50% as recorded from TN and Karnataka respectively. Total field yield in SPLAT was 20.86 tons/acre whereas in control 11.92 tons/acre was recorded. Therefore, the investigation results proved that SPLAT Tuta effectively managed to tame the Tomato pinworm population.

O24-10. Distribution and genetic diversity of Indian *Tuta absoluta* populations in relation to the sterile insect technique (SIT) and *Wolbachia* based technologies

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The tomato leaf miner, *Tuta absoluta* (Meyrick) is one of the major invasive insect pest on solanaceous crops. This insect pest has recently reported in various tomato growing areas of India in open as well in closed field conditions and causing significant losses to yield. Due to its invasion capacity, adaptability and high reproductive potential, this pest is being considered for worldwide pest management programmes including Sterile Insect Technique (SIT). Before implementation of SIT, it is essential to fill the gap on insect pests population distribution, genetic structure, mass rearing protocols, optimising sub-sterility dose and compatibility with other control strategies. Extensive survey was undertaken in tomato growing regions of India during September 2017 to May 2019. The infestation of *T. absoluta* was recorded in Maharashtra, Karnataka, Telangana, Tamil Nadu, Haryana and Himachal Pradesh. Severe incidence of *T. absoluta* infestation was recorded in Maharashtra (Nashik district) and Telangana (Mahabubnagar district) followed by Karnataka (Kalaburgi and Raichur districts). The moths collected during survey were characterised using mitochondrial cytochrome c oxidase subunit I (*COI*) gene analysis and *Wolbachia* presence. Nine *T. absoluta* populations were grouped under single clade revealing no genetic variation within populations and showed high genetic homogeneity thereby an ideal candidate for SIT application. Tomato leaf miner samples collected from 9 locations showed 42.66% *Wolbachia* infection. Based on the phylogenetic analysis, the prevalent *Wolbachia* strain belongs to super group B in tomato leaf miner populations, which are parasitic in nature. Currently, tomato leaf miner is being mass reared on tomato seedlings in laboratory conditions and mass-reared pupae will be used for irradiation. Further, significance of population dynamics, host range, local and area-wide management strategies for the effective management of *T. absoluta* will be discussed.

25. Biosystematics for effective crop protection under changing climatic scenario

Organizers: Debjani Dey and Naresh M Meshram

Lead

O25-1. Indian insect diversity: current status, threats and its conservation

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Biodiversity, an important cornerstone of sustainable development represents the biological wealth of a nation. Insects are the most diverse group of animals on earth with over a million described species comprising of more than half of all known living organisms with estimates of undescribed species being as high as 30 million. They are important because of their diversity, ecological role, and influence on agriculture, human health and natural resources. They have been used in landmark studies in biomechanics, climate change, developmental biology, ecology, evolution, genetics, and physiology. Many have also been identified as bio-indicators. The most successful group Insecta currently includes about 10,29,741 species worldwide, which is only 10-30% of the actual number of estimated existing species. India, a megadiverse country is one among the twelve mega bio-diversity countries of the world with two hotspots , viz., the eastern Himalayas and the Western ghats. Insect diversity in India is characterized by a high level of endemism. The diversity of insects is greater in the north-eastern states, the Western Ghats and the Andaman and Nicobar Islands, and these areas also have a high level of endemism. Efforts of taxonomists have led to the discovery of 65,466 species of insects representing 26 orders from India. Changes in habitats all across the country, and forests areas, pollution of streams, conversion of natural habitats for agricultural purposes etc. have impacted the insect diversity of India. However certain approaches have been adopted for the conservation of diversity by the Government of India.

O25-2. Systematics in pest risk analysis for safe international exchange

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Pest-risk analysis (PRA) is a multistage process that includes identification of risk of introduction and spread of pests and their impact both economic and environmental in the new locality. The International Plant Protection Convention has developed several standards *viz*., ISPM-2, ISPM-11 and ISPM-21, which provide guidelines for PRA for regulated pests. Being a signatory of SPS Agreement, India is also obliged to base and justify its trade negotiations on PRA. There are two ways of initiating a PRA: pathway-based and pest-based. Pests that are present in the PRA area, unless they are limited in distribution and under official control, do not meet the criteria for quarantine pests and need not be considered for the PRA. This categorization step largely depends on the accuracy in identification of the pest in order to establish its quarantine status and provides an opportunity to eliminate the pest from analysis at an early stage in the PRA process thus avoiding unnecessary in-depth examination. Systematics is also useful for undertaking the pest risk assessment of a number of known hosts and the phylogenetic distance between known hosts and other species of interest- can be used to predict which plant species are likely to be susceptible to a particular pest. This can help in rapid assessment of risk from novel pests when empirical host range data are not yet available and guide efficient collection of empirical data for risk evaluation.

Invited

O25-3. Impact of climate change on abundance of soil arthropods

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The soil is home to a large proportion of the world's genetic diversity. The linkages between soil organisms and soil functions are observed to be incredibly complex. Direct and indirect benefits of improving soil biological management in agricultural systems include economic, environmental and food security benefits. Soil arthropod biodiversity is an important component in the development of sustainable agriculture because of its role in maintaining soil fertility, control of arthropod pests and different plant diseases. Effects of global change on soil fauna communities may include both moisture and temperature responses, which may have influence on many soft-bodied animals such as collembolans and soil mites. Various studies indicated that temperature also affects many aspects in the life of soil fauna. Seasonal temperature variations commonly induce vertical movements of soil animals in the soil profile. The developmental rate of collembolans is often temperature-dependent. In some collembolans, fecundity and sex ratio in the populations may also be affected. As the effects will depend not only upon the abiotic factors acting on the component species, but also upon the interactions between different species, studies at the community level are needed. Soil arthropod responses to climate change differed among species, both in terms of species diversity and abundance suggesting that coarse taxonomic monitoring is needed to understand the impact of such climate change on these organisms.

O25-4. Multiplex PCR assay for concurrent identification of major thrips vectors of India

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Thrips (Thysanoptera) are the sole transmitters of economically damaging tospoviruses (family Peribunyaviridae, order Bunyavirales) in ornamental and vegetable crops. Till date 15 thrips are known to be vectors of more than 29 tospoviruses, among them, four *viz*., *Thrips palmi*, *Scirtothrips dorsalis*, *T. tabaci*, and *Frankliniella schultzei* are reportedly transmitting five tospoviruses in India. Their identification at an early stage is crucial in formulating appropriate pest management strategies. Since morphometric key-based identification of adults is time consuming, diagnostic tools that are rapid, accurate and independent of developmental stages are required. We report a multiplex PCR assay to identify four major vectors *viz*., *T. palmi*, *T. tabaci*, *S. dorsalis*, and *F. schultzei*. Cytochrome oxidase subunit III, and internal transcribed spacer 2 region were utilized to design species specific primers. Of 38 pairs of primers tested, primer pairs AG35F-AG36R, AG47F-AG48R, AG87F-AG88R, and AG79F-AG80R amplified 568 bp, 713 bp, 388 bp, and 200 bp products from the DNA templates of *T. palmi, S. dorsalis, T. tabaci*, and *F. schultzei*, respectively at same PCR conditions. The specificity of the primer pairs was validated with large number of known specimens and no cross reactivity was observed with other thrips species. The multiplex PCR assay with a cocktail of all the four primer pairs detected four species efficiently and could discriminate all the four species concurrently in a single reaction. The assay will be useful in rapid and concurrent identification and ascertaining distribution profile of major thrips vectors present in India.

O25-5. Museum data validates change of crabronid wasp diversity at Delhi

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Crabronidae (Hymenoptera: Sphecoidea) includes over 200 genera and 9000 species worldwide. Subfamily Crabroninae, the most diverse group of family Crabronidae, includes around 100 genera and 9,000 species around the world. However, the Indian fauna is poorly known. During the current global warming, collection data of museums have proved to be valuable sources of information indicating changes in diversity and distribution of species. As isotherms shift away from a particular location, warming at the location may occur, but the spatial context of temperature change will influence the regional setting of species diversity change. This study focuses on the effect of climatic variables on species diversity. Long term annual and monthly trends for maximum and minimum temperature of North West Region of India were used for trend analysis with Sen's slope estimator and Mann-Kendall Statistics for assessing differences, if any. Intensive surveys for collecting these wasps were made during 2017 to 2018 at IARI, New Delhi. The current data were compared with the collection data of 1959 to 1960 housed at National Pusa Collection. Changes in abiotic conditions affected the diversity of species. Maximum temperature showed significant increasing trends during the months of February, April, August, November and December while minimum temperature showed significant negative trends in January and June. In response the crabronid wasps shifted their time of occurrence from summer to winter, which might be due to the presence of optimum temperature. Thus museum data can validate observation based species occurrence data.

O25-6. Barcoding and Phylogenetic analysis of delphacid plant hopper complex in rice

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Delphacid planthoppers constitute the economically important planthopper complex in rice. They cause inevitable damage directly by feeding and indirectly as vectors. Delphacidae is the largest family of the Fulgoroidea superfamily and most economically important group feeds on graminaceous crop plants. The Delphacids are easily distinguished at family level by the presence of a large, movable spur on the apex of the hind tibiae. In rice, the major pests *viz*., brown planthopper *Nilaparvata lugens* (vector of grassy stunt and ragged stunt viral diseases); small brown planthopper, *Laodelphax striatellus* (Fallen) (vector of rice stripe and black streaked dwarf); white backed planthopper like *Sogatella furcifera, S. kolophon, S. vibix* and minor pests, *viz*., *Toya propinqua, Tagosodes pusanus, Coronacellas inhalana, Sardia rostrata, Peregrinus maidis, Nycheuma cognatum, Cemus sauteri,* etc. These species are known for their complexity like cryptic species, wing polymorphism, sexual dimorphism etc, which hinders their identification. The conventional taxonomy combined with molecular tools will give explicit identification. In this regard, we generated DNA barcodes by targeting four gene loci mtCOI, 28srDNA- D2 region, 28srDNA- D9-10 region and Histone gene. The molecular phylogeny analysis has been made to give the evolutionary relationship among these pest species. This will give a comprehensive account on identification, which in turn helps in the survey, monitoring and early warning of the major Delphacid pests of rice.

O25-7. Linnean shortfall in biodiversity research: a case study of tortricidae

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India is one of the signatories of Convention on Biological Diversity and like any other member country it is also having specific goals to achieve through national strategies, plans or programs for conservation and sustainable use of biodiversity. The conservation actions and assessments rely on priority setting due to paucity of time and funding. Any conservation efforts will start from assessing species or taxonomic groups, which are threatened worldwide. However, many developing countries are planning to create fresh priority list of species for conservation efforts. The major hindrances in global conservation status assessment is the so called Linnean and Wallacean shortfalls. Lepidoptera (moths and butterflies) conservation in recent years has grown from arcane topic to an everyday concern. However, more numerous smaller moths have been largely ignored, which may be due to limited taxonomic studies in these groups. To understand the status of taxonomic studies we have selected family Tortricidae that belongs to general group of smaller moths. In the present study we explored patterns of species description of tortricid moths from 1775 to 2018. A total of 392 species has been described. Eight authors have described more than 85% of tortricid species from India. The cumulative curve of the number of tortricid species described showed highest peak during 1901-1925 where in 226 species were described from India. The biogeographic zone recorded highest species was North East (47.19%) followed by Deccan (10.71%). This study helps in planning our future expeditions.

O25-8. Native pollinator diversity in temperate vegetable ecosystem

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Kullu valley in Himachal Pradesh is well known for fruits, vegetables and temperate vegetables seed production. Yield and quality of these essentially cross pollinated temperate fruits and vegetables are largely dependent on efficient delivery of pollination service. Although the valley is the habitat for diverse group of native wild pollinators, their number is in continuous decline due to climate change, intensive agriculture, habitat fragmentation and injudicious use harmful agrochemicals. As a consequence, native pollinators now exist well below the population density essential for rendering required pollination service, which force most of the farmers to depend entirely upon hired pollination service of managed bees (*Apis cerena* and *Apis mellifera*) during peak pollination period. Unfortunately these domesticated managed bee colonies are also facing additional challenges of increasing diseases, predator attack and mite infestation due to climate change. In this context other non-Apis bee pollinators as well as native wild pollinators can play a crucial role in supplementing pollination service of managed bees. Extensive biodiversity surveys conducted during last three years recorded 68 species of flower visiting insect belonging to 6 orders and 27 families from temperate vegetable ecosystem of Kullu Valley. Of these, 22 species belonged to Hymenoptera, 26 to Diptera, 12 to Lepidoptera, 6 to Coleoptera, 1 to Hemiptera and 1 to Thysanoptera. Since it is well known that all flower visitors are not important pollinators of crops, an effort was also made to identify most important pollinators for temperate vegetable ecosystem through pollen transport network analysis.

O25-9. Headspace analysis to compare the volatile emissions from different cowpea cultivars that differ in resistance to *Megaluro thripss* Jostedti Trybom

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Cowpea is an important subsistence crop for rural smallholder farmers. The flower thrips, *Megalurothrips sjostedti*, is the major constraint to pod production in cowpea. Cowpea varieties differ in the degree of susceptibility/resistance to thrips and cowpea volatiles are hypothesized to play a role in this. Therefore, we collected and analysed VOCs by coupled gas chromatography-mass spectrometry from four resistant [Moussa Local (ML), TVu1509 (TV), Sewe (SW), Sanzisabinli (SZ, n=14)], two moderately resistant [KVx404-8-1 (KV), IT90K-277-2 (IT)], and two susceptible [Ife Brown (IB) and Vita 7 (VT)] in two studies. In the first study, 68 VOCs were identified comprising benzenoids, alkanes, alkenes, terpenoids, ketones, alcohols, phenols, esters, in the eight cultivars at varying amounts. Multivariate data analysis projection to latent structures discriminant analysis of VOCs yielded two major clusters; the resistant varieties (TV, SZ, SW, ML) separated from the moderately resistant and susceptible ones (IT, IB, VT and to a lesser extent KV). Similarly in the second study, Principal component analysis of VOCs also showed that two main components provided differences in the cultivars IB (susceptible) and TV (resistant) yet, they both had 26 VOCs (benzenoids, alkanes, monoterpenoids, ketones, fatty aldehyde, alcohol, phenol, ester, acyclic olefins) but at varying amounts. In conclusion, the data indicate that cowpea cultivars differ in headspace composition and that the differences recorded correlate with the level of susceptibility/resistance to thrips. These compounds could be synthesized and incorporated in traps to act as attractants or repellents to thrips in cowpea cropping systems.

26. Endophytes for plant protection

Organizers: Nutan Kaushik and Azucena González Coloma

Lead

O26-1. Biocidal compounds from *Betehncourtia* sp. endophytes

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Metabolites from endophytic microorganisms have been suggested as a potential source of biopesticides. Research on fungal endophytes has led to the discovery of new natural products, including compounds active against insect pests and plant parasites.We isolated a series of fungal endophytes from leaf fragments of the Canarian endemic plant, *Bethencourtia palmensis*, a source of silphinene-based insect antifeedants, and their microextracts were screened against fungal pathogens (*Alternaria alternata, Botrytis cinerea, Fusarium* sp. and *Aspergillus niger*), insect pests (*Spodoptera littoralis, Myzus persicae, Rhopalosiphum padi*), ticks (*Hyalomma lusitanicum*) and plant parasites (*Meloidogyne javanica*). Among these fungal species, we have selected the isolate SPH2 based on the biocidal effects of its ethyl acetate (EtOAc) extract against fungal pathogens and ticks. The bioactive components of the EtOAc extract have been characterized following a bioguided isolation. Mellein, a dihydroisocoumarin, produced by *Aspergillus ochraceus* has been identified as the main ixodicidal, component of the extract with additional nematicidal and fungicidal effects. In this work we will discuss on the bioactive products pool of SPH2 and their time-course production / optimization by liquid fermentation.

O26-1. Endophytic microbes and their metabolites for crop protection

Kirti Rawat[1], **Nutan Kaushik**[2], Bishnu Maya Bashyal[3] and SB Tripathi[1]

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Bakanae caused by *Fusarium fujikuroi* (Nirenberg) is an important emerging disease of rice in India. Several biocontrols have been implemented and developed for its prevention and management. In this context, we screened 47 endophytic fungi by dual culture and enzymatic plate assays like chitinase activity, β 1,4glucanase activity, phosphate solubilization and siderophore production. Cell culture free extracts of all the three species were poured onto the different media prepared for different activity detection against the pathogen. Out of 47, three, namely, *Fusarium equiseti, Fusarium* sp. and *Trichoderma* sp**.** showed maximum antagonism, phosphate solubilization, siderophore production, chitinase and βglucanase activity. Furthermore, they were evaluated in net house and field for pathogenicity tests, vigour index, root-shoot length, and grain yield. Plants treated with biocontrol showed high vigour index compared to those inoculated with pathogen. Lowest disease incidence was observed in *Fusarium equiseti* (17%) followed by *Trichoderma* sp**.**(21%),which also depicted highest root-shoot ratio and plant weight (98g) along with maximum grain yield (775g). Dual culture, enzyme assays and field evaluation results concluded that the *Trichoderma* sp., and *Fusarium equiseti* treatments showed best results against the disease. Hence, both can prove to be useful biocontrol agents for bakanae against *Fusarium fujikuroi*.

Invited

O26-1. Performance of dual application of endophytes *Trichoderma harzianum* and *Glomus etunicatum* as root protectant against *Meloidogyne graminicola*

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In the present paper, the role of both endophytes, *Trichoderma harzianum* and AM fungus *Glomus etunicatum* has been confirmed as 'root protectant' against soil borne hidden enemy particularly root knot nematode *Meloidogyne graminicola* on rice Cv. Basmati 1509 exhibiting reduced pathogenic incidence in AM fungal colonized roots. This densely colonized AM fungal zone with vesicles and arbuscules help in preventing the root invaders in the zone of root elongation which is known as main entry point in the vicinity of which no trace of either infective larvae (J2) of root knot nematode as primary pathogen or rot causing fungus *Rhizoctonia solani* was observed. In disease-complex situation role of root knot nematode as primary pathogen and other fungi as secondary pathogen is well established by various workers round the globe. The role of *Trichoderma harzianum* as a biocontrol agent through parasitism and as an activator for plant growth hormones is well known. In the treatments, where both the endophytes were taken seedlings were found disease free and healthier than other treatments.

O26-2. Bio-control activity of endophytic *Bacillus* strain against pathogenic fungi

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Abstract: Bacterial endophytes (199 isolates) isolated from tomato seedlings were screened for their antagonistic activity against five pathogenic fungi such as *Rhizoctonia solani, Alternaria solani, Fusarium solani, Botrytis cinerea* and *Verticillium lateritium.* These pathogens are responsible for causing many diseases in tomato crop. Sixteen percent of all the isolated bacterial endophytes was found antagonistic to these fungi with percentage inhibition of more than 60% in dual culture assay. One endophyte, molecularly characterized as *Bacillus siamensis*, was found to be most effective against all the test fungi with percentage inhibition more than 70%. It also inhibited the mycelial growth of *R. solani* up to 60% in double plate assay by producing volatile organic compounds. GC-MS analysis of this *Bacillus* strain revealed the presence of some volatile compounds such as Heptadecane (44.11%), Pentadecane (5.85%) and Dodecane (4.89%). This chitinase positive endophytic bacterial strain can be a potential biocontrol agent for crop protection.

O26-3. A novel bioformulation of *Purpureocillium lilacinum* to manage root-knot nematodes

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Root-knot nematodes (*Meloidogyne* spp.) pose a major threat to agriculture and forest systems owing to their short life cycle and a wide range of host preferences. Considering the drawbacks of chemical management and control strategies, biological control of nematodes has lately been accepted as an alternative solution.

This encompasses microbial agents, especially fungi that are antagonistic to root-knot nematodes. Keeping all these facts into consideration, bioformulation of a potent fungal biocontrol agent, *Purpureocillium lilacinum* was developed using non-traditional agro-industrial wastes, *viz*., non-edible oil cakes, biogas slurry and fly ash to manage plant parasitic nematode i.e. *Meloidogyne incognita*. Bioefficacy studies on tomato plants in green house revealed that the formulation was 1.19 times more effective than traditional formulation in controlling nematodes.

O26-4. Endophytic fungi for the management of bakanae disease of rice

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Bakanae caused by *Fusarium fujikuroi* (Nirenberg) is an important emerging disease of rice in India. Several biocontrols have been implemented and developed for its prevention and management. In this context, we screened 47 endophytic fungi by dual culture and enzymatic plate assays like chitinase activity, β 1,4glucanase activity, phosphate solubilization and siderophore production. Cell culture free extracts of all the three species were poured onto the different media prepared for different activity detection against the pathogen. Out of 47, three, namely, *Fusarium equiseti*, *Fusarium* sp. and *Trichoderma* sp**.** showed maximum antagonism, phosphate solubilization, siderophore production, chitinase and βglucanase activity. Furthermore, they were evaluated in net house and field for pathogenicity tests, vigour index, root-shoot length, and grain yield. Plants treated with biocontrol showed high vigour index compared to those inoculated with pathogen. Lowest disease incidence was observed in *Fusarium equiseti* (17%) followed by *Trichoderma* sp**.**(21%),which also depicted highest root-shoot ratio and plant weight (98g) along with maximum grain yield (775g). Dual culture, enzyme assays and field evaluation results concluded that the *Trichoderma* sp., and *Fusarium equiseti* treatments showed best results against the disease. Hence, both can prove to be useful biocontrol agents for bakanae against *Fusarium fujikuroi*.

O26-5. Genomics of biocontrol mediated by endophytes

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The capabilities of endophytic microorganisms for plant protection have been amply documented (see other presentation in this Symposium). Endophytic microorganisms, mainly bacteria and fungi, constitute a fraction of the microorganisms that thrive in the proximity, on, and within plants, and that constitute the plant microbiome. For many years, healthy plants had been thought of as essentially sterile, and known cases of microbial-plant interactions had been written off as special cases. Technological advances in high throughput DNA sequencing during the last fifteen years have made it clear that plants live in close association with its microbiome and that, in much the same way as humans and their microbiome, depend on it for growth, nutrition, development and defence, among other processes. In fact, the plant holobiont is nowadays considered as the combination of the particular plant plus its particular phytobiome (a term that includes all the biotic and abiotic factors affecting the plant growth, development and activity). This presentation will highlight examples of how recent genomic and metagenomic methodologies are being used to characterize plant microbiomes, to help in the guided isolation of endophytes, to identify potential candidates for

biocontrol, to mine genes important for biocontrol traits, and to facilitate manipulation of the endophyte for enhanced biocontrol capabilities.

O26-6. Nematicidal compounds from endophytes of the canarian laurel forest

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Fungal endophytes have been widely bioprospected to find new drugs and drug leads including antimicrobial agents and antifungals. However, an important role in host plant protection has been suggested for their presence and their metabolites. Therefore, nematicidal effects of their metabolites should be expected. In this work, we present a revision of the nematicidal compounds identified from endophytic fungi. Additionally, we will present the results from our ongoing search for active biocidal compounds of endophytic origin isolated from endemic plants of the Canarian laurel forest.

O26-7. Insecticide susceptibility is influenced by endosymbionts in whitefly, *Bemisia tabaci*

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The whitefly, *Bemisia tabaci*, harbours an array of endosymbionts that provide the nutritional, ecological and fitness benefits to the host. Insecticide resistance is considered to be a driving force for the geographical preponderance of whitefly genetic groups. The present study was conducted to ascertain the association of endosymbionts *vis*a *vis* insecticide susceptibility/resistance in select Asian *B. tabaci* genetic groups. A detailed log dose probit analysis was done to assess the susceptibility levels of *B. tabaci* field populations to different insecticides. Diagnostic PCR using symbiont specific primers coupled with Fluorescence in situ hybridization (FISH) analyses were done to assess the infection frequency of secondary symbionts in *B. tabaci* field populations. Results revealed that the prevalence of Wolbachia ranged from 40 to 80% with statistical significance. About 45 to 64 percent of the individuals of all test populations of *B. tabaci* were infected with Arsenophonus; However, the infection rate of Rickettsia was found below 50% in the tested samples of *B.tabaci* genetic groups. Significant differences were observed between insecticide-resistant and susceptible populations for the infection frequencies of secondary symbionts *viz*., Cardinium and Rickettsia. A strong correlation exists between insecticide resistance and infection frequency of endosymbionts, Cardinium and Rickettsia harboured by *B. tabaci* genetic groups. Our studies have demonstrated that infection frequencies of select secondary endosymbionts have been strongly associated with the susceptibility or resistance of Asian genetic groups of *B. tabaci* populations to insecticides. The impact of endosymbiont frequencies on pest management strategies of whitefly, *B. tabaci* is also discussed in this paper.

O26-8. Isolation, characterization, *in vitro* and *in vivo* studies of banana endophytes fromAssam as a potential biocontrol agents gainst *Fusarium oxysporum f*.sp. *cubense* (Foc) inciting panama wilt of banana

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Fusarium wilt of banana is a major constraint in banana production worldwide. Pathogen is a soil inhabitant and there is an urgent need to develop novel methods of plant disease management. Endophytic microorganisms (Fungi, bacteria & actinomycetes) are those that inhabit the interior part of the plants. In the present study, banana samples (leaf, pseudostem, root) were collected from different agroclimatic zones of Assam. In all, 200 bacterial endophytes were isolated from 300 processed samples by following standard protocols and they are categorised based on colony morphology and evaluated against *Fusarium oxysporum* f sp *cubense* by dual culture technique. Out of 220 candidate endophytic bacteria, only 3 bacterial species showed 60 per cent and above inhibition and other bacteria showed less than 40 per cent inhibition. Three endophytic bacteria were further evaluated for their efficacy *in vivo* and positive correlation in increase of biometrical parameters of the plants were observed. Bacterial isolates were further studied for their extracellular enzymes activities. Molecular characterization of 16s RNA region of bacteria has identified the promising endophytic bacterium as *Sphingobacterium tabacisoli*. Further endophytic bacteria also exhibited different levels of ammonia, siderophore, IAA, phospahtesolubulization and zinc solubulization. The challenge inoculation of the promising endophytes to the banana plant has shown an increase in activity of peroxidase (POD), Polyphenol oxidase (PPO) and Phenyal alanine ammonia lyase (PAL).

O26-9. Utilization of Endophytes for the management of fungal diseases of groundnut

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Fungal pathogens are one of the major constraints for low productivity and quality of groundnut. Endophytes are becoming very popular in recent years for management of biotic stress. Total of 124 fungal endophytes (28 from groundnut leaf, 35 from groundnut stem, 43 from groundnut root, 9 + 9 from ocimum stem and leaf) and 35 bacterial endophytes (7 from leaf, 16 from stem and 12 from root) were isolated from different parts of apparently healthy plants. They were evaluated against stem rot, *Sclerotium rolfsii*, root rot (*Rhizoctonia solani*) and rust (*Puccinia arachidis*) by *in vitro* and *in vivo* studies. Among the fungal endophytes, SFBeBu-18 showed maximum mycelial inhibition of *S. rolfsii*. TSFE-4 showed maximum mycelial inhibition of *R. solani* and against *P. arachidis* TSFE-7 showed maximum inhibition of uredospore germination. Among the bacterial endophytes, the maximum mycelial inhibition of *S. rolfsii* was recorded by SBDwSo-9, against *R. solani* was by RBBeJa-3. Among the 12 selected fungal endophytes evaluated against diseases, LFDwAC-7(*Nigrospora sphaerica*) showed the least disease incidence/severity of all three diseases. Among the fungal endophytes, SFDwAC-7 (*Fusarium brachygibbosum*), SFBeBu-18 (*Chaetomium globosum*) and SFDwAC-11(*Curvularia australiensis*) endophyte inoculated plants showed highest plant growth parameters against *S. rolfsii, R. solani* and *P. arachidis*, respectively. Among the bacterial endophytes, RBBeJa-3(*Bacillus megaterium*) endophyte inoculated plants showed highest plant growth parameters against all three diseases.

27. Detection and diagnosis of plant pathogens: DNA barcoding

Organizers: V K Baranwal, Rashmi Aggarwal, S C Dubey, Deeba Kamil and Dinesh Singh

Lead

O27-1. Detection and diagnosis of fungal diseases of crops: technological advancements and challenges

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Plant disease diagnostics and pathogen detection are fundamental components of successful agriculture. Management practices in crop health and food safety are critically linked with detection of plant pathogens at the early stages of the diseases. At present specific, fast and sensitive technologies, which should be simple and grower friendly, are very valuable, requiring no specialized staff for diagnosis of a disease in the field. This is essentially required in the recent scenario of changing climatic conditions, which is causing the appearance of a pathogen in areas where years ago they were unexpected. In this paper some of the diagnostic tools currently being used for fungal plant pathogens will be discussed along with some novel tools/techniques developed. Laboratory based techniques such as polymerase chain reaction, immunofluorescence, fluorescence *in-situ* hybridization, enzyme-linked immunosorbent assay, flow cytometry and gas chromatography-mass spectrometry are some of the direct detection methods. Indirect methods include thermography, fluorescence imaging and hyperspectral techniques. Biosensors based on highly selective bio-recognition elements such as enzyme, antibody, DNA/RNA etc are being developed as new tools for the early identification of crop diseases. Some of the promising techniques that can be applied to in-field molecular detection of plant pathogens and how these techniques can change the way farmers and pathologists are diagnosing plant diseases further impacts the management. Loop mediated isothermal amplification and recombinase polymerase amplification, are already being successfully used for routine diagnosis. However, most technologies still need validation in the field, where they have a promising future for in-field diagnosis when combined with simple DNA extraction methods, reagent stabilization techniques and their integration into portable devices. Further, with the increasing computational power, areas such as machine learning, image processing, deep learning, etc are also potential tools for plant disease diagnosis. In this presentation, applications of these techniques for accurate identification and quantification of plant diseases/pathogens and challenges faced shall be discussed.

Invited

O27-2. Current status of taxonomy of genus *Cercospora* in India

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Cercosporoid fungi are an assemblage of dematiaceous hyphomycetes that cause leaf spot diseases in most of the climatic zones of the globe. The genera *Asperisporium*, *Cercospora*, *Distocercospora*, *Passalora*, *Prathigada*, *Pseudocercospora*, *Scolecostigmina*, *Sirosporium*, *Stenellopsis*, *Stigmina*, *Verrucisporota* and *Zasmidium* are recognised as true cercosporoids. In the present investigation, records of all the species of

Cercospora described from India up to 2018 were revisited using global databases for fungi, *viz*., MycoBank, Index Fungorum and Fungal Names. It was found that out of 935 species of *Cercospora* described from India on around 600 hosts, only 570 species were found to have current status, and 365 species were found redundant and therefore removed from the lists. It was further observed that out of 570 species of *Cercospora*, 477 species were currently retained in the same genus whereas 51 species were transferred to *Pseudocercospora*, 24 to *Passalora*, 9 to *Stenella* and 9 to other miscellaneous genera. As observed further, two species of *Passalora viz*., *P. caladii* and *P. janseana* are now recognized as *C. verruculosa* and *C. janseana*, thus a total of 479 species of *Cercospora* were recorded in the study. Identification of *Cercospora* species based on the barcoding, host range with morphological features is yet a long way to go. Out of 479, only 47 species of *Cercospora* are sequenced and cultures of only 7 species are available in national culture repositories. An initiative should be called to resolve the chaos in the taxonomy of cercosporoid taxa from India. The species described need to be recollected from the original host and evaluated by morphology and sequence data. Inoculation tests to be conducted to confirm inferences from taxonomic studies about host specificity and their plant pathogenic behavior. Sequence data and culture deposition would enhance the value of the species description, reduces the confusion among the species, and enrich the national and international culture collection banks as well. These critical issues, which have significant importance related to plant health and quarantine, should be resolved by fresh collections from type locations.

O27-3. Challenges and opportunities of virus diagnostics in vegetatively propagated crops in resource constrained laboratories

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Viral pathogens are of great concern in many of horticultural plants because of vegetative propagation and perennial growth habits, due to which the viral load gets accumulated over the years and the polyetic viral diseases cause serious losses to the production and productivity. Therefore, use of virus free clean planting material is of prime importance to improve the quality and reduce the losses induced by viral diseases in vegetative propagated crops. ELISA and PCR/RT PCR are the two most common methods used in indexing of I viruses. For parallel detection of multiple infections of viruses in crops like grape, DNA microarray chip has been developed and several new reports of viruses and viroids have been made in India using this method. Next generation sequencing has been used for identification of several viruses/viroids in grapevine. These methods are complex, require skills and may be expensive but are highly useful for quarantine and biosecurity. Availability of polyclonal antibodies and conjugates are major constraints for development of ELISA. Expressed and purified recombinant coat protein of several viruses infecting banana, grapevine, potato and orchids has been utilized as an alternative to purified virus. The development of lateral flow assay for detection of plant viruses is a simplified and quick method but has not been very popular. The other common method of virus diagnostics has been PCR and variants of PCR based assays including IC-PCR, multiplex PCR and isothermal PCR based assays. Isothermal sequence independent rolling circle amplification has been used to detect and characterize circular DNA viruses in banana in India. PCR based assays are more sensitive than ELISA but they are laborious, time consuming and require well equipped laboratories and skilled manpower. To overcome the complexities of PCR/RT-PCR based virus detection, a novel and rapid isothermal recombinase polymerase amplification (RPA) assay has been developed which can be easily performed in less than 30 min using a very small amount of crude sap extract at a constant low temperature (37 °C - 42 °C) dispensing the use of expensive thermal cycler. RPA is superior to other isothermal amplification techniques such as loop mediated isothermal amplification (LAMP). RPA has been successfully used for detection of few plant DNA/RNA viruses and can be an ideal technique for plant virus indexing on a large scale in resource constrained laboratory. These diagnostic approaches have helped Indian agriculture to prepare for production of clean planting material. Successful implementation of virus

indexing in production of certified tissue cultured plants such as banana, potato, apple and gerbera is a testimony to application of diagnostic virus assay in Indian horticulture industry.

O27-4. Recent development in diagnosis of seed and propagating material borne bacterial diseases of plants

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Many bacterial pathogens causing diseases in plants survive on/ in seed and propagating material and serve as primary source of inoculum. A seed-borne inoculum not only secures the presence of a virulent strain of the pathogen but also favors the earliest possible establishment of the infection in early stage of the plant along with possible threat of introduction of new races or stains. Proper and correct diagnosis of the bacterial diseases plays a vital role in disease management by following procedures. Traditional methods of detection are biossays, microscopy, isolation, biochemical characterization, serological techniques, and pathogenicity techniques. Serological assays include enzyme-linked immunosorbent assay, immunofluorescence, and lateral flow strip tests or flow-through assays. Molecular techniques based on hybridization or amplification on PCR, have been developed for the most important seed and propagating material borne bacteria using sequences of most published primers based on conserved genes. Liquid enrichment also allows the detection of *Ralstonia solanacearum* in a viable but non culturable state from water samples at low temperature. When the sensitivity of detection is not good enough, for culturable bacteria, enrichment of target bacteria on semi selective media also has been used to enhance the sensitivity of PCR reactions; such test often termed BIO-PCR. This technique has been used for detection of *Xanthomonas campestris* pv. *campestris*, *X. oryzae* pv. *oryzae* and *R. solanacearum* from seeds and planting materials with greater sensitivity and specificity. Moreover, nested PCR is used generally in non culturable bacteria in which two rounds of amplification in different tubes are used. Multiplex PCR allows the simultaneous and sensitive detection of different DNA of bacteria. A multiplex polymerase chain reaction (PCR) protocol has been developed for simultaneous detection of *R. solanacearum* and *Erwinia carotovora* subsp. *carotovora* from potato tubers. Loop-Mediated Isothermal Amplification (LAMP) method proved to be the best approach for amplifying nucleic acid with high specificity, efficiency, and rapidity without the need for thermo cycling. Species-specific primers were designed by targeting the *R. solanacearum fli*C gene coding for flagellar proteins and this technique is more sensitive and require lesser time as compared to conventional PCR. The integration of different methods (traditional and innovative) depending on the particular features of each host-pathogen combination could be conveniently used in order to select only for the advantages, avoiding the limitations of each method.

O27-5. Diagnosis and management of biotic & abiotic factors through information and communication technology

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Diagnosis of disease problems is important for the farmers to go for their effective management. An attempt was made to develop ICT tools in detection, diagnosis and timely management of diseases/insect pests for crops. Diagnosis in field is mainly based on the characteristics symptoms, signs and syndrome produced by different plant pathogens/insects pests and host pathogen interactions. However, in laboratory a lot many molecular and diagnostic tools are now available to detect and diagnose a variety of plant diseases/insects pests. In Chhattisgarh, regular Agro advisories through Dept of Meteorology, in consultation with plant

protection scientists, are provided to the farmers on every Tuesday and Friday of the week. The same is communicated to the farmers though SMS sent by 26 KVKs of IGKV under our guidance and close supervision. A strong, vibrant and responsive extension system is required in order to provide a range of agricultural advisory services, which may be achieved through input agencies, large agri-business firms, farmer organisations and producer co-operatives, non-governmental organisations (NGOs), media (print, radio and television) and web based knowledge providers. The most commonly used low cost ICT tools are mobile and smart phone. The new ICT tool, which is now widely adapted by the extension personnel in rural areas of Chhattisgarh is the use Mobile Apps *i.e.* e-Crop Doctor, which can diagnose not only the diseases but also the insect pests and nutritional deficiencies in cereals, vegetables, pulses and oilseed crops. Alexnet model is a deep CNN model pre-trained on large Image Net dataset extracts different features from the image and based upon this feature, Support Vector Machine classify the images of rice diseases with classification accuracy of 91.37% based on the features extracted by Alexenet. 619 images were taken from IGKV fields for rice plants diseases including one healthy leaf class. The performance of proposed model can be further improved with large dataset of rice diseased images.

O27-6. DNA barcode, conventional and real-time PCR assay for identification and detection of major fungal plant pathogens of pulse crops

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The exchange of germplasm both at National and International levels has immense importance for their utilization in developing high yielding varieties. The germplasm exchange always has a risk of introduction of new exotic pathogens or virulent races/pathotypes/biotypes. Reliable identification and detection is essential to avoid introduction, further spread and effective management of pathogens. The conventional method of pathogens identification associated with the seeds is time consuming and tedious. DNA barcoding and molecular marker based techniques are the powerful, efficient, accurate and high throughput methods for identification and diagnosis of fungal plant pathogens. Universal internal transcribed spacer (ITS) region based DNA barcodes were developed for identification of *Alternaria alternata, A. tenuissima, Ascochyta rabiei, Fusarium oxysporum* f. sp. *ciceris, Macrophomina phaseolina, Rhizoctonia solani, Sclerotinia sclerotiorum* and *Cercospora canescens* and submitted to the Barcode of Life Data System (BOLD). The specific, highly sensitive and reliable conventional and real-time PCR assays were developed for diagnosis of the pathogens. The real-time PCR assay proved more sensitive for same-day diagnosis of fungal infection and could be used as a rapid and effective procedure for routine detection and identification of the pathogens. The labelled probes were also designed and tested for cross reactivity and sensitivity and they proved to be highly sensitive and specific. The DNA barcode and diagnostics developed are being utilized for quick and reliable detection of the pathogen, which is helpful in the early release, safe exchange and healthy conservation of germplasm during quarantine processing.

O27-7. DNA barcoding for authentic identification of agriculturally important fungal pathogens

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More diverse pathogen populations have greater evolutionary potential, with increased genetic variation, available for response to environmental change resulted in the association of multiple closely-related

fungal species with many important fungal diseases. These diseases cause severe losses to agriculturally important crops. Such related species belongs to fungal species complexes, are often morphologically very similar or even indistinguishable by eye, and consequently this can result in taxonomic confusion. To tackle these diseases, first and most decisive step is accurate identification of the causal pathogen. Routine identification of invasive fungal infections has progressed away from culture-dependent methods toward molecular techniques, including DNA barcoding, a highly efficient and widely used diagnostic technique. DNA barcoding is aimed at developing a 'biological barcode' to enable identification of any organism at the species level and it has been promoted as a powerful method for efficient, accurate and high throughput assignment of unknown specimens to known species. Fungal DNA barcoding previously relied on a single barcoding region, the *internal transcribed spacer (ITS) region*. However, this allowed only for 75% of all fungi to be correctly identified. Many other protein coding genes such as the *translational elongation factor 1α (TEF1α); large subunit (LSU), RNA polymerase II gene (RPB2), calmodulin (CAM)* etc. have been recently introduced as the secondary barcode region to address the limitations. Any of the above loci along with ITS region together form the dual fungal DNA barcoding scheme. The present study investigates the impact of the secondary barcode on the identification of many important fungal taxa that have been demonstrated to cause severe fungal diseases in plants. Analysis of the barcoding regions was performed using barcoding gap which is based on the genetic distances generated with the Kimura 2-parameter model. The secondary barcode demonstrated an improvement in identification for all the taxa which were unidentifiable only with the primary barcode; but when the secondary barcode combined with the primary barcode ensured accurate identification for all taxa analyzed, making DNA barcoding an important, efficient and reliable diagnostic toolset of complex fungal diseases.

O27-8. Detection of *Ralstoniasolanacearum* (Phylotype I) in soil by different techniques

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Ralstonia solanacearum, a phytopathogen, causes wilt in over 200 plant species and is responsible for significant economic losses worldwide. The bacterium being well adapted to life in soil necessitates the need for early and rapid detection in soil or soil related habitats to prevent crop losses and curtail the pathogen spread. Phylotype 1 strains are of Asian origin and infect many hosts in India. Different techniques *viz*., plating on selective medium, PCR and LAMP to detect *R. solanacearum* from soil were standardized and the validation using the field samples is discussed in this paper. Soil samples (n=142) were collected from infected and apparently healthy plant root zone during three crop seasons and subjected to the above techniques for detection. The highest detection percentage (83%) was observed in LAMP followed by plating of samples on selective medium (68%). On the other hand, detection efficiencies of PCR using specific primers as well as Bio-PCR were considerably lower than other detection assays. Variations in LAMP assay indicated that using a water bath to maintain isothermal conditions provided better detection efficiency. Detection of *R. solanacearum* in the soil would help in better planning of crop or variety choices and management strategies.

O27-9. Current status of nematode detection, diagnosis and pest risk analysis in India

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The first plant-parasitic nematode reported from India was the root-knot nematode of tea in 1901 by Barber. A recent estimate indicated that plant-parasitic nematodes cause an approximate yield loss of Rs 102,039.79

million (US$1577 million) to various crops in India. The top plant nematode threats to Indian agriculture are *Meloidogyne* spp., *Rotylenchulus reniformis*, *Globodera* and *Heterodera* spp., *Pratylenchus* spp., *Aphelenchoides besseyi*, *Ditylenchus angustus*, *Radopholus similis*, *Tylenchulus semipenetrans*, *Hirschmanniella* spp., *Helicotylenchus multicinctus* and *Tylenchorhynchus brevilineatus*. Also, two extremely dangerous nematodes not present in India are pinewood nematode (*Bursaphelenchus xylophilus*) and red ring nematode of coconut (*B. cocophilus*). Nematodes are detected by plant symptoms, diagnosed by analysis of soil or plant tissues, and their identity is ascertained by either morphological or molecular methods. Most nematode diagnosis labs can identify the above nematodes by morphological methods and molecular markers such as ITS, LSU, SSU, D2/D3 or *cox-1* barcodes. In recent years, rice root-knot nematode, *M. graminicola* has emerged as a serious threat to rice crop in all rice-growing regions of India. In parallel, despite the domestic quarantine, the potato cyst nematodes (*Globodera pallida* and *G. rostochiensis*) have been recently reported from some potato growing hilly regions of India. These instances are worrying because the spread of these nematodes happened despite the technical knowhow and advances in nematode detection and diagnosis indicating a systemic failure in containing these nematodes. The pest-risk analyses for major nematode pests of crops for India are lacking and must be done to prevent and contain any future threat of nematode-pest.

O27-10. Impact of diagnostics and phytosanitary regulations in biosecurity against transboundary plant viruses

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The global trade of agri-horticultural commodities and exchange of germplasm have the potential to introduce new viruses, which may pose potential risk to the agriculture. The increasing numbers of plant viruses discovered in the last 15 years has increased the requirement for countries to protect crops from exotic viruses. Imported germplasm material including transgenics are quarantined at ICAR-National Bureau of Plant Genetic Resources. As per the Plant Quarantine (Regulation of Import into India) Order 2003, 264 viruses are regulated pests for India. Sensitive and accurate diagnosis is necessary for virus detection in quarantine. Combination of ELISA and PCR technologies are used to improve sensitivity of detection and to avoid problems during PCR with inhibitors. Attention is now given to techniques like Multiplex-PCR, Real-time PCR, LAMP, HDA, etc. LAMP and HDA are isothermal DNA methods, which do not require a thermal cycler and has potential applications in quarantine. Adopting post-entry quarantine growing/inspection followed by use of serological and molecular techniques, 45 viruses including 19 viruses not reported from India were intercepted in imported germplasm including transgenics during last two decades. As an example, *High plains virus* (HPV), not reported from India, was intercepted in exotic germplasm of corn from France and USA. If introduced, HPV would have caused annual yield loss of Rs.3166.3million, with the incidence of 1%. India needs to establish a network of interconnected diagnostic laboratories and strong surveillance programme to identify new viruses. Adopting appropriate technique for virus detection and stringent quarantine would ensure biosecurity against transboundary viruses.

O27-11. DNA macroarray for rapid detection of plant fungal pathogens

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In plant disease management, rapid and accurate detection, and identification of pathogens is necessary before any effective control measures can be recommended. Conventional method of disease diagnosis *via*

morphological characterization is tedious, time consuming and requires extensive taxonomical knowledge. DNA macroarray system, which utilizes dot-blot hybridization mechanism provides a high throughput, rapid and accurate alternative detection method. Furthermore, a chromogenic detection simply conducted on a bench provides a convenient alternative for researchers with no access to X-ray film developing facilities, specific CCD cameras or Chemidoc XRS systems to conduct chemiluminescent detection. In this study, four specific oligonucleotides were designed for each fungal and oomycete species based on ITS region of the 18S rRNA gene for the production of array on a nylon membrane. Fragment of ITS region from each fungal and oomycete species was PCR amplified, simultaneously labelled with digoxigenin (DIG) and hybridized to the respective oligonucleotide array. Hybridization signals were visualized using chromogenic method via incubation with anti-DIG antibody conjugated with alkaline phosphatase and NBT/BCIP substrates in comparison to chemiluminescent detection using DCP-Star and X-ray films. Two DNA arrays were successfully developed: 1) an array of 120 oligonucleotides for the detection of 30 species major fungal and oomycete pathogens of solanaceous crops and 2) an array of 20 oligonucleotides for the detection of 5 species leaf fungal pathogens of nursery oil palms. Chromogenic detection was shown to yield comparable results with chemiluminescent detection in regard to signal specificity, duration of hybridization between the array and targets, and cost.

O27-12. On-site detection of plant viruses to ensure quality planting materials in vegetatively propagated horticultural crops

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Plant viruses cause serious diseases that lead to significant production and economic losses in the agriculture and horticulture industries worldwide. Seed is a propagating material in most of the crop plants, whereas most of the horticultural crops are vegetatively propagated. Horticultural crops like banana, potato, bamboo, citrus, and grapes; commercial crops like sugarcane, black pepper, cardamom, orchids, and bulbous ornamentals; and tuber crops like cassava, yam, etc., have been known to be infected by a range of viruses that belong to different genera and families. In these crops, the primary mode of transmission of viruses is through infected plant propagules. Enzyme-linked immunosorbent assay or polymerase chain reaction has been widely used for detection of plant viruses. However, these methods are complicated and laborious; they require qualified personnel, expensive equipment and well-equipped lab facilities. On-site diagnosis of plant viruses can help the growers and tissue culture firms for timely decisions. For on-site based on molecular detection, sensitivity, specificity, robustness, and efficiency are crucial factors for consideration. The promptness and sensitivity of these methods can help growers avoid potential secondary infections. There has been tremendous advancement on the early diagnosis using on-the-spot diagnostic tools such as lateral flow immunoassay, loop-mediated isothermal amplification, recombinase polymerase amplification and multiplex technologies like microarray, microsphere immunoassay, nanopore based detection etc. In this talk, the development of on-site detection tools for the plant viruses with more emphasis on clonally propagated horticultural crops shall be presented and discussed.

O27-13. Development of early detection assays for the fungal pathogens of rice

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Rice (*Oryza sativa* L.) is one of the important staple food crops for a large part of the world's human population. Rice crop is susceptible to many diseases. Bakanae caused by *Fusarium fujikuroi* (Nirenberg) is an emerging disease of rice in India. Sheath blight caused by *Rhizoctonia solani* Kuhn has been considered to be second most important disease. Correct diagnosis and identification of the pathogen is the key to the successful management of plant diseases. PCR based detection marker $BMFf_{1900}$ (Genbank accession no. KY953210) was developed for the detection of *F. fujikuroi*. For precise quantification of the inoculums, real time primers (NRPS31RT-F and NRPS31RT-R) were designed and sensitivity of the assay was increased to 10 fg. Loop mediated isothermal amplification (LAMP) based colorimetric detection assay was developed and standardized for the detection of *F. fujikuroi* DNA. These PCR and LAMP based assays have been validated under field conditions, seed testing and in resistance evaluation of rice genotypes. Similarly, PCR and LAMP based detection assays were developed for the detection of different anastomosis groups (AG1-IA and AG2-2) of *R. solani* of rice. The diagnostics developed are efficient, rapid and sensitive for the detection of *F. fujikuroi* and *R. solani*, which would be useful for testing seed health, validating varietal resistance and monitoring the pathogen inoculum.

O27-14.Robust and simplified diagnostics for emerging virus and virus-like pathogens infecting major horticultural crops in North-East India

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Virus and virus-like pathogens are the major constraint in production and productivity of horticultural crops in North East region of India. Present study focused on development and validation of simplified and robust detection systems for major and emerging viruses and virus-like pathogens infecting diverse horticultural crops in the region. Simplified multiplex diagnostics were developed for the simultaneous detection of *Chilli veinal mottle virus* and *Cucumber mosaic virus* infecting chilli in North East India. A simplified template preparation using crude sap extract of plants in isothermal recombinase polymerase amplification (RPA) was developed for the detection of potyviruses infecting passion fruit and chilli. Similarly, the robust RPA assay for detection of huanglongbing-associated *Candidatus* Liberibacter asiaticus and *Citrus tristeza virus* were developed using crude sap of infected citrus plant as template. Crude sap from infected citrus leaves extracted in simple buffers was best suited for the simplified detection of these virus and virus-like pathogens. Developed RPA assay could detection the target pathogens up to 10^{-7} of crude sap dilution and was as sensitive as bench mark PCR. These assays were validated using large number of field samples and found highly robust. Developed detection assays will have applications in routine indexing and production of virus-free planting materials in the region.

28. Artificial intelligence (AI) based smart plant protection – futuristic scenario

Organizers: *P Krishna Reddy,Padmavathi, Jagdeeshwar and Katti Gururaj*

Lead

O28-1. Building a smart phone based field diagnosis guide for farmers by extending the concept of generalization

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Indian farmers are facing difficulty in acquiring actionable agricultural advice in a real-time manner from call centers and web portals due to communication and perceptual issues. The radio, video, SMS and voice-based services push generic information to farmers. The farm specific advisory systems like eSagu suffers from scalability issues. To enable the farmer to get the actionable agro-advisory, we are making an effort to build a smart-phone based Field Diagnosis Guide, which we named as "Crop Darpan" by extending the concept of generalization. It is assumed that the farmer possesses a smart phone with internet connection and visits the field. Being semi-literate, a farmer is able to identify the generalized visual perceptions (or symptoms) of the crop. The low-level visual perceptions of field problems of the given crop can be collected from subject matter specialists. The proposed Crop Darpan contains a hierarchy of visual perceptions of field problems that consists of generalized, middle-level, and lower-level perceptions. A prototype was built for a cotton crop (www.cropdarpan.in) in English and Telugu languages. It was found out that the farmers are able to identify the field problem with the Crop Darpan system.

Invited

O28-2. Predicting the introduction, spread and impact of invasive pests: the evolution of regulatory pest informatics

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A major pathway for the introduction of exotic invasive pests that impact the agriculture and natural resources of a region is through international trade of agricultural commodities and planting materials. Therefore, it is important to predict the likelihood that a pest may enter, establish and impact a new area. This knowledge allows allocating the right amount of resources to identify and stop these pests before they reach or establish within our borders. In this presentation, we will discuss pest forecasting systems that use information on pest biology, crop phenology and distribution, high-res satellite images and climate data, and the path forward in this new era of big data and artificial intelligence.

O28-3. Application of artificial intelligence and IoT in rice pest management

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Artificial intelligence (AI) holds the promise of driving an agricultural revolution for producing more food using fewer resources. Rice is the major crop in India and biotic stresses play a crucial role in limiting the rice production. Farmers often face critical situations for diagnosis and management of several pests. Integrated pest management practices need to be employed harmoniously to meet the above challenges. Recent Advancement in AI and Internet of Things (IoT) opened up many opportunities to fulfill the needs of farmers for up-to-date and precise information. Web based Rice Expert System has been developed to diagnose pest and disease problems and recommend management practices at field level. In this system, knowledge base contains general decision rules that represent the knowledge of experts on pests and diseases. It has 90 rules for identifying insect pests and 105 rules for identifying diseases. Beside this, one attempt was made to find out the influence of weather parameters on pest infestation using machine/deep learning algorithms. Further working on integration of wireless weather sensors with AI tools to generate forewarning alerts and precautionary measures. After few years sensors data will be trained and an intelligent mobile app with cloud database will be developed for real time pest identification and management and updated from time to time automatically.

O28-4. OPTIMA-Optimised integrated pest management for precise detection and control of plant diseases in perennial crops and open-field vegetables

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OPTIMA develops an environmentally friendly IPM framework for vineyards, apple orchards and carrots that includes all critical aspects related to integrated disease management, such as i) novel bio-PPPs, ii) disease prediction models, iii) spectral early disease detection systems and iv) precision spraying techniques. It will contribute to the reduction of the European agriculture reliance on agrochemicals resulting in lower residues and reduced impacts on human health. OPTIMA (http://optima-h2020.eu) will 1) optimize disease prediction models for grape downy mildew, apple scab and Alternaria leaf blight in carrots to envisage faster disease outbreaks and develop advanced early detection methods based on spectral imaging and deep learning techniques to precisely localize and quantify the infection, 2) evaluate biological and synthetic PPPs for their combined ability to control the selected diseases and assess the optimum dosage and application timing and identifying and characterize induced host resistance mechanisms to achieve higher and durable resistance, 3) enhance and develop three innovative prototype sprayers (for carrots, apple orchards and vineyards) actuating different nozzle types and adopting variable rate control based on canopy characteristics, the pathogen

dispersal and disease development, 4) test and assess the holistic developed IPM system in field conditions with the three selected crops. The advanced sprayer prototypes and the monitoring system will be tested in real-time to record field efficacy and potential discrepancies from the expected effectiveness, 5) assess health, environmental and socioeconomic impacts of the proposed IPM system in comparison to conventional systems using an extended Life-Cycle approach integrated with human and environmental risk assessment.

O28-5. AI initiatives in plant protection in India

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Increasing population, food and nutritional security concerns along with climate change effects have forced Indian Agriculture for searching more innovative approaches for increasing crop yields. Recent advances in Artificial Intelligence (AI), big data analytics and Internet of things (IoT) are becoming major driving forces for providing digital solutions in agriculture in general and plant protection in specific. At present, the most popular AI initiatives in plant protection include pest identification/ diagnostics, early detection of pests, pest prediction along with advisories to farmers on their mobile phones. Crop specific expert systems were developed for almost all the crops based on response to query and solutions were provided to farmers directly. Currently, image based pest identification is being provided based on machine learning (ML) techniques through various apps in India. Pest monitoring and forecasting is also being done using AI & ML approaches with data on pest occurrences, weather parameters, growth stage of the crop in the field for pest prediction that helps in timing the insect activity for decision making in pest management. Drones are being used for precise and accurate delivery of pesticides. Remote sensing techniques along with hyper spectral imaging by satellites powered with AI algorithms can be used to monitor crop health. Thus, AI applications help farmers to avoid losses from pest attack and thereby increase crop yields through smart decision making.

O28-6. Artificial intelligence (AI) tools for pest identification and prediction in rice

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Insect pests are one of the key biotic constraints affecting rice crop resulting in yield loss of about 20 -25%. Farmers are having a lot of trouble in identifying damage symptoms and insect pests because of which their management is becoming a problem. We developed an app called “Avishkar”, which identifies pests based on the image classification patterns. Correct diagnostics play a major role in the management of pests in rice. After identification, the app also provides farmers with IPM strategies to be followed for efficient management of the pest. The time of activity of a given pest can vary greatly from region to region and from year to year. Understanding the influence of temperature on insect development helped in predicting their seasonal occurrence. In this study, we selected major rice growing areas in India and using data on weather parameters for > 20 years developed a machine learning model. Based on insect development at constant temperatures, threshold temperatures were estimated using thermodynamic SSI model. Using these temperature constants and biofix (first appearance of pest) in the field at that region, pest activity was predicted and advisories were being provided to farmers. These AI and machine learning technologies are being used as a part of decision support system (DSS) to help rice farmers predict pest occurrence to initiate scouting or timing the pesticide application. Such tools are needed in India for informed IPM decisions to reduce yield losses due to insect pests and to enhance rice productivity and profitability.

O28-7. Android application that uses artificial intelligence to diagnose diseases and monitor them real-time

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Information and communication technologies were revolutionized after the rise of smart phone usage around the globe. Numerous applications are now available for users with innovations in applications on artificial intelligence. Artificial intelligence in the field of agronomy and specifically in plant protection has been demonstrated from all around the globe. In this, we focus on a German startup, PEAT, which introduced 'Plantix', an android application for smart phones to diagnose pest/ disease and nutrient deficiencies. Plant damage symptom images taken by a smartphone user are uploaded using mobile internet. The image is processed using machine learning software through deep neural networks to determine the identity of the disease. The user gets back the feedback within few seconds diagnosing the disease related to the damage symptom and an advisory to manage their losses in terms of cultural, biological and chemical control measures. Over 385 disease and pests are now detected by Plantix app and as all images are geo-time tagged, it is possible to generate and visualize disease spread on a heat map in real-time. Recently, Plantix app was useful in monitoring of a recently introduced invasive pest, the fall armyworm (*Spodoptera frugiperda*). This was possible with collaborations of PEAT with ICRISAT, CABI and the Agricultural department teams in Andhra Pradesh and Karnataka. A live tracker is available online at https://plantix.net/en/live/fall-armyworm. There is potential in the future to develop mathematical models for predicting pest and diseases by combining weather and soil data.

O28-8. Power in your hands – ADAMA's farmer app – REACH

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Farming in India is changing rapidly in some parts of the country and now farmers would like to have more information at their finger tips to make informed decisions. New crop of farmers seem to come from entirely a different background and would like to take the farming to the next level, making it more attractive personally and financially. ADAMA India is in the forefront to support this initiative and has launched a farmer friendly app called REACH. In simple words – its POWER IN YOUR HANDS – for the farmers. The app aims to provide all latest and needed information at the finger tip of the farmers to make their decisions and guide them properly at every moment of their crop production life cycle. It provides details of the product, crop calendar, package of practices, *Mandi* prices etc. It also enables the farmers to solve their queries INSTANTANEOUSLY by sending their queries either through text, or photos, or videos and get answer. REACH is supported by a strong back end office – Farmer service centre, which helps the farmer to get answers for their problems through dedicated agri professionals. It has also personal visit services as the case is. All this is possible at their finger tips through REACH. We expect to include various other services to make the farmer app REACH as one of the apps where farmer can rely upon for their crop protection needs.

O28-9. Spatio-temporal prediction of pest attack in India

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Pest infestation causes losses in fields especially to small-scale farmers whose livelihood depends upon the produce from their fields. It becomes imperative to predict when and where pest attack can occur next so that early preventive measures can be taken. Here, we take Fall Army Worm (FAW), *Spodoptera frugiperda* attack in India as a case study. In 2016, it spread from Latin America to Africa and Asia. In India, it was first reported in Karnataka in July 2018. Since then it has already gripped 8 states. It becomes important to predict where it might hit next and also predict the severity levels. Most of the studies have been around predicting migratory routes of pests. These studies are, however, specific to the pest in consideration. In this study we have tried to build Machine Learning (ML) models that can be deployed to predict the spread, agnostic of the pest. This study uses time-series data that were agronomist verified from the Plantix database for FAW attacks, historical weather information and the geo coordinates of non-hit Indian states. The worm can affect 80 different plant species but rice and maize being its preferred crops, additional categorical information pertaining to the state's type of crop preference was also added. The location (spatial) and the time of hit (temporal) are responses to be predicted making it a multivariate problem. Multiple ML models like linear algorithms like Regression and tree-based algorithms like Random Forest were trained but they cannot exploit the seasonal trends in the data. Thus, for time-series analysis we build a Multivariate Autoregressive Integrated Moving Average (MARIMA) on the training data. As the latitude and longitude coordinates cannot be used directly as features, these coordinates had to be feature engineered to distance and bearing. The distances were calculated keeping Karnataka as reference point. The distance and bearings gave more accurate results with lower Mean Absolute Error and significantly higher correlation between predicted and the ground truth values.

O28-10. Classification of biotic and abiotic stresses on grape berries using deep learning convolutional neural networks

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Grape farming is one of the most lucrative agricultural enterprises in India. There are several biotic and abiotic stress conditions that may adversely affect the yield if not tackled at the right time. It is crucial that the farmer is able to correctly identify and monitor the type of stress so that steps can be taken to prevent undesirable outcomes. We have gathered a dataset of these stress conditions on grape berries and categorized them into eight classes, necrosis, shrivelling, honeydew by mealybug, mealybug incidence, spray injury, thrips scarring, pink berry, and powdery mildew. Pictures of stress conditions on the grapes were taken from experimental vineyards of National Research Centre for Grapes in Pune, India. The pictures were taken between mid-February and early April when the berry stage ranged from veraison to maturity. Transfer learning was used to test the performance of six major deep learning image classification convolutional neural network architectures (namely MobileNet-v2, Inception-v3, Inception-ResNet-v2, ResNet-v2, NASNet, and PNASNet) with variations in training conditions and hyper parameters. The results were compared in order to determine the most feasible and accurate deep learning architecture and its hyper parameters for the given problem statement. The experiment shows that Inception-ResNet-v2 obtained maximum classification accuracy of 88.75\% when learning rate of 0.035 and minibatch size of 10 were

applied using 8000 training steps. This result will act as a pre-requisite for the development of an application for mapping vineyard stress conditions on berries and give automated advisory.

O28-11. Fitting of arimax-ann hybrid model to forecast the damage caused by yellow stem borer (*Scirpophaga incertulas*) in Telangana State

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Agriculture plays a vital role in Indian economy. Among the cereals, Rice has shaped the culture, diet and economy of thousands of millions of peoples. The total Rice production in the world is 488.60 million metric tonnes as estimated by the United states Department of Agriculture in November 2017 (USDA). India ranks second in rice production in the world with the production of 165.3 million metric tones. In India, rice productivity is low due to vagaries of monsoon, poor soil fertility, undulating topography, biotic stresses and lack of adoption of improved technologies. Among the biotic stresses insect pests constitute the key factor. In Telangana state, among the key insect pests of rice, yellow stem borer (*Scirpophaga incertulas*) is one of the pests, which causes major damage to the crop yields. In this study, two time series forecasting models, Artificial neural network (ANN) and ARIMAX-ANN Hybrid models were compared to forecast the damage caused by yellow stem borer during both *Kharif* and *Rabi* seasons of Telangana state. To compare the effectiveness of these two models, 27 years data of both *Kharif* and *Rabi* seasons pertaining to Telangana state was used *i.e*., from 1990-2016. The results showed that the ARIMAX-ANN Hybrid model outperformed the ANN model.

29. Taxonomy and diversity of pest populations

Organizers: Mukesh Dhillon and Mamta Sharma

Lead

O29-1. Genetics of diapause in spotted stem borer, *Chilo partellus* (Swinhoe)

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Diapause is an endocrine controlled arrested metabolic activity to delay development or reproduction under unfavorable conditions. To gain an understanding on importance of diapause for ecological adaptation, it is important to study diapause regulation in insects. We examined genetics of diapause in *Chilo partellus* using five parental populations viz., hibernating (HD), aestivating (AD), post-hibernating (PHB), post-aestivating (PAB), and nondiapause (ND) for making crosses in all possible combinations including reciprocals in a diallel fashion. Data were recorded on fecundity, egg hatching, larval survival, diapause induction and termination and adult emergence in the parents (P1, P2), F1 hybrids, and the reciprocal crosses. Genetic analysis showed that AD strain is general combiner, which also improved egg hatching, larval survival, diapause termination and adult emergence. The HD strain increased incidence of diapause in F1 hybrids. Incidence of diapause was highest in HD × AD, whereas termination was greatest in PHB × AD. However, ND strain and its reciprocal crosses with other strains did not exhibit any noticeable developmental response associated with diapause. Specific combining ability analysis revealed that pre-existence of PHD and ND or AD and PAD populations under unfavorable conditions might result in drastic reduction in active population, while co-existence of PHD and AD populations might reduce diapause incidence, increase survival and faster multiplication of their progenies resulting in outbreak of *C. partellus*. Degree of dominance estimates revealed that diapause and associated traits in *C. partellus* are governed by overdominance gene effects, and mainly depends on parental diapause history.

Invited

O29-2. Dire need of biodiversity studies in the midst of "sixth mass extinction": challenges in Indian pretext with vivid examples

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The dreadful climate change is leading to 'biological annihilation' at a very rapid rate in this Anthropocene era. As presumed, this impact is going to be harsher and more rapid in tropical regions. Apparently, the biodiversity is well studied, documented and preserved in the west than in India. We are already in the midst of "sixth mass extinction" without even having the knowledge of what and how many species are getting extinct or getting evolved! Current knowledge on many taxa from India is diminutive when compared globally. For instance, Braconidae- the second largest family of wasps though of enormous agricultural and ecological importance, remains poorly documented. The arbitrary global diversity estimates of total valid species described to date is 18,000. Perhaps barely 3,000 species are known from Asia (tropical), approximately 1,100 species from India, as compared to 17,000 species from Africa and 11,000 species from the Neotropics. In this deplorable scenario, are we in a position to ascertain species dynamics and interactions of the lost ones when we were totally unaware about their existence! This presentation would highlight how

more than a decade of taxonomic research, many times integrating three different sets of data (morphology, host records and multiple genes), helped to generate accurate boundaries between species/species-groups of many wasp taxa from different geographical regions which led to the discovery of more than 50 new species to science. Biodiversity documentation with core emphasis on bio-systematic studies needs to be focused ardently if we pretend to be anxious about its conservation!

O29-3. Genetic and toxicological variations in an insecticidal binary-toxin 'Photox' from Indian Photorhabdus bacteria

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Insecticidal protein-toxins, for e.g. Cry toxins, have been successfully used for the management of insect-pests of crops. *Photorhabdus* bacteria are symbiont of entomopathogenic nematodes of the genus *Heterorhabditis*. *Photorhabdus* genome encodes for several secondary metabolites and insecticidal protein-toxins. Photox is a 46 kDa binary-toxin of mono-ADP-ribosyl-transferases (mARTs) enzyme class, and is known to kill insects of up to 25 different orders. We investigated the genetic and toxicological variation in Photox toxin isolated from seven *Photorhabdus luminescens* strains (IARI-SgMg3, IARI-SgGj2, IARI-SgHr2, IARI-SgHr4, IARI-SgMs1, IARI-SgLdk1, IARI-SgHp1) isolated from *Heterorhabditis* species collected from different geographical regions of India. The nucleotide sequence of Photox from Indian *Photorhabdus* was 951 to 960 bp long and showed considerable differences from the *Photorhabdus* luminescens ssp. *laumondii* TTO1 Photox gene which was 1227 bp long. The Photox gene from each of these strains was cloned into pGEMT Easy vector in *E. coli* DH5α. Rapid Virulence Assay (RVA) confirmed the toxicity of Photox on *Galleria melonella*. Photox from IARI-SgHr4 was identified as the most toxic in RVA. Injection of purified Photox protein confirmed that IARI-SgHr4 and IARI-SgLdk1 were the most pathogenic Photox variants against insect *G. mellonella*. This hypertoxic Photox variant may be introduced into commercially valuable crops through transgenic approaches for sustainable insect-pest management.

O29-4. Systematic notes on species complexes in tribe *Dacini* (Diptera: Tephritidae: Dacinae)- an Indian perspective

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Fruit flies of tribe Dacini are one among the major threats to horticultural crops as many of them are pests of quarantine concern across the world. Four species complexes have been recognised in Dacini by Drew and Romig (2013, 2016), namely *Bactrocera dorsalis*, *B. nigrotibialis*, *Zeugodacus scutellaris* and *Z. tau* complex with 85, 15, 20 and 26 described species, respectively. Of these, three species each in Z. tau and *B. nigrotibialis* complex; four species in *Z. scutellaris* and 14 species in *B. dorsalis* complex were recorded from India (Drew and Raghu, 2002; David and Ramani, 2019; David et al., 2017). Precise identification of the members in these complexes have been a perplexing task for even trained taxonomists as most of the external morphological characters used to delineate them are highly homoplasious. In this study post abdominal structures of males and/or females of eleven species of *B. dorsalis* complex, two species of Z.tau complex, three species each of *B. nigrotibialis* and *Z. scutellaris* complex have been studied and illustrated to demonstrate the utility of characters in precise identification. Combination of characters like spicule pattern of eversible membrane and shape of aculeus tip in females; shape of sternite V, epandrium, length of anterior

surstylus and dorsal sclerite pattern of glans in males were found to be effective in screening cryptic species in these complexes. Apart from these, phylogenetic analysis of species of these complexes were undertaken using morphological characters by Tree Analysis using New Technology (TNT) to study the relationships among them.

O29-5. Characterization, genetic diversity and reproduction potential of South African *Meloidogyne* spp

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Root-knot nematodes (RKN) are an economic important nematode pest worldwide. A survey was conducted to elucidate the identity (using morphological and molecular techniques), genetic diversity and reproduction potential of 37 South African RKN populations. Morphologically, the presence of *Meloidogyne enterolobii*, *M. hapla*, *M. incognita* and *M. javanica* was confirmed. Although three perineal-pattern characteristics were useful in discriminating between *M. enterolobii* and *M. incognita* females, most morphometric characters overlapped among the species. Molecular characterization using the D2-D3 and COI genes were appropriate only for accurate identification of *M. enterolobii*. Conversely, SCAR-PCR and the NADH5 gene discriminated accurately among the species. For genetic diversity, 653 common single nucleotide polymorphisms (SNPs) were identified using genotyping by sequencing and compared single-species populations of the species at genetic level. Principal component and phylogenetic analyses grouped the *M. enterolobii* and *M. javanica* populations in different clades, showing a distant relation. Alleles (e.g. a serine/threonine phosphatase and zinc finger) identified only occurred in the genome of *M. enterolobii* and are located in genes involved in virulence. Greenhouse-study results indicated that a mixed community of *M. enterolobii* and *M. javanica* (Rf = 15.7), and a pure population of *M. javanica* (Rf = 19.1) had the highest reproductive potential (initial and repeat experiments). However, a pure population of *M. enterolobii* had the lowest Rf values in the initial (Rf = 1.0) and repeat (Rf = 6.1) experiments. Data generated are novel and crucial to develop and apply effective control strategies against these RKN species.

O29-6. Biology and host range studies indicate invasive potential of the alien mite species, *Tetranychus okinawanus* (Prostigmata: Tetranychidae) Ehara in Kerala

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The spider mite, *Tetranychus okinawanus* was recently recorded on an ornamental plant, *Adenium obesum* in Thrissur district, Kerala for the first time in India. The mite, first reported on *Pueraria lobata* from Okinawa Islands of Japan during 1995, is now known from Japan and Taiwan on more than 90 host plants. Studies were conducted on the host range and biology to assess the invasive potential this alien mite species in the new environment. Field survey and collection of spider mites from Thrissur and neighboring districts during 2016-18 recorded the occurrence of *T. okinawanus* on 13 different plants viz., cucumber, papaya, ashgourd, brinjal, cowpea, banana, Gerbera, tulsi, amaranthus, marigold, Ipomea, balsm and orchid in addition to *Adenium*. Biology of *T. okinawanus* was studied in the laboratory following leaf disc method. The mite recorded an incubation period of 2.9 and 3.2 days respectively for male and female. Male and female mite recorded larval period of 0.95 and 0.97 days, protonymphal period of 0.98 and 1.00 days and deutonymphal

period of 1.97 and 2.02 days, respectively. Male recorded a total developmental period of 7.27 days, while female recorded 7.74 days. Mated and unmated female recorded fecundity of 101.33 and 73.50 eggs, respectively. Adult recorded longevity of 7.40, 10.65 and 13.38 days, respectively for male, mated female and unmated female. Several new host records, short developmental period and high reproductive potential of *T. okinawanus* brought out in the study is indicative that the alien mite has potential to become invasive.

O29-7. Identification of shoot fly, *Atherigona species* from India

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Shoot fly maggot damage i.e. drying of central shoot, called dead-heart was collected from different parts of the country. Among fifteen, two species belong to *Acritocheata* viz., *A. orientalis*, *A. daviesi* and other thirteen species belonging to *Atherigona*.subgenus are from different parts of India viz., *Atherigona falcata*, *A. approximata*, *A. pulla*, *A. reversura*, *A. simplex A. soccata* and *A. naqvi* on barnyard millet, foxtail millet, little millet, sorghum, kodo millet sorghum and wheat, respectively. Few specimens were collected on grassy species viz., *A. sigma*, *A. reddyi*, *A. kappa*, *A. attripalpis*, *A. hylinipennis* and one unidentified specimen. Presence of presutural acrostichal setae often in 4-5 rows at suture and cross vein r-m usually at or beyond middle of cell dm in subgenus *Acritochaeta .orientalis* Schiner while in subgenus *Atherigona* species have presutural acrostichal setae often in 2-3 rows at suture and cross vein r-m always well in basal half of cell dm. Male genitalia characters are widely recognised as being the variable and divergent of all morphological structures. Trifoliate process is entirely absent in *Acritocheata* whereas it is the main diagnostic character found in *Atherigona*. *A. pulla* has a clear bifurcated hypopygial prominence; trifoliate process with median piece equals to length of parameres. Broad and flat parameres are seen in *A. falcata* and trifurcated hypopygial prominence and parameres with inner lobe is present in *A. reversura*. Other three species vary in length of median piece, shape of the parameres and number of setae on the tip of median piece.

O29-8. Status of pink bollworm, *Pectinophora gossypiella* (Saunders) resistance to Bt cotton in India

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India is a global leader in the area under cotton while it ranks at second position in production. More than 88.13% of the area under cotton is being cultivated with (Boll- II) Bt cotton hybrids. Since 2010, five years after introduction of BGII, reports of Pink Bollworm (PBW) *Pectinophora gossypiella* (Saunders) PBW infestation on BG-II was observed. The incidence was confined in Khandesh region of Maharashtra and Saurashtra regions of Gujarat where farmers extended the cotton crop till May in 2010. PBW larval incidence on Bt cotton was nil in Northern India but in Central and Southern India, the annual average PBW larval recovery from BGII cotton was high at 28.85–72.49% during 2014–2017. In Central and Southern India, LC50 of Cry1Ac increased from a mean of 0.330 µg mL^{-1} in 2013 to a mean of 6.938 µg mL^{-1} in 2017. The LC_{50} value for Cry2Ab increased from a mean of 0.014 µg mL^{-1} in 2013 to a mean of 12.51 µg mL^{-1} in 2017. High PBW larval recovery on BG-II in conjunction with high LC_{50} values for Cry1Ac and Cry2Ab in major cotton-growing districts of Central and Southern India provides evidence of field-evolved resistance in PBW to BG and BGII cotton. The LC_{50} of Cry1Ac and Cry2Ab has declined during (2018-2019) due to implementation of Insecticides Resistance Management strategies (IRM) strategies.

O29-9. Biodiversity and community structure of soil biota in relation to SOC in subtropical sugarcane production system

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Soil micro-faunal and floral diversity helps in pedoturbation, humification and nutrient mineralization in soil. Decline in soil organic carbon is directly linked to the loss of soil biodiversity. Like any other intensive agriculture system, sugarcane cultivation may have impact on soil in terms of quality and biodiversity. In this study community structure of soil arthropods and microflora of sugarcane was assessed in relation to nutrient management, initial SOC level. Also, some uncultivated habitats like grass, grass + tree and forest were observed. The Acari were represented by 42 families and Collembola represented by 14 families. Population of microbes i.e. Trichoderma and fluorescent Pseudomonas ranged from 0.8×10^3 to 5.0×10^3 cfu g^{-1} soil and 2.2×10^7 to 16.8×10^7 cfu g^{-1} soil, respectively. The soil pH and EC ranged between 7.0 to 8.0 and 0.12 to 0.28 dSm^{-1} among systems while, SOC ranged from 0.43 to 1.27 percent. In high SOC (>0.8 %) micro-arthropods were higher in number (22.12×10^4 m^{-2}) and more diversified (20 species) than low SOC (< 0.50 %) soils (9.59×10^4 m^{-2}; 6 species). In general, predatory arthropods were more in sugarcane trashes than soil. Micronutrients analysis indicate that soil disturbances effect micronutrient contents of soil as Cu, Mn, Fe were lower in sugarcane soils (0.84, 10.11, 6.95 ppm respectively) than uncultivated fields (2.42, 65.70, 14.88 ppm respectively).

O29-10. Diversity of plant-parasitic nematodes associated with Khasi mandarin in Assam, India

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A systemic investigation was undertaken in Kamrup (R), Kamrup (M), Tinsukia and Biswanath districts of Assam to assess the diversity of plant-parasitic nematodes from the soil rhizosphere of Khasi mandarin growing regions. Total five species of plant-parasitic nematodes were encountered viz., *Tylenchulus semipenetrans*, *Helicotylenchus dihystera*, *Hoplolaimus indicus* and *Tylenchorhynchus* sp. and *Heterodera* sp. In addition to these, several dorylaimid, rhabditid and predatory nematodes were also encountered. Amongst the plant-parasitic nematodes, *T. semipenetrans* was highly abundant (100%) followed by *H. dihystera* (87.5%), *Tylenchorhynchus* sp. (54.15%). The absolute density of *T. semipenetrans* was maximum (42.22) followed by *H. dihystera* (16). While, *Pratylenchus* sp., *Heterodera* sp. and *Hoplolaimus indicus* were the least abundant.

O29-11. Variegated *Alternaria alternata*: identification, pathogenic capacities and management strategies

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Small-spored species of the fungal genus Alternaria are very common over the world. Taxonomy of this group has not still been completely developed regardless extensive use of molecular phylogenetic approaches.

Usually these fungi subsist as saprobes colonizing many various plant substrata. At the same time *A. alternata* or other related species are frequently reported as a cause of diseases of potato, apple, wheat and many other plants. A considerable number of works has been done since 1990th on pathogenicity and nature of pathogenic properties of small-spored Alternaria species. Several causes leading to acquiring pathogenic capacities have been found. Small-spored *Alternaria* strains can colonize old or damaged tissues which can be easily mortified. Several *Alternaria* pathotypes obtained genes for a decade of host-selective phytotoxins. Less studied scenario is the usage of exterior pathogenicity factors like metabolites of other fungi in case of co-infection. Very likely some other mechanisms and conditions to gain *Alternaria* pathogenicity exist. There is no entire conception explaining genetic and biochemical regulation of virulence. Phylogenetic and biochemical markers of plant pathogenic strains or species are also controversial. Plant protection specialists are often confused when encounter blights with *A. alternata*-like fungi. They have difficulties with species and strain identification, recognition of primary reason of disease and conditions favoring disease, and determination of potential losses. Different cases require different approaches to plant protection. Fungicide treatment against namely *A. alternata* is not always needed.

O29-12. Male post abdominal structures in Pentatominae (Hemiptera: Pentatomidae)- A key to unravel the taxonomic conundrum

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Pentatominae is the most speciose subfamily of Pentatomidae with 3484 described species across the world. In spite of their abundance and diversity, the taxonomy of Pentatominae, in India, is still in infancy. Over reliance on external colouration by most of the earlier researchers lead to ambiguity in identification of Pentatominae even in higher level taxa besides the inherent uncertainty associated with the species level identification. Deployment of male post abdominal structures by Ghauri (1980, 1982); Salini and Schmidt (2018), Salini (2019) lead to several nomenclatural changes besides the splitting and/or amalgamation of several principal taxonomic categories. Kment and Březíková (2018) could disprove the occurrence of the invasive pestiferous species, Halyomorpha halys Stål in India, based on variation in male post abdominal structures. In this study, sibling species occurring in the tribes Halyini, Nezarini and Bathycoeliini were analyzed based on male post abdominal structures especially the shape of dorsal and ventral rim of genital capsule and shape of paramere. This lead to the synonymization of four species in Halys Fabricius, description of two new genera and three new species in Halyini; a new record for India, Glaucias nigromarginatus (Stål) of Nezarini. In addition, it also helped to delineate the closely allied tribe of Nezarini viz., Bathycoeliini based on the shape of genital capsule and paramere. Hence, male post abdominal structures can be considered as an effective tool to resolve taxonomic confusion in Pentatominae.

O29-13. Morphological characteristics and life cycle of two fungal pathogens of dragon fruit, *Hylocereus undatus* (Haw.) Britton & Rose in *Compostela* valley province, Philippines

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Dragon Fruit, *Hylocereus undatus*, is a popular fruit in South East Asia and now gaining popularity around the world as an ornamental plant and as a fruit crop. Like many other fruits, dragon fruit is also susceptible to fungal diseases. Thus, this study aimed to isolate, characterize and identify fungal pathogens infecting dragon

fruits in the Philippines through morphological and cultural characterization; and to observe the life cycle of each fungal isolate. Isolated pathogens from infected stems were characterized and identified morphologically as *Fusarium* sp. which causes stem rotting and *Neoscytalidium* sp. that causes stem canker in dragon fruit. *Fusarium* sp. asexually sporulates quickly and completes its life cycle from micro and macro spores to chlamydospore formation within 96 hours. While, *Neoscytalidium* sp. sporulates quickly through asexual reproduction by disarticulation of conidia. It completes its life cycle within 24 hours at a temperature of 28-30 °C.

O29-14. Race distribution pattern of *Magnaporthe oryzae* infecting rice from mid and high altitudes of Uttarakhand

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Rice is a major cereal crop of Himalayan ecosystem of the country contributing in diet of the people and it occupies ~ 31% area among cereal crops in Uttarakhand hills. Among the different diseases, rice blast is one of the most destructive diseases under hill conditions owing to its severity and yield loss caused during a given season. In the present study virulence analysis of 16 *M. oryzae* isolates were performed using 26 rice blast monogenic lines carrying blast R-genes namely, Pia, Pib, Pii, Pik, Pik-h, Pik-m, Pik-p, Pik-s, Pish, Pit, Pita, Pita-CP1, Pita2-PI, Pita2-Re, Piz, Piz-t, Pi1, Piz-5, Pi3, Pi5(t), Pi7(t), Pi9, Pil2(t), Pi11(t), Pi19, and Pi20 in the genetic background of a japonica rice variety Lijiangxintuanheigu (LTH) along with a susceptible check LTH and a resistant check VL 8657. Among 16 isolates, the percent virulence ranged from 23 to 92 and the least virulent isolate was Mo-nhz-09 from Raulsera and highly virulent isolate was Mo-nhz-04 collected from Mukteshwar rice growing areas. Among the R-genes tested, it was found that Piz5, Pita2, Pi9 and Pizt showed high degree of resistance and Pikp, Pish, Pikm and Pi19 showed low degree of resistance. Out of 16 isolates, 16 races were classified, and the predominant race was U42-i7-k177-z17-ta513 which showed compatibility with maximum R-genes. These findings of the study will be helpful in deploying identified R-genes for effective management of blast disease.

O29-15. Population dynamics of major insect pests of sesame (*Sesamum indicum* L.) and their effect on sesame yield in Owerri, Imo State, Nigeria

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This research was carried out at the Department of Crop Science and Technology Teaching and Research Farm, Federal University of Technology Owerri, (FUTO) Imo State in 2018. The study was carried out to assess the population dynamics of major insect pest that attack different sesame varieties in Imo state, Nigeria. Six varieties of sesame comprising Ncriben ose (Kennana 4), Ncriben 04E (Ex-Sudan), Ncriben – 02M, Ncriben E-8, Ncriben O/M and Mai Jigida were laid out in a randomized complete block design with three replications. The result showed that Ncriben O4E (Ex-Sudan) and Ncriben-O2M were attacked more by insect pests during its reproductive stage. This pest attack reduced its capsule yield (kg/ha). Ncriben O5e (Kenna) and Mai Jigida exhibited high capsule yield potential and so should be recommended to farmers in Owerri ecological environment.

30. Germplasm health: Facing future challenges

Organizers: P Lava Kumar and Rajan Sharma

Lead

O30-1. CGIAR germplasm health: a global network for germplasm phytosanitary safety and prevention of transboudnary spread of seed-borne pests

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The risk of harmful seed-borne pests (pathogen and insect) transmission along with plant propagation materials is a primary concern of the CGIAR global germplasm distribution activities. The Genebank Platform annually provides >100,000 germplasm samples to the partners located in about 100 countries worldwide. To ally phytosanitary risks, in 1993, the 11 CGIAR centers have established Germplasm Health Unit's (GHUs) with a main responsibility to ensure production, maintenance and distribution of propagation material free of harmful quarantine pests. Located strategically in Africa, Asia, Europe and Latin America, the GHU network collaborates with national and regional plant protection organizations in ensuring phytosanitary protection and compliance to phytosanitary regulations regarding movement of germplasm from the genebanks and the breeding programs of CGIAR located in about 35 countries around the world. Alignment of the GHUs to the CGIAR Genebank Platform in 2017 has further strengthened the network and led to the establishment of a common GHU strategic framework focused on (i) phytosanitary service delivery to the centers "safe germplasm" distribution activities; (ii) research for improving diagnostics for virus indexing and seed health assurance, and innovative protocols for establishment of pest-free germplasm stocks; and (iii) advocacy and outreach to augment policies and capacity for timely access to phytosanitary safe germplasm to the end users. Unique multidisciplinary capacity to recognize diverse seed-borne pests and a wide network enabling frequent interactions with stakeholders around the world has given GHUs a unique position to combat seed-borne pest risks, and ultimately fulfilling its mission of "securing the path of food security".

Invited

O30-2. Safe conservation and exchange of germplasm of ICRISAT mandate crops

Rajan Sharma[1], P Humayun[1] and B Devamani[1], Vania Azevedo[1], Anitha Kodaru[2], K S Chakrabarty[2], Prasanna Holajjer[2] and B Sarath Babu[2]

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Success of any crop improvement program depends on the availability of diverse germplasm. However, no country in the world is self-sufficient in having diverse germplasm with which it can fulfill all its

requirements. Therefore, the seeds of germplasm conserved in the genebanks and that of improved breeding lines available with the breeding programs are vital and irreplaceable heritage resource, which must be shared with the global community. Though germplasm exchange plays a significant role in crop improvement, there is an inherent risk of introduction of new exotic pathogens/new races of the pathogens. Plant Quarantine Unit (PQU) of the ICRISAT helps genebank in conserving healthy germplasm for the safe exchange. ICRISAT in collaboration with the Indian authorities facilitated export of 1.34 million seed samples of ICRISAT's six mandate crops and small millets to 174 countries and imported 190882 seed samples from 96 countries during 1974-2018. Till date, 69 insect pests and pathogens of quarantine importance have been detected in imported seed materials and 53 in the seed samples processed for exports. To assess the seed health status, a total of 38,236 genebank accessions of sorghum, pearl millet, chickpea, pigeonpea, groundnut, finger millet and five small millets were tested during 2012 to 2018. Saprophytic fungal contamination was found in 22,306 accessions that can be cleaned. A total of 9144 accessions were found to be unfit for long term conservation and need to be regenerated as these accessions were infected with pathogenic fungi such as *Pyricularia grisea*, *Fusarium oxysporum*, *Phoma* sp, *Bipolaris* spp, *Exserohilum* sp. *Curvularia* spp., *Colletotrichum dematium*, *Alternaria alternata*, *Aspergillus flavus* and *Macrophomina phaseolina*.

O30-3. Advances in safe exchange of rice germplasm from IRRI

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Germplasm exchange is a regulated process governed by the phytosanitary policies and procedures of the International Plant Protection Convention and individual countries governing policies, laws and procedures. National Plant Protection Organizations. Seed health testing is a mandatory component of germplasm exchange between CGIAR international centers and national agricultural research and extension system (NARES) partner organizations. It ensures the movement of seed in a safe manner to prevent unintended transmission of pathogens, insect pests, and contaminants such as weed seeds. IRRI prioritizes safety of germplasm which is exchanged among partners and for recipients of the germplasm in general. For this reason, the Seed Health Unit (SHU) at IRRI functions as the gatekeeper of safe germplasm movement from and within IRRI, to and from the Philippines and other countries. The SHU collaborate and receive guidelines and compliance requirements from the Philippine Plant Quarantine Service. Bureau of Plant Industry (BPI) and IRRI established an on-site SHU with laboratory facilities and BPI has deputized IRRI to undertake major routine activities on rice seed health testing under their guidelines and phytosanitary certification process. IRRI also developed a policy framework for dispatch of any outgoing rice seed for any purpose from IRRI and receipt of any incoming seed. Under this policy all seed outgoing and incoming including Non Seed Biological Materials (NSBM) are channeled and cleared through SHU to ensure safe seed is received and dispatched.

O30-4. Management of seed-borne insect pests and diseases in cool season grain legumes and cereals

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Composition and worldwide distribution of nurseries for cool-season grain legume and cereal crops for evaluating by national and international cooperators is a major component of the ICARDA's Genebank and the plant breeding programs. Using high quality and healthy seed stocks is critical for international nursery

trails. Several seed-borne pests impair seed quality, thereby impacting yield potential, end user product quality and market values. For instance, *Botrytis* and *Ascochyta* infection leads to undesirable staining of legume seed coats, which renders seeds less valuable for canning, affect storage and germination. Production of wheat is severely hampered by seed-borne diseases like common bunt and loose smut, which result in reduced crop yield and poor grain quality. Adequate care in selection of pathogen-free seed is essential for facilitating international seed trials and other uses. Quarantine monitoring and seed phytosanitation are the cheapest and most effective preventive measure in use for controlling transboundary spread of pathogens. Seed health testing for incoming and outgoing shipments using up-to-date diagnostic methods at ICARDA is a primary component of crop management program particularly with an international germplasm distribution dimension. Through this process infected seeds are spotted and replaced with health stocks. Control measures are aimed either at decreasing the pest source or at preventing pest spread within the crop, usually by a vector. The different types of control measures available can be classified as host resistance, phytosanitary measures, cultural practices, and chemical treatment.

O30-5. Post-border biosecurity in Africa: Exotic detections, case study Kenya

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Africa is increasingly susceptible to biological invasions due to weak cross border biosecurity and limited intervention capacity. The increasing occurrence of non-native pest and pathogens targeting indigenous and exotic trees in Africa is proliferating and the impact can immensely threaten conservation of African orphan crops and impact rural livelihoods, economic development and biodiversity across the continent, frustrating benefits of agroforestry. Globalization and exchange of germplasm has driven the emergence of significantly more complex biosecurity challenges. Weak porous borders and policies have continued to expose Africa to these biological threats. Border and post-border biosecurity surveillance, programmes and policies are pivotal to counteract these threats. Adoption of robust pre-border and border quarantine practices and use of emerging technologies to improve bio surveillance and monitoring are more holistic management paradigm. We reviewed forest-related pest and pathogens detections and responses in Kenya between 2000-2018. There were more than 30 detections on new exotic pests and pathogens made in this timeframe and only few species eradicated showing low success rate of Kenya forest eradication programs. There is need to strengthen phytosanitary capacity and systems in Africa.

O30-6. A decade of global exchange of crop germplasm by ICRISAT: NBPGRs quarantine support system in ensuring India's plant biosecurity

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India has very strong quarantine legislation to protect the country from ingress of exotic pests during global exchange of crop germplasm. International Crops Research Institute for Semi-Arid Tropics (ICRISAT) has been involved in the global exchange of crop germplasm and ICAR-National Bureau of Plant Genetic Resources, Regional Station, Hyderabad is the nodal agency for regulating and facilitating the quarantine processing of import and export germplasm. During 2009 to 2018, ICRISAT imported 23,594 seed samples of sorghum (11,542), pearl millet (3757), finger millet (2630), foxtail millet (18), groundnut (1190), chickpea

(4272), pigeon pea (26) and cowpea (159) from 18 countries. All standard test procedures, and specialized techniques viz., washing test, agar plate method using special medium, enzyme linked immunosorbent assay etc. were employed. Post-entry quarantine inspections were also conducted to detect the latent infection, if any. Of the 23,594 samples processed, 23,552 samples were released and 42 samples (0.17%) were rejected. NBPGRs intervention prevented the entry of two quarantine pests for India, viz., *Ralstonia solanacearum*, and Peanut stripe virus on groundnut from Senegal as the infected samples were detained. The other important pathogens that were intercepted include *Botrytis cinerea* on chickpea; *Macrophomina phaseolina* on cowpea, Peanut mottle virus on groundnut; *Colletotrichum graminicola* and *Sporisorium cruentum* on sorghum; *Rhizoctonia bataticola* and *R. solani* on pearl millet etc. Similarly, NBPGR facilitated the export of 2,14,028 samples of different crops without any non-compliance reports. Indian mechanism and approaches followed for safe release of germplasm through diagnostics, surveillance and eradication will be discussed.

O30-7. Phytosanitary risk of mealy bugs in import of plant material into India

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In India, import of plant material is regulated by Plant Quarantine (Regulation of Import into India) Order 2003 to safeguard the country against the ravages of exotic pests. Despite this mechanism, some pests specifically cotton mealy bug (*Phenacoccus solenopsis*) and papaya mealy bug (*Paracoccus marginatus*) have been introduced into the country during last 15 years and are causing serious economic losses. According to available literature, there are approximately 2200 species of mealy bugs known throughout the world in more than 270 genera. These get introduced through plant material such as bud wood, grafts, plants cutting, fruit sapling, leaves, fruits, rooted plants, sprouts, seedlings, plants for propagation etc. Mealy bugs pose a high phytosanitary risk as their body is covered with wax secretion so are difficult to control through chemicals. As per PQ Order, there are 17 species of mealy bugs associated with different agri-horticultural crops, a few examples are *Paracoccus caraticus, P. cavaticus, P. marginatus, Pseudococcus calceolariae* and *P. comstocki*. Besides, the ones listed in PQ Order, there are several mealy bugs which are likely to accompany the plant material e.g. *Rhizoecus hibisci* (root mealy bug), having wide host range and moves with the rooted plants in trade. An analysis of risk of mealy bugs not yet present in the country and not regulated under PQ Order has been undertaken. This information is of great significance for safe movement of plant material into India.

O30-8. Who is afraid of CPV (Consular, Passport and Visa) Division?

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Several factors have made the scale insects (particularly mealybugs – Pseudococcidae, soft scales – Coccidae, armoured scales – Diaspididae, lac insects – Kerridae and Iceryines – Monophlebidae) serious invasive species. Some of the important factors are - the growing transport of planting materials and fruits all around the world is a successful dispersal means of these insects with limited mobility; asexual mode of reproduction (parthenogenesis) leading to rapid multiplication and polyphagy allowing proliferation on various plants in different habitats. The earliest examples of non-native coccids becoming major pests are San Jose scale (1911), Lantana bug (1915) and Cottony cushion scale (1921). This was followed by series of accidental introductions and invasions of coccid species like Solenopsis mealybug (2008), Papaya mealybug (2008), Madeira mealybug (2012) and Jackbeardsleyi mealybug (2013). During 2015 to 2016, noiseless incursion of four soft scales and one mealybug species from various country borders was ascertained. In course of the

same period, seven mealybugs, four armoured scales and two soft scales were encountered at the Indian ports of entries in various fruits shipped from Sri Lanka, Thailand and Egypt. While these coccids were making their way from different countries to India, two species of mealybugs were enjoying freedom of unrestricted movements between the state borders within the country, and causing damage to various crop plants. Coccids don't need to pass immigration or custom, however security in the form of strict quarantine measures, across the countries and between the states within a country, need to be enforced.

O30-9. Changing dynamics of plant quarantine in India: emerging issues & way forward

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In the present era of liberalized global trade, import/export of plants and plant materials has gone up many folds and are likely to go up further, thereby warranting for a strict and dynamic plant quarantine regulations. India having a diverse climatic condition and rich biodiversity has always been vulnerable to the pest vagaries. Therefore, enforcement of plant protection regulations like the Destructive Insects & Pests Act (1914) and Plant Quarantine Order (2003) for prevention of entry of exotic pests are playing a crucial role in safe guarding the Indian agriculture. Based on pest risk analysis, import of various agricultural commodities is either prohibited under schedule IV or restricted for entry with certain conditions under schedule V & VI of the Plant Quarantine Order, 2003. Despite having a very robust plant quarantine regulations in India, there have been pest incursions off and on. There is urgent need to restrict import of certain agricultural commodities or impose additional condition for freedom of the pests in the consignments for the fact that several quarantine pests are now reported in other countries hitherto not known to occur. Also, there is need to regulate seed movement of certain commodities from one region to other within India in order to restrict pest movement through domestic quarantine. The present paper throws light on various emerging issues and strategies for their mitigation in order to ensure desired level of agricultural bio-security.

O30-10. Colonization pattern and potential for seed transmission of *Verticillium longisporum* in winter and spring oilseed rape (*Brassica napus*)

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Verticillium longisporum (VL) is a Brassicaceae specific pathogen that causes *Verticillium* stem striping without symptoms until ripening stages. In the present study, VL colonization was followed in roots, stem bases and stem tissues of field-grown OSR using real-time PCR and displayed differential colonization patterns in winter and spring OSR. In winter OSR, VL showed a strongly discontinuous colonization pattern with low fungal growth in roots during juvenile stages. In contrast, VL displayed a later root colonization followed by continuous shoot colonization in spring OSR. Average soil temperatures in 5 cm depth during seven days before sampling time points showed a significant relationship with fungal colonization in the roots, which explained the contrasting colonization patterns of VL in winter and spring OSR. Seed transmission was partly related to the type of plant colonization. In a series of greenhouse experiments with resistant and susceptible cultivars of winter and spring OSR, recovery of viable VL colonies from seeds harvested from inoculated winter and spring OSR ranged from 0.08 to 13.3%. A DS red labelled transformant strain of VL confirmed these findings resulting from systemic growth of VL from the roots to the seeds.

Complying with the colonization pattern, seed transmission of VL from field harvested seeds was only found in spring but not in winter OSR. Similarly, only 1.7 to 2.3% of offspring plants from seeds from greenhouse-grown winter OSR showed disease symptoms, while none of the offspring grown from seeds from severely VL-infected field-grown winter OSR developed any disease symptoms.

O30-11. Detection and diagnosis of seed fungal microflora associated with four varieties of maize

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Maize has exported 7,05,513.8 MT during 2017-18 to Japan, Yemen Republic, Malaysia, Vietnam, Pakistan, Myanmar, Sri Lanka, Philippines and Bangladesh. A seed health test is a requirement of phytosanitary regulations imposed by national plant quarantine authorities of importing countries before import of seed to their territory. India is a member country of WTO, hence under sanitary and phytosanitary agreement, importing countries requirement has to be fulfilled. Keeping above in mind, maize seeds of four varieties (DHM-121, DHM-117, BML-06 and local from chenevelli) tested for seed borne fungal microflora. Detection and diagnosis of different seed fungal microflora were carried out by blotter and agar plate method of seed testing as recommended by International Seed Testing Association (ISTA). *Aspergillus flavus, A. niger, Fusarium* species, *Fusarium verticillioides, Alternaria alternata* and *Curvularia lunata* were detected in both blotter and agar tests. Whereas *Bipolaris maydis, Colletotrichum graminicola*, were detected only in Agar plate method. Hence, it is recommended that for the detection of seed borne pathogens, the blotter and agar test methods are required. In *Bipolaris*, taxonomic delimitation and precise species identification is difficult within this genus because it displays close resemblance with genus *Drechslera* and *Exserohilum* in morphological features. Hence the DNA isolated can be used for diagnostics of *Bipolaris* fungal plant pathogens. Here, we will attempt to identify a barcode gene from 4 isolates (one from each variety) belonging to five species of *Bipolaris* using five markers i.e., ITS, tef-1, tubulin, LSU and SSU.

31. Emerging pathogens and their management: phytoplasmas, viruses and viroids

Organizers: D V R Reddy and Celia Chalam Vasimalla

Lead

O31-1. Engineering for virus resistance in crop plants: challenges & opportunities

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Plant viruses cause severe crop losses across the globe and increase in global temperature has resulted in serious outbreak of pests and pathogens making the situation much more complicated. Developing virus resistant crop cultivars through genetic engineering is the most effective and economical way to control plant viral diseases. Transgenically induced RNA interference (RNAi), has-been employed to control both DNA and RNA plant viruses. This method will be dealt in greater-detail with special-reference to the control of cassava-infecting viruses in East-Africa. Cassava (*Manihot esculenta*) cultivated in tropical-regions, is vulnerable to at least 20 different viral-diseases, among which cassava mosaic-disease (CMD) and cassava-brown streak-disease (CBSD) are the most-important. Although CMD-occurs in almost all cassava-cultivating regions of sub-Saharan-Africa, CBSD has emerged as the most-important viral disease of cassava in Africa and is one of the biggest-threats to global food-security. CBSD is caused by two distinct-species of ipomoviruses (Family Potyviridae), Cassava brown-streak virus (CBSV) and Ugandan-cassava brown streak-virus (UCBSV). Previously CBSD was-reported only from coastal-lowlands of eastern-Africa, however recently it-has taken an epidemic form in entire East-Africa. Strong CBSD resistance-remains elusive within cassava-genotypes traditionally grown by farmers, meaning that development of transgenic-varieties holds-significant potential to address the CBSD pandemic. Through a collaborative project called Virus Resistant-Cassava for Africa (VIRCA), researchers at the Danforth Plant-Science Center with partner institutions at NaCRRI, Uganda and KARI, Kenya and IITA, BecA, Kenya have demonstrated the proof of principle for the control of CBSD by RNAi. Recently one-of the genome editing-technology CRISPR-Cas9 has-been successfully-employed to-get resistance against CBSD.

Invited

O31-2. Volatile Secondary metabolite release in banana plants due to aphid, *Pentalonia nigronervosa* Coq. f. *typica* infestation

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Hanana plant volatiles play important role in host location by herbivorous insects such as aphids. weevils and beetles. In banana, Banana Bunchy Top Virus (BBTV). Banana Bract Mosaic Virus (BBMV) and Banana streak Virus (BSV) are the predominant viral diseases causing considerable crop and yield loss. Volatile and non-volatile chemicals from banana plants of different categories were studied by air entrainment method and extraction methods. Gas chromatography coupled mass spectrometry analysis of volatiles emitted by the three months old banana plants of cv Poovan (AAB-Mysore sub group) of different matrices for 24 hours indicated changes in the volatile blend. Virus infection induces changes in plant volatile emission profiles of healthy plant and this change in volatile profile makes more attractive to the vector, banana aphid, *Pt'ntalonia nigronervosa var.tyyica.* Studies indicated considerable variations in the volatile blend of aphid feeding on banana plants of healthy, viral infected, viruliferous aphid and non-

viru1iferous aphid. GC-MS analysis of healthy banana plants indicated four volatiles; BBTV infected plants released six volatiles besides two host volatiles. Feeding of non-virulifreous aphid on BBTV infected plants produced eight volatiles and besides two plants specific volatiles. Feeding of BBTV viruliferous aphid on BBTV infected plants did not produce any additional volatiles due to aphid feeding and all components are entii ely new .Similar studies in cv. Nendran (AAB-Plantain sub-group) plants infested with aphids on healthy, infected, winged and wingless aphid volatiles collected indicated considerable variations in the profile

O31-3. Identification of tomato leaf curl virus interactive proteins in *Bemisia tabaci* using Y2H system

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Extensive economic losses caused by the whitefly-transmitted viruses has threatened food security and poverty alleviation efforts globally with losses ranging from 20 to 100%. *Tomato leaf curl Bangalore virus* (ToLCBV) (Geminiviridae) is one of the most prominent viruses infecting tomato and is transmitted by the whitefly, *Bemisia tabaci* (Gennadius) (Aleyrodidae: Hemiptera). The emergence and establishment of whitefly-transmitted diseases is attributed to genetic changes in the virus through mutation and recombination, genetics of vector population, polyphagous nature of *B. tabaci* and the movement of plant material or vectors through trade. After the acquisition of virus, many host proteins interact with the viral coat proteins, while a few of them are beneficial to the virus (e.g. heat shock proteins), a few may be harmful. We screened the proteins of the *B. tabaci* Asia 1 genetic group interacting with ToLCBV coat protein using a yeast two-hybrid (Y2H) assays. The Y2H revealed 425 putative interactions in a low stringent media, which were reduced to 324 interactions on a high stringent media and of which, about 274 colonies produced single bands in colony PCR experiments. Upon re-streaking of the remaining colonies, 25 of them produced a single band. Further, selection pressure assays confirmed 102 positive interactions between ToLCBV CP and whitefly proteins. The proteins found to be interacting with ToLCBV CP were HSPs 70kDa, GroEL, nucleoproteins, vitellogenins, apolipophorins, lachesins and enolase. These proteins are the potential targets for novel whitefly control strategies such as RNAi or insecticide target sites for developing future whitefly control strategies.

O31-4. Management of whitefly, *Bemisia tabaci*, a vector of leaf curl virus disease in tobacco

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Tobacco is a low volume and high-value commercial crop in India providing livelihood security to millions of people. Tobacco whitefly, *Bemisia tabaci* Gennadius is an important pest, which adversely affects the yield and quality of Virginia tobacco. It causes damage by sucking the sap and as a vector of tobacco leaf curl virus (TLCV). At present, the management of TLCV is possible only through control of its vector, whitefly with insecticide sprays. Sole dependence on synthetic insecticides for whitefly control is beset with adverse effects which are well known. Keeping these problems in view, studies were conducted to evaluate different modules for the management of tobacco whitefly. A field experiment was conducted during 2015-17 to evaluate an integrated module (IM), chemical control module (CC), sorghum barrier crop (SB) and a check plot (C). The results showed that the mean leaf curl infected plants were least (2%) in IM followed by CC (2.4- 2.6%) as against 8.6-8.8% in tobacco with SB and 12.4-12.6% in C plots. The whitefly population was also found to be

significantly less at all the observations in IM and CC plots. The natural enemy population was appreciably higher in SB and IM plots compared to CC plot. The yield parameters *viz*., curled leaf, bright leaf and grade index were higher in IM and CC plots compared to C and SB plots. The integrated module proved to be a promising strategy in the management of whitefly in tobacco.

O31-5. Understanding the pathogenicity of Napier grass stunt phytoplasma infection in Napier grass

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Cultivation of Napier grass, *Pennisetum purpureum*, the most important fodder crop in East Africa is severely constrained by Napier grass stunt (NGS) disease. The disease affects Napier grass plants in smallholder farms causing forage yield loss between 40 and 90%. In some areas, the entire Napier grass crop is lost, forcing farmers to reduce the number of animals or purchase fodder from the local market. The disease is caused by a phytoplasma and introduced by infected plant material or by phloem-feeding insects which vector the pathogen. The mechanisms by which the phytoplasma alters the host plant physiology and cause a variety of symptoms are of considerable interest but are poorly understood in Napier. There is, therefore, need to detect the plant genes that respond to an infection by the NGS phytoplasma. We analysed the leaf transcriptomes from healthy and phytoplasma-infected Napier grass (asymptomatic) using high-throughput mRNA sequencing (RNA-Seq) combined with differential gene expression analysis. The pathway and gene function analysis show that NGS-phytoplasma response is regulated by pathways related to photosynthesis, plant hormone, pathogenesis-related genes, transcription factors, and transport and carbon metabolism in Napier. Besides, reduced and oxidized glutathione and reduced and oxidized ascorbic acid were lower while H_2O_2 accumulated in symptomatic plants. The photosynthetic activity was not affected in symptomatic plants, but infected Napier leaves had small-sized vascular tissues with significantly reduced phloem mass flow.

O31-6. Identification of virus-free elite mother plants of apple from apple orchards of Kinnaur in Himachal Pradesh

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Apple (*Malus domestica* Borkh.) is important temperate fruit grown in the north-western Himalayan region of India. This study was conducted to identify virus-free elite mother plants of apple from the farmer's field at Kinnaur, Himachal Pradesh, India. Most of the important viruses in apple are latent; their elimination during the selection of mother plant in field condition is not possible. Hence, these plants were screened through enzyme-linked immunosorbent assay (ELISA) and reverse transcriptase-polymerase chain reaction (RT-PCR) in subsequent years. Initially, apple trees on farmer field having elite traits were marked. These plants were screened through ELISA and RT-PCR for five important apple viruses *viz*., *Apple Chlorotic Leaf Spot Virus* (ACLSV), *Apple Mosaic Virus* (ApMV), *Apple Stem Grooving Virus* (ASGV), *Apple stem pitting virus* (ASPV) and *Prunus necrotic ringspot virus* (PNRSV). Apart from viruses, one viroid i.e., Apple scar skin viroid (ASSVd) and one phytoplasma i.e., Apple proliferation phytoplasma (App) were also screened. Based on results, it was found that ASPV was the most prevalent virus with 76.7% incidence followed by ACLSV (72.11%), ASGV (47.65%). ASSVd incidence (3.9%) was recorded through RT-PCR whereas App (0%)

incidence was recorded through ELISA. In the present study, only 13 plants were selected which were free from infection of viruses and virus-like pathogens as well as having elite traits. Scion wood from these plants was collected for further multiplication and distribution to the farmers. It can be concluded from the present study that virus indexing is necessary for the selection of mother plants.

O31-7. Monogenic dominant resistance to chilli leaf curl virus (ChiLCV) for most prevailing virus species of begomovirus in Guntur district of Andhra Pradesh

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Chilli Leaf curl virus disease (ChiLCVD) is one of the major biotic stresses of *Capsicum* spp. The disease has been endemic in major pepper growing regions of India during the recent past and is becoming a major threat to chilli and sweet pepper production in the country. Its occurrence is very severe with yield losses up to 100 per cent have been reported. Development of resistant varieties is considered the most effective, economical, ecologically safe and durable approach for management of virus diseases in crops. Hence, with this objective, a source of resistance i.e., LCA-801 was identified using natural and artificial screening against *Chilli leaf curl virus* (ChiLCV). To study the genetics of resistance, MS-276 (a cytoplasmic genetic male sterile susceptible parent) was crossed with LCA-801 (resistance donor). After the artificial screening, the F1 plants were found resistant. In the F2 generation, 223 plants segregated into 167 resistant and 56 susceptible plants. The results of Chi-square analysis indicated a good fit in the ratio of 3:1. Backcross to the susceptible parent segregated into 23 resistant and 17 susceptible plants, which also fit in the test cross-ratio of 1:1 suggesting that the resistance carried by LCA-801 is controlled by a single dominant gene. This resistant source can further be used for the transfer of the gene and may also be used for mapping the gene conferring resistance. The study suggests that LCA-801 may serve as a donor for the development of chilli cultivars with commercially acceptable fruit morphology and pungency.

O31-8. Mapping of aphid vectors of potato viruses in India using mt COI marker and their implications on potato seed production.

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The present study was conducted to map aphid vectors occurring on potato and to determine their viruliferous nature in India during 2013-2016. Mitochondrial COI marker was used to map aphid vector species. Interestingly, a total of 14 distinct aphid species were identified of which *Myzus persicae* and *Aphis gossypii* have been known as the most abundant vectors on potato in India. Among which we report ten new aphid species on potato with the advent of diverse cropping pattern, climate change-induced geographical expansion of pests. Intra-specific and inter-specific distances of aphids ranged from zero to 2% and 2.4 to 10.9%, respectively. Thirteen aphid species have been recorded in Indo-Gangetic plains of India where 90% of the potato is produced. Seven out of 14 aphid species were colonizing potato and carry virus inoculum to healthy plants. Seven good colonizing aphid vectors including *M. persicae*, *A. gossypii*, *Alternaria solani* and

Macrosiphum euphorbiae have been reported to be viruliferous to *Potato Virus Y* (PVY) and *Potato leaf roll virus* (PLRV). However, among the non-colonizers, *Rhopalosiphum maidis*, *Rhopalosiphum padi*, *Brevicoryne brassicae* and *Lipaphis erysimi* have been reported as major vectors of PVY and at high densities. Vector efficiency of *Hyadaphis coriandri* and *Apis nerii* is unknown. It is the first exhaust study of its kind in India. Present study reports occurrence of new aphids on the potato that includes colonizing and non-colonizing in nature and are vectors of PVY and PLRV in India which will have a significant effect on healthy seed and ware potato production in India which necessitates revisiting of seed plot technique.

O31-9. Survey on viroids infecting citrus in Northeast Morocco: identification and characterization of Citrus exocortis viroid, Hop stunt viroid and Citrus bent leaf viroid

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Citrus species are natural hosts of at least seven viroids in the family Pospiviroidae. Viroids are the smallest known pathogens of plants. They are single-stranded, circular, rod-like RNAs with no protein capsid and not any detectable messenger activity. Citrus exocortisviroid (CEVd), Hop stunt viroid (HSVd) and Citrus bent leaf viroid (CBLVd) were previously reported from citrus in Morocco. To assess the incidence and distribution of CEVd, HSVd and CBLVd, extensive surveys were conducted, between 2015 and 2018, in the Gharb region (Northeast Morocco). A total of 21 commercial citrus groves of different varieties were inspected for specific symptoms of viroid infections, and 1012 samples were collected for laboratory analyses, using imprint hybridization. Representative positive and negative samples for each viroid were selected for additional confirmatory RT-PCR assays using specific primers and were submitted for further characterization. The incidence of infection by viroids was about 32.5%. The average incidence of CEVd was 30.2%, HSVd (12.9%), and CBLVd (6.1%), respectively. No major sequence divergences between the sequenced CEVd, HSVd and CBLVd variants from Morocco and those previously described from other countries were observed. Phylogenetic analysis supported the close relationships among CEVd, HSVd and CBLVd variants from Morocco and other Mediterranean countries. Since citrus viroids are readily mechanically transmissible via working tools, they affect both old and young plantings in all citrus groves surveyed.

O31-10. Acibenzolar-S-methyl restricts infection of *Plantago asiatica* mosaic virus at two distinct stages in an NPR1-dependent manner.

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Acibenzolar S-methyl (ASM) is one of the most studied plant defense activators (PAs), which stimulate defense mechanisms against a variety of pathogens in the plant. However, our knowledge of their mechanisms of action against plant viruses, which has three infection stages, replication, cell-to-cell movement, and long-distance movement, is fragmented. We treated one leaf of *Nicotiana benthamiana* with ASM and inoculated with *Plantago asiatica mosaic virus* (PlAMV) tagged with a green fluorescent protein (GFP) on the treated leaf. ASM treatment inhibited infection of PlAMV in inoculated cells and delayed its long-distance movement. Furthermore, the ASM-mediated delay of long-distance movement of PlAMV is not due to the suppression of viral accumulation in the inoculated leaves, indicating that ASM restricts

PlAMV infection in at least two independent steps. To reveal the mechanism underlying the ASM-mediated restriction of PlAMV in the inoculated cells, we performed protoplast assays and showed that ASM treatment restricts the replication of PlAMV. Furthermore, using *Arabidopsis thaliana* mutant, we revealed that ASM-mediated restriction of PlAMV infection requires the NPR1 gene but independent of the dicer-like genes essential for RNA silencing. Moreover, regarding the mechanism underlying the inhibition of the long-distance movement, we found that ASM does not restrict loading of PlAMV into the vascular tissue in the inoculated leaf but restricts unloading of PlAMV in systemic leaves. Considering that ASM-mediated inhibition of PlAMV-GFP infection also occurred in the upper, untreated leaves, a phenomenon similar to systemic acquired resistance likely regulates the inhibition of long-distance movement of PlAMV by ASM.

O31-11. Yam mosaic virus control using 'positive selection'

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Yam mosaic virus (YMV, genus Potyvirus) caused yam mosaic disease (YMD) is a major constraint to white yam (*Dioscorea rotundata*) production in West Africa. Decades of vegetative propagation using recycled tubers (seed yams) has resulted in the widespread occurrence of YMD with incidence and prevalence exceeding 80% in most of the white yam cultivating zones. Durable resistance to YMD is not available. In the lack of formal seed yam system, reuse of YMV-infected tubers as seed source was unabated. In this study, "Positive Selection" (PS) method was applied to select asymptomatic or mildly symptomatic plants as mother plants for sourcing seed yams for next season planting. Two experiments were conducted using *D. rotundata* varieties between 2015–2018 comprising multi-seasonal research station (RS) trials in IITA station in Ibadan, and multi-location farmer-managed (FM) trials in 50 farmer plots located in the Federal Capital Territory in Nigeria. Trials evaluated PS influence on reduction of YMD incidence, severity, and yield advantage between tubers harvested from PS seed source and control. Two cycles of PS resulted in overall YMD incidence reduction of 24% to 40% compared to controls. A higher proportion of YMD-free plants and mildly symptomatic plants were detected in PS plots. Tuber yields increased by up to 40% in plots established with PS sourced seed. This study demonstrated the potential of PS in on-farm management of YMD, and as a simple alternative to replace contaminated seed in farm systems dominated by reuse of saved seed.

32. An overview of frameworks used for predicting, monitoring and responding to new pests

Organizers: Godshen Pallipparambil and Karl Suiter

Lead

O32-1. An overview of strategies used to predict pre-emergent invasive pests

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Prior to predicting the potential establishment and impact of invasive species into a new ecological niche, the universe of pre-emergent pest species that might be invasive must be identified. These lists serve to direct and focus invasive species policy, management and regulatory decisions prior to invasion. Most commonly, expert elicitation is used to create lists of potential invasive pests. However, these lists tend to be subjective in nature and focus on pests with a recent history of invasiveness or are currently a problem pest elsewhere in the world. In order to reduce the subjectivity in building these lists, data-driven methodologies have been developed that serve to generate objective lists of pre-emergent pest threats. The objective prioritization and risk ranking of pests can identify pests of concern within regions that may not be apparent using other methods. During this presentation, I will provide an overview and comparison of the strategies used to generate pre-emergent invasive pest lists and discuss how data-driven analyses can provide new insights into pest prioritization.

O32-2. Forecasting and management of Asian rice planthoppers

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Outbreaks of brown planthopper (BPH) and white-backed planthopper (WBPH) have occurred frequently in East Asian countries since mid-2000s. These species are distributed over wide areas of Asia, but they can overwinter only in tropical regions where their host plant (rice) can grow throughout the year. In temperate areas, colonization of these species occurs annually following long-distance migration. Thus, occurrence of these species in temperate areas is highly dependent on populations in the overwintering areas. To achieve high-precision migration prediction for rice planthoppers, we developed a real-time prediction system. In this system, the migration simulation model calculates movement of a number of modeled planthoppers and predicts their relative aerial density at three-hour intervals. The results are converted to maps and are available on the web. Recent outbreaks of the rice planthoppers are closely related to the development of insecticide resistance. Thus, we determined and compared insecticide susceptibilities of rice planthoppers collected from East and Southeast Asian countries. BPH developed high and moderate levels of resistance to imidacloprid and thiamethoxam, respectively, but did not develop resistance to fipronil. In contrast, WBPH developed a high level of resistance to fipronil. The resistance level of BPH against both imidacloprid and thiamethoxam were similar between East Asia and the Red River Delta (RRD), and were different in the Mekong Delta, suggesting that resistant populations migrate from the RRD to East Asia. Therefore, continuous monitoring of the insecticide susceptibility of rice planthoppers in the RRD is very important for insecticide resistance management in East Asia.

Invited

O32-3. Detecting new pest introductions: surveillance and resource allocation decisions

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Invasive species threaten agriculture and natural resources in a country and affects its trade opportunities with other countries. Considering these significant impacts, it is imperative to rapidly detect and respond to new pest introductions. For example, massive losses due to fall armyworm in Africa and Asia may have been reduced by proactively tracking its global spread, surveying for its rapid detection in case of an introduction, and by having an action plan for its rapid eradication after detection. To ensure the plant biosecurity of a region, pest surveillance has to be implemented in multiple phases (1) monitoring the movement of exotic pests beyond the country's borders to estimate their likely time of entry, (2) inspecting for pests at the borders to prevent their entry (3), and surveillance within the borders to rapidly detect new harmful pests soon after they enter. That said, there are thousands of exotic pests that can damage a new region, and therefore, it is important to allocate surveillance resources judiciously based on the probability of a pest to enter, establish, and damage a new area. In this presentation, we will discuss surveillance strategies and examples of systems that allow decision makers to optimally allocate resources.

O32-4. Real-time tracking of invasive species in the Southeastern United States: early detection and rapid response

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Invasive species are a constant threat to agricultural, forested, and natural ecosystems. Mitigation of that threat requires directed efforts to detect new invasives, dedicated resources to contain recently introduced pests, coordinated research to develop new management strategies, and timely outreach to help extend the latest information. Limited resources and the wide ranging impact of invasive species require all organizations to work together and leverage each other efforts. Our program embraces the need for collaboration and leveraging of resources, though the following methods: Facilitation of early detection and rapid response programs with prompt communication between citizen scientists, taxonomic experts, diagnostic labs, regulatory agencies, and rapid response teams; Enabling open access to and sharing of verified invasive species data to improve decision support capacities at all levels of government and in the private sector, including public and private learning institutions; Documentation of actions taken to control new infestations to show impact of management programs; Support for regional and international coordination efforts of federal agencies, states, territories and federally-recognized tribes to prevent the introduction and spread of invasive species; Promoting the development and application of innovative tools and technologies for prompt and effective prevention, eradication, and control of invasive species; Improving public engagement on the invasive species issue by supporting and expanding existing education and outreach efforts, applying unified messaging and social media platforms.

O32-5. Informing an emergency response to the detection of a non-native plant pest in the landscape

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The objective of an emergency response to the introduction of a non-native plant pest is to eradicate or contain the exotic pest population. Those accountable for this work requires information relevant to the identification, survey, and control of the introduced species. Emergency responders must be able to distinguish the non-native pest from native species, delimit the distribution of the pest population in the invaded landscape, and eradicate or suppress that population. This presentation will focus on the sources and application of information to these facets of an emergency response after the detection of a new pest.

O32-6. A spatial analytic framework to manage plant pest species in regulatory phytosanitary applications

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Non-native pests cause economic and environmental damage to managed and natural U.S. forests and agriculture. When such species are detected in the United States, response must be rapid. Part of this response includes control efforts focusing on population management, eradication, port inspections, surveillance and monitoring, shipment treatments and pre-clearance programs. However, because each disease or pest and its associated outbreak has its own idiosyncratic characteristics, responses are often highly complex, operationally difficult and challenging to coordinate. To help phytosanitary management agencies respond more quickly to pest threats, we developed an integrated system called the Spatial Analytic Framework for Advanced Risk Information Systems (SAFARIS). SAFARIS is designed to provide a seamless environment for pest predictive models. It supports pest forecast models and tools for researchers, risk analysts, decision/policy makers, rapid-responders, and land managers in need of a streamlined and tractable system to support pest surveys, pest forecasts, pest risk analyses, emergency response, and economic analyses. The case studies of an Oriental fruit fly (*Bactrocera dorsalis* (Hendel)) and a spotted lanternfly (*Lycorma delicatula* (White)) demonstrate building analytic models and tools with multiple data sources within a single framework.

O32-7. Effect of varied weather parameters and different sowing dates on the incidence of insect pest in chickpea

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It is important to identify genotypes with resistance varied sowing windows. Therefore, evaluated a five diverse genotypes for resistance to *H. armigera* for three years over four sowing window. More number of eggs were observed in 2012 than in 2013 and 2014. Highest numbers of eggs were recorded in the crop sown

in October in cumulative three seasons. Among the genotypes tested, ICC 3137 had the highest number of *H. armigera* eggs (11.6) across the seasons. The lowest number of *H. armigera* eggs was observed on JG 11 (6.3) in 2012, on ICCV 10 (3.6) in 2013. The *H. armigera* larvae were highest in October sown crop (80.7) and lowest in the January sown crop (21.1) in 2014-15. The larval incidence decreased from October to December but increased in the January. Greater numbers of cocoons were recorded in the December sown crop (3.4) in 2012-13.However highest number of cocoons were recorded on ICC 3137 (2.5) and lowest on KAK 2 (1.6). The maximum temperature and minimum temperature shows a significant negative and positive correlation with *H. armigera* larvae population for October and November sown crop. Multiple regression analysis of the *H. armigera*, *S. exigua* eggs and larval population showed a significant interaction with weather parameters during all cropping seasons. The coefficient of multiple determinations (R2) was varied per cent during across different seasons for *H. armigera*, *S. exigua* population

O32-8. Risk assessment and preparedness: an encounter to agricultural transboundary pests and diseases

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The transboundary crop pest and disease (P&D) outbreaks over large geographical regions jeopardizes the food security and have broad economic, social and environmental impacts. The climate change accelerated transboundary P&D are responsible for food chain catastrophes and upsurge of minor pest into major. Such accelerated events require more attention on a greater scale to strengthen food security and protect the livelihoods of poor and most vulnerable countries of the world. The ICRISAT, Center of Excellence on Climate Change Research for Plant Protection (CoE-CCRPP) is a joint initiative with Department of Science and Technology and ICRISAT to study impact of climate change on agriculture P&D in an inclusive manner with key audience (adaptation funding entities, planners, policymakers and practitioners) at national and regional level (NARS, ARIs and CGIAR). The CoE-CCRPP emphasis is on mapping the potential pest risk distribution and forecasting; short and medium term climate resilient pest management practices; as well as capacity building of various stakeholders on climate resilient agriculture. The ICRISAT center, further focus to determine and establish priority pest indicators ranking, risk assessment and distribution, socio-economics of P&D to assist in enhancement of pest policies, pre-emptive breeding, improved P&D monitoring and surveillance to strengthen global efforts to alleviate P&D complications on sustainable agriculture and food security.

Oral

O32-9. Biological control of recent invasive whiteflies (Hemiptera: Aleyrodidae) of coconut in India: a success story

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Invasion and establishment of four whitefly species viz., Rugose spiralling whitefly, *Aleurodicus rugioperculatus* (Hemiptera: Aleyrodidae) in 2016, Bondar's nesting whitefly, *Paraleyrodes bondari*, nesting whitefly, *P. minei* in 2018 and palm infesting whitefly, *Aleurotrachelus atratus* in 2019 reported in coconut ecosystem in India. All the species are reported as highly polyphagous, invasive and believed to be originated from Neotropical regions. Co-existence of this species in coconut palms indicate probable simultaneous

introduction from the New World, though it was reported in different time. Invasive pests in the absence of natural enemies are often to flare up at initial phase of introduction in new areas. Nymphal parasitoid, *Encarsia guadeloupae* (Hymenoptera: Aphelinidae) on *A. rugioperculatus* and *Encarsia* spp. on *A. atratus* were found be very effective upto 82% natural parasitism. However, no natural parasitism reported on nesting whiteflies. *E. guadeloupae* was well established by augmentation by re-distribution and field insectary techniques. The parasitoid population can also be conserved through planting of intercrop such as *Canna indica* as banker plants in coconut ecosystem. However, it activity is not uniform across the infested locations and lack of temperature tolerance observed. Therefore, a potential alternative entomopathogenic fungus, *Isaria fumosorosea* Wize (ICAR-NBAIR pfu-5) was evaluated against *A. rugioperculatus* and *A. atratus*. The eggs mortality of 35-99%, early nymphal instars (48-91%) and late nymphal instars (36-86%) and pupae (28-80%). The fungus kills all the developmental stages of this pest and further, its bioefficacy was validated under condition in different states in India for further integration of management strategies.

O32-10. Distribution, dispersal and biological control of recently introduced pests of sweet chestnut ecosystem in Northwest Portugal

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The European chestnut agro-ecosystem is of high social, economic, and landscape importance in Portugal, being actually very debilitated by alien and invasive pests. *Cryphonectria parasitica* associated to Chestnut Blight, and the Asian chestnut gall wasp, *Dryocosmus kuriphilus* are alien and invasive pests recently introduced in Portugal, that rapidly spread to all important chestnut areas with consequent chestnut production losses. To manage *C. parasitica* and *D. kuriphilus*, biological control was implemented. For Chestnut Blight, hypovirulent strains (CHV1) was applied, and the parasitoid *Torymus sinensis* was introduced to control the chestnut gall wasp. This work describes, in the Minho Region (Northwest Portugal), the population structure related to vic genes (vegetative incompatibility system) of the virulent pathogenic fungus for CHV1 application, and the results of biocontrol of *D. kuriphilus* by the introduced *T. sinensis* and native parasitoids. The average percentage of parasitism in 2018 was 9.8%, although it varied across time and the sites studied. In 2019 a higher percentage of 18.74% was observed. The average number of cells per gall in 2018 was 5.94, and 6.3 in 2019. Nine species belonging to the genus *Torymus*, *Megastigmus*, *Sycophila*, *Eurytoma*, *Mesopolobus*, *Ormyrus* and *Eupelmus* were identified in 2018. The results indicate that native parasitoids are important in the natural limitation of *D. kuriphilus*, but insufficient for controlling the populations of the chestnut gall wasp. The percentage of parasitism by *T. sinensis* on *D. kuriphilus* is still low, as a consequence of its recent introduction in the orchards.

33. Emerging pests and their management: Nematodes

Organizers: Suresh Pande and Davabhai Patel

Lead

O33-1. Bio-management of plant parasitic nematodes to enhance crop production in India

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Phyto-nematodes induce about Rs. 21 billion only in 24 crops covered under AICRP on Nematodes in India. However, together with other crops, it would be Rs.100 billion plus annually. Root-Knots, Cysts, Stunt, Reniform, Lance and burrowing nematodes are major ones are chemical nematicides are not only hazardous to human health but pollute atmosphere andsoil environment leaving residues in crop produce. Hence, bio-nematicides are safer and environmentally eco-friendly. Application of 25 kg *Purpureocillium lilacinum* (Pl) @ 25 kg + Carbofuran 1 kg/ha significantly reduced RKI (1.8) with maximum banana fruits. Pl @ 25kg spore dust with carrier/ha (109cfu/g) either with poultry manure @ 10t/ha or mustard or neem cake @ 2 t/ha reduced gall index andgave higher brinjal fruit yield (ICBR 1:18.5). Neemcake enriched with Pl @ 10 kg/ha reduced PCN and increased potato tuber yield by 88.2%. Seed treatment with *Pseudomonas fluorescens* (Pf) @10 g/kg seeds followed by Pf soil application @ 2.5 kg/ha decreased soil and root population of Reniform by 74.2 and 53.9 % in cotton. Pf @ 20 g/m2 applied in nursery and subsequently transplanting treated seedlings in field reduced RKN on seedlings and increased 38.45% tomato yield (ICBR 1:2.90), 27.27%. Brinjal yield (ICBR 1:2.5) and 37.75% chili yield (ICBR 1:3.0). Field application of Pl and Pf each @ 2.5 kg/ha along with 2.5 t FYM/ha reduced RKN by 32.01 and 35.67% and increased okra pod yield by 92.97 and 71.24%. Seed treatment of Pl @ 20 g/kg seeds coupled with Pf soil application @ 2.5 kg/ha reduced 35.45% RKN, 72.75% stem rot and increased 38.88 % groundnut yield. Even seed treatment with Pl @ 20g/kg seeds reduced 74.87% Reniform and increased 67.80% cotton yield (ICBR 1:68.74).

Invited

O33-2. Effect of methanolic extracts of *Chromonaela odorata* and *Ageratum conzyoides* Linn on mortality rate of plant parasitic nematodes of federal capital territory-Abuja

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Comparative studies of methanolic extracts of *Chromolaena odorata* Linn. and *Ageratum conyzoides* Linn. on the mortality rate of plant parasitic nematode was carried out. This was intended to screen leaf extracts for activity against nematodes and to compare the efficacy of the test plants with nematicidal properties. Dry leaves were extracted using methanol and was fractionated using different solvents using standard method. Phyto-chemical analysis was carried out. Mortality rate of plant parasitic nematodes isolated was tested using extracts. The results of the phyto-chemical analysis showed that all both plants contain the same phyto-chemical but in varying quantities. *C. odorata* was found to have a higher quantity of saponin and alkaloids at 81.5 and 12.6 (mg/g^{-1}), respectively, in addition, phenols and tannins were also found to be higher in *C. odorata* than in *A. conzyoides*. Flavonoids, glycosides, phlebotanins and terpenoids are found to be higher in *A. conzyoides* than in *C. odorata*. Phlebotannins, glycosides, flavonoids are also found to be higher in *A. conzyoides* than in *C. odarata*. The mortality rate of plant parasitic nematode tested on *C. odorata* is

significantly higher than that of *A. conzyoides*. The population of nematode juveniles reduced significantly on application of *C. odorata* and there is also inhibition of egg hatch after 48 hours of application of the extract. *A. conyzoides* also was found to have a nematicidal effect only on the female nematodes which has delay in egg hatch.

O33-3. Application of waste-mediated silver nano particles in rice nematode (*Heterodra saccharri*) management

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Significant decrease in rice production has been attributed to various factors one of which is infestation by plant parasitic nematodes. An important pest in rice production is the *Heterodera sacchari*. Methods of control with synthetic nematicides are laden with environmental pollution. Great attention has been diverted to the application of nanoparticles in agriculture. Nanoparticles exhibit biological activities based on their size and morphology. Silver nanoparticles (AgNPs) are the most promising because of their very high anti microbial properties. As part of our research towards the development of environmentally safe bio-nematicide, we investigated the nematicidal potential of waste mediated silver nanoparticles using corncobs, rice husks and milled sorghum residue. Rice seedlings (Nerica 1) planted in sterilized soil contained in 12 litres experimental pots were inoculated with approximately 500 eggs and second stage juveniles of *H. sacchari* per pot at three weeks after planting in a screen house trial. The experiment was a randomised complete block design (RCBD), with four treatments, each replicated three times and four dosages of application (0, 25, 50 and 75g). The silver nanoparticle produced was characterised with UV-Vis absorption spectroscopy, FTIR and SEM. AgNPs treated rice plants had ($p<0.05$) significantly higher vegetative growth, with corresponding higher yield as opposed to the untreated rice plants. The AgNP at 75g dose showed high efficacy and good root protection. Fewer numbers of white females were extracted from treated rice roots as opposed to the untreated. AgNPs is a promising method of managing cyst nematodes on rice.

O33-4. Biotechnological approaches for using chitooligosacharides (COS) to control the plant parasitic nematode *Meloidogyne incognita* in tomato plants

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Root-knot nematodes, *Meloidogyne incognita*, are common pathogens for more than 230 host genera, such as tomato, potato, onion, lettuce and others, including ornamentals. These nematodes cause losses of 30-40% of the harvest per year, translating into $157 billion annually. Nowadays these nematodes are controlled mainly by cultural practices, chemical nematicides, and by the growing of resistant cultivars. Chitosan is a natural, safe and inexpensive biopolymer produced from chitin, the major constituent of arthropod exoskeletons and fungal cell walls, with several favourable biological properties such as biodegradability, biocompatibility and non-allergenicity, as well as bio-stimulant activity for different crops. The biological activity of chitosan depends on the concentration, molecular weight, degree of acetylation, degree of polymerization, among others. In this study, five different treatments, including seed coating, soil drench, root dipping, soil amendment, and a mix of seed coating with soil amendment were applied to tomato (Money maker) plants prior to infection, using two different chitosans and one type of chitin. The biopolymers were used in different concentrations at different time points with the aim of finding the most efficient treatment to

significantly reduce the reproduction of M. incognita. One treatment was able to reduce significantly the reproduction of *M. incognita*. We are currently investigating the molecular mode of action of this treatment.

O33-5. Managing nematodes using fermented tomato fruit crude extracts: an alternative to synthetic nematicides

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The international withdrawal of fumigant nematicides due to their environment-unfriendliness, shifted the focus on alternative nematode management strategies towards possible use of phytonematicides. Phytonematicides use allelochemicals, products of secondary metabolism as active ingredients. Wide range of allelochemicals occur in tomato fruits with potential nematicidal activities. Large quantities of fruits from commercially preferred indeterminate tomato cultivars are left to rot in the fields after harvest. The effects of tomato fruit fermented crude extracts (FCEs) on nematode suppression is not documented. The objective of this study, therefore, was to determine whether tomato fruit FCEs could suppress nematodes and improve plant growth under field conditions. Uniform 4-week-old tomato cv. 'Floradade' seedlings were transplanted to an open-field with high population densities of *Meloidogyne* species. Treatments, viz., 0, 50 and 100% FCEs with Nemacur as positive control, were arranged in RCBD, with eight replications. Relative to the untreated control, 50 and 100% FCEs significantly ($P \leq 0.05$) reduced nematodes by 83 and 125%, respectively, and reproductive potential by 136 and 89%, respectively. Although the impact of the FCEs were significantly less than those of Nemacur, the FCEs from tomato left-overs demonstrated strong nematicidal activities. Plant growth variables were not affected by all treatments. Nutrient elements, P and S were significantly higher in plants treated with Nemacur. In conclusion, FCEs from tomato fruits have the potential to serving as an alternative phytonematicide in managing root-knot nematodes.

O33-6. Effect of glyphosate application on plant-parasitic nematodes associated with a soybean-maize rotation: A South African study

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Information about the effect of glyphosate, active substance of numerous herbicides used extensively, on nematode assemblages is limited and sometimes contradictory. A small field experiment was conducted during two consecutive summer-growing seasons to investigate the response of plant-parasitic nematode communities to the application of glyphosate on genetically-modified glyphosate-tolerant soybean (cultivar LS 6164 R) and maize (cultivar DKC 80-30 RR). A mixed *Meloidogyne incognita* and *M. javanica* population dominated in the roots of both crops during both seasons. Five other plant-parasitic nematode genera (*Criconema*, *Helicotylenchus*, *Nanidorus*, *Pratylenchus* and *Tylenchorhynchus)* were also identified. Glyphosate application (leaf spray) had no effect on M. incognita, *M. javanica* and *Pratylenchus* spp. numbers. No significant differences were observed between the glyphosate-treated and non-treated plots for *Meloidogyne* population densities per 50 g of roots for both soybean and maize. Significant ($P \leq 0.05$) differences recorded for other nematode genera between glyphosate-treated and non-treated plots in 5 g of roots and 200 g of rhizosphere soil were mainly due to their absence during some of the sampling dates.

O33-7. The reproduction potential of Nigerian *Meloidogyne* species and host status of six commercial watermelon cultivars to such pests

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From a nematode survey, conducted across south-western Nigeria in 2016/17, 25 *Meloidogyne* spp. communities (mixed species) were isolated from watermelon roots and species identification done using morphological and molecular techniques. The reproduction potential of the 25 *Meloidogyne* spp. communities and host response of six commercial watermelon cultivars (to pure populations of the three predominant species identified, viz. *M. incognita*, *M. javanica* and *M. enterolobii*) were conducted in separate glasshouse experiments. Approximately 5000 eggs and second-stage juveniles (J2) were inoculated on roots of two-leaf stage seedlings of a susceptible tomato cultivar. The number of nematode egg masses, final nematode population densities (Pf) and reproduction factors (Rfs) did not show significant interactions ($P<0.05$) between the initial and repeat reproduction potential experiments, while the opposite applied for the host status experiments. The *Meloidogyne* spp. community with the highest Rf was L15 (*M. enterolobii* and *M. javanica*), while populations with the lowest were L7 (*M. incognita*) and L20 (*M. enterolobbi*). All cultivars were susceptible (Rfs >1) to the three *Meloidogyne* spp. used, but their Rfs were significantly lower ($P < 0.05$) than that of the susceptible tomato standard. 'Koloss F1' supported the lowest densities of *M. enterolobii* (Pf = 40; Rf = 6.1); 'Sugar Dragon' for *M. javanica* (Pf = 13; Rf = 2.6); and 'Sugar Baby' for *M. incognita* (Pf = 11; Rf = 2.1). Valuable and useful information were generated for watermelon growers as well as breeders, contributing towards sustainable crop cultivation in sub-Saharan Africa.

O33-8. A synopsis of strategies investigated for integrated nematode control in cereal and leguminous crops in South Africa

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Intensified cropping systems, limited availability of resistant crop cultivars and the continuous withdrawal of red-band synthetically-derived nematicides steered researchers, producers and related crop industries to invest in research on alternative, environmentally-friendly nematode management strategies. A synopsis about these control strategies investigated during the last 10-15 years is presented. Research was conducted under laboratory, glasshouse and field conditions with standard protocols used for nematode inoculation, extraction, counting and identification. Highlights of this research, which mainly focused on *Meloidogyne* spp., are discussed, viz: the identification of resistant and/or poor-host soybean, Amaranthus (African Leafy vegetable) and grass genotypes; adverse effects of biological agents (*Bacillus* and others) and plant-derived products (Vetiver root and leaf exudates; furfural, a by-product of sugarcane; Neem extracts) on the biology of *Meloidogyne* spp.; efficacy of soil amendments (animal manures; Brassicaceae aerial parts) as well as crop rotation sequences in reducing *Meloidogyne* spp. densities. The use of genetic host plant resistance (reducing *Meloidogyne* densities up to 90% compared to susceptible genotypes) should be a preferred strategy and first line of defence to reduce *Meloiodgyne* spp. in local cereal- and leguminous-based cropping systems. In addition, the use of secondary metabolites of biological control agents (>90% effective in paralyzing *Meloidogyne*), plant-derived products (inhibiting *Meloidogyne* respiration up to 94%) and soil amendments (reducing *Meloidogyne* densities >50%), together with the manipulation of cropping sequences will contribute substantially to enable sustainable crop production and food security.

O33-9. Comparative effect of *Rotylenchulus reniformis* and *Meloidogyne incognita* on okra in Nigeria

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Present study evaluated the impact of growing okra in soils infected with *Rotylenchulus reniformis* and *Meloidogyne incognita* on it growth and yield. A pot experiment was conducted in the screenhouse with three popular okra cultivars (NH 47-4, LD66-1 and Clemson spineless) inoculated with either *R. reniformis* or *M. incognita* and compared to non-inoculated plants. The experiment was arranged in a completely randomized design with five replicates. The field trial was conducted using one cultivar, Clemson spineless and the same treatments as the pot trial laid out in a randomised complete block design with five replications. Data were collected on number of leaves, leaf area, plant height, number of fruits and fruit weight and submitted for analysis of variance. Significant reduction in number of leaves and plant height was observed in inoculated compared to non-inoculated plants. Inoculated plant produced smaller and fewer fruits in comparison to the control. Yield reduction in pots was 31-72% in pot experiments with *R. reniformis* and 51-76% in pots with *M. incognita*. Yield of Clemson spineless in the field was reduced by 40% and 36% by *R. reniformis* and *M. incognita* respectively. The reniform nematode has gone beyond being a potential pest of vegetable crops such as okra in Nigeria to being an actual pest that requires serious management interventions.

O33-10. Host-status of twenty sweet potato lines to *Meloidogyne* species in South Africa

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Due to serious economic challenges posed by root-knot (*Meloidogyne* species) nematodes in sweet potato (*Ipomoea batatas*) production, the Sweet Potato Programme (SPP) of the Agricultural Research Council (ARC) in South Africa had since included screening for nematode host-status in its breeding-selection activities. Twenty sweet potato lines were screened against *M. javanica*, *M. incognita* race 2 and *M. incognita* race 4 in parallel trials inoculated with 3 000 eggs and second-stage juveniles (J2) per established cutting. At 56 days after inoculation, the reproductive potential (RP) of all test *Meloidogyne* species on sweet potato line 1990-10-2 was zero, whereas RP values on other lines had 19.48-342.7, 31.9-995.1 and 10.3-380.44 ranges for *M. javanica*, *M. incognita* race 2 and *M. incognita* race 4, respectively. In conclusion, among the test sweet potato lines, line 1990-10-2 was non-host to populations of tropical *Meloidogyne* species in South Africa and could therefore be subjected to nematode resistance test.

O33-11. Nematode damage by cucurbitacin-containing phytonematicides

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After hatch, second-stage juveniles (J2) of root-knot (*Meloidogyne* species) nematodes spend some time in soil solutions searching for suitable penetration sites along the root systems. Consequently, J2 are ideal candidates to suffer damage when exposed to Nemarioc-AL and Nemafric-BL phytonematicides in soil

solutions. Post-72 h exposure to 0, 2, 4, 8, 16, 32 and 64% of each product in parallel trials, specimens were mounted on slides, with selected morphometric data collected and ultrastructure evaluated. Results showed that the two phytonematicides each significantly affected morphometric and ultra-structures of J2. The observed morphological and ultrastructural changes in J2 at various concentration of phytonematicides, all constituted notable structural damage, which provides potential explanation on consistently high J2 mortalities post-exposure. The products appear to have nematicidal as opposed to nematostatic properties on J2.

O33-12. Assessment of nematode population and occurrence on local white yam (*Dioscorea rotundata*) cultivars in Wukari and Ukum local government areas

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Dioscorea spp. are food crops of growing significance in West Africa unfortunately, nematodes are major pests to their production. A survey was undertaken in two major yam markets in Ukum Local Government and Wukari yam market in Wukari Local Government to identify different white yam cultivars in Benue and Taraba state. A total of 34 different local white yam cultivars were identified. Sampling of the yams was conducted to determine the types, frequency of occurrence (FO) and population densities (PD) of plant parasitic nematodes in soil samples associated with major white yam (*Dioscorea rotundata*) cultivars in the two Local Government Areas; using random sampling for soil collection and Baerman funnel for parasitic nematode extraction. Identification of plant parasitic nematodes to the generic level was done using Lucid key of Bell. A total of 11 genera of plant parasitic nematodes were detected, which included *Pratylenchus*, *Scutellonema*, *Meloidogyne*, *Aphelenchoides*, *Rotylenchus*, *Radopholus*, *Helicotylenchus*, *Aphelenchus*, *Trichodorus*, *Xiphinema* and *Rotylenchulus*. Plant parasitic nematodes most widely encountered were *Pratylenchus* spp., *Scutellonema* spp. and *Meloidogyne* spp., with frequency of occurrence recorded as 90, 76 and 70%, respectively.

O33-13. Study of the genus *Helicotylenchus* from Iran and South Africa using 28S rDNA

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Helicotylenchus, (Hoplolaimidae), is a cosmopolitan and polyphagous genus. This spiral nematode is commonly found associated with crops. During surveys in Iran and South Africa on plant-parasitic nematodes belong to the family Hoplolaimidae, several species of *Helicotylenchus* were recovered. The 28S rDNA of these nematodes were studied. The Nblast results showed 95% similarity among undescribed *Helicotylenchus* species from Iran and South Africa. The phylogenetic analysis using maximum likelihood showed close relationship of the Iranian and South African population of *Helicotylenchus* with highly supported bootstrap (100) values. The average C+G composition showed 63.1 and 60.5 for the Iranian and South African respectively. Distribution map, measurements and comparative illustration for the species studied of both countries are given.

34. Integrated pest management (3)

Organizers: P K Chakraborty and Noriharu Umetsu

Invited

O34-1. A non-pathogenic *Fusarium commune* W5 has ability to control seedborne "Bakanae" disease of rice, soilborne tomato *Fusarium* wilt and banana Panama disease

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"Bakanae" (foolish seedling), caused by *Fusarium fujikuroi*, is one of the most important seedborne diseases of rice (*Oryza sativa*) worldwide. Though chemical fungicides (e.g. ipconazole) are effective in the control of "Bakanae" at present, the future emergence of fungicide resistant strain of the pathogen is of concern. We screened 70 isolates of *Fusarium* spp. from rice plants in "Bakanae" outbreak fields in Japan and selected a non-pathogenic *F. commune* W5 with a clear "Bakanae" control activity by seed treatment. W5 additionally showed "Bakanae" control activity in the rice plants generated from the seeds obtained from the flower treated with W5 bud cell suspension during flowering. According to the fluorescence imaging and dual-culture assay, it was suggested that W5 competes with *F. fujikuroi* for nutrition and/or space on the rice plant tissues. We also evaluated the biocontrol efficacy of W5 against soil borne diseases of vegetables caused by *F. oxysporum*, such as tomato (*Solanum lycopersicum*) *Fusarium* wilt, banana (*Musa* spp.) Panama disease and cabbage (*Brassica oleracea*) yellows. Seed dipping into W5 bud cell suspension (10^5 bud cells/ml) significantly controlled tomato *Fusarium* wilt. Banana Panama disease was significantly controlled by soil drenching with W5 bud cell suspension (10^8 bud cells/ml). However, W5 did not significantly control cabbage yellows in this study. In order to reveal the control mechanism of W5 against seed borne and soil borne diseases, we obtained the whole-genome sequence of W5 and currently analyzing. Control ability of W5 against *Fusarium* wilt diseases of other vegetables is also under investigation.

O34-2. Microscopic examination of mycelium changes of phytopathogenic fungi of the genera *Fusarium* and *Pyrenophora* when co-cultured with the biopesticide-producing strains *Bacilus subtilis*

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The development of effective microbiological plant protection products involves the study of the interaction mechanisms of antagonist microbes with pathogens. Therefore, the aim of this research is to study the antifungal action mechanism of advantageous strain *Bacilus subtilis* BZR 336g against Fusarium blight and winter wheat yellow spot pathogens. The object of study were new bacteria strains producing biopesticide B. subtilis BZR 336g and B. subtilis BZR 517, as well as the cultures of phytopathogenic fungi *Fusarium graminearum*, *F. oxysporum* var. *orthoceras* and *Pyrenophora triciti-repentis* from the collection of the All-Russian Research Institute of Biological Plant Protection. In the course of microscope observation of the opposite-culture of *B. subtilis* strains with fungi of the genus *Fusarium*, we conditionally identified two forms of antagonist action on the tested fungi: distant and contact, and only distant when interacting with *Pyrenophora triciti-repentis*. We found that the studied strains producing biopesticide have fungicidal activity, that is, they can secrete antifungal substances, under the influence of which the inhibition and

destruction of phytopathogenic fungi occurs. Antifungal metabolites of the studied strains are represented by antibiotic compounds, presumably of a peptide nature, and exoenzymes, mainly lipase and protease groups. It is important to emphasize that the considered aspects do not exhaust all possible mechanisms of action, and therefore further research is needed.

O34-3. New management possibilities for the pine processionary moth *Thaumetopoea wilkinsoni* using entomopathogenic bacteria and fungi

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The pine processionary moth (PPM), *Thaumetopoea wilkinsoni* Tams (Lepidoptera: Thaumetopoeinae) is the major defoliator of pine trees in the eastern Mediterranean, and utricating reactions to humans and pets. In Israel, the activity of existing PPM natural enemies, do not efficiently restrain PPM populations. PPM management in the forest relies on aerial application of *Bacillus thuringiensis* (Bt) and synthetic insecticides. Due to phasing out of synthetic pesticides and development of resistance to both synthetic and Bt pesticides, there is a growing need to integrate more sustainable solutions. In the present study, we aimed at: a) screen for novel Bt strains with higher efficacy than commercial strains and b) to develop a novel formulation of entomopathogenic fungi (EPF) against PPM. Fifteen novel Bt strains assays were conducted using PPM early larval instars fed on Bt treated pine needles. Two strains out of 15 showed higher toxicity than commercial strains. PPM is known to be susceptible to EPF including *Metarhizium brunneum*. Compared the efficacy of formulated and non-formulated *M. brunneum* strain7 (Mb7) against late instars of PPM and fed on conidia treated needles. PPM mortalities, LT50 were 3.3 and 4.3 days for emulsion and triton water formulations. We compared applications of conidia suspended in triton water and novel emulsion. Conidia were found to be dispersed more evenly in the novel emulsion than in the triton water. Our study demonstrates the emergence of new possibilities in the field of microbial control, by integrating new strains and formulation technologies in the management of PPM.

O34-4. PGPR effect of Actinomycetes: impact on the morpho-biochemical characters of tomato

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Actinomycetes are known for their enhancing effect and promoter of plant growth and its protective activity of plants against bio-aggressors. For this purpose, four actinomycetales strains were tested to study their effect on the growth of tomato seeds and to highlight the insecticidal and antifungal activity a of these bacteria, which has been remarkable in Ac 70, Ac 33, Ac 24 and Ac 25 strains. Both size of the above ground plant parts, root part, and the germination and growth rates are remarkable particularly with strains Ac 70, Ac

33, Ac 24 and Ac 25. The measures of fresh weight of seedlings as well as the dosage of chlorophyll a, b and total chlorophyll have determined that Streptomyces can help plants grow with their presence in Rhizosphere as they may be Endophytes and colonize various parts of the plants.

O34-5. Efficacy of pesticides on soybean diseases and yield

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Foliar, stem, and root diseases of soybean (*Glycine max*) are significant components of yield loss. Fungicides are the main disease management options in soybean. Trials were conducted at the Northeast Research and Demonstration Farm in Nashua, IA, USA, and the Central Research Farm in Ames, IA, during 2011-2017. Eight Triazoles (DMI), five strobilurins (QoI), five premixes, and ten other fungicides (neither DMI nor QoI) were tested. Three insecticides and two herbicides were tested as well. Pre- and post-spray disease ratings were recorded weekly beginning 1 week before spraying and ending 1 week before harvest. The diseases assessed were anthracnose, bacterial leaf blight, downy mildew, frogeye leaf spot, brown stem rot, charcoal rot, *Phomopsis*, *Phytophthora* root rot, soybean vein necrosis, sudden death syndrome, and white mold. Yields were measured in metric t/ha with an adjusted 13% grain moisture. Some fungicides resulted in significant differences ($P < 0.05$) in disease incidence and severity, and most fungicides resulted in a yield advantage over unsprayed controls. Across 163 treatments, spread over 7 years, the average yield advantage was 0.16 t/ha (rang of -0.46 to 0.69 t/ha). The mean yield advantage of fungicides sprayed versus unsprayed controls was 0.27 t/ha (range of -0.07 to 0.69 t/ha) in 2011, 0.12 t/ha (range of -0.22 to 0.43 t/ha) in 2012, 0.12 t/ha (range of 0.03 to 0.37 t/ha) in 2013, 0.14 t/ha (range of -0.22 to 0.43 t/ha) in 2014, 0.16 t/ha (range of -0.31 to 0.47 t/ha) in 2015, -0.07 t/ha (range of -0.46 to 0.22 t/ha) in 2016, and 0.07 t/ha (range of -0.21 to 0.43 t/ha) in 2017.

O34-6. Biocontrol potential of the non-pathogenic lineage A1/D2 of *Verticillium longisporum*

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Verticillium longisporum is a soil-borne vascular fungal pathogen of oilseed rape, causing stem striping disease. The long survival in the soil of its resting structures, the inefficiency of fungicides in the vascular system and the lack of cultivar resistance make the control of *V. longisporum* a challenge, which calls for research on alternative control methods, such as biocontrol. *V. longisporum* consists of three different lineages putatively originated from three independent hybridization events from four different haploid parents. Thus, the three lineages of *V. longisporum* are referred to as A1/D1, A1/D2 and A1/D3. With a lineage monitoring in European and Canadian oilseed rape fields, we have shown that A1/D1 is the most predominant in this crop. On the other hand, lineage A1/D2 has only been found in horseradish in the USA and induces mild to no disease symptoms in most Brassica crops. It is known that non-aggressive or weak strains of closely related vascular pathogens are good candidates for biocontrol. For this reason, the biocontrol potential of the non-aggressive lineage A1/D2 against the aggressive lineage A1/D1 was investigated. Mixed inoculations with pathogenic A1/D1 strains and non-pathogenic strains of A1/D2 of V. longisporum led to a significant reduction of disease severity. Microscopic studies revealed that A1/D2 colonizes the root surface and outer root cell layers, which implies a competition effect to be involved in the biocontrol mechanism. Additionally, the potential field application of A1/D2 by means of seed coating is investigated.

O34-7. Occurrence of white mold disease of country bean caused by *Sclerotinia sclerotiorum* (Lib.) de Bary in Bangladesh and its management

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A total of 165 fields in ten districts of Bangladesh were investigated to examine the white mold disease infestation in country bean during 2016-2018. The maximum numbers of disease infested fields were recorded in Bogra district (100%). Three fungal and four bacterial antagonists were examined for its effectiveness to control *S. sclerotiorum* on potato dextrose agar (PDA) medium in vitro. Mycelium growth inhibition was 96.33, 96.96, 92.67, 92.42, and 92.50% in *Trichoderma harzianum*, *T. viride Pseudomonas* sp. (S), *Pseudomonas* sp. (N), and *Bacillus subtilis* BVC38, respectively. A disease susceptible field at Shahjahanpur, Bogra was selected to test two IPM packages for field management of the disease. IPM package 1 (a. Raising seedlings in poly bag; b. Land sub-merged for 22-25 days; c. Tricho-compost @ 2.5 t/ha applied in soil; d. Weeding two times; e. Rouging virus infected plants; g. Using sex pheromone complex; f. Bio NEEM plus (0.1%) applied; g. Foliar spray of Tricho-leachate) and IPM package 2 (Package 1+ Application of bio-control agents (*B. subtilis* strain BNC38 and *Pseudomonas* sp.) at 10, 30, 50 and 80% of the major stems flowering. Farmer's practice (control) was maintained. Both the IPM packages reduced disease infestation and gave better yield compared to control. Both packages markedly reduced RKN infestation and increased yield. Marketable yield was negatively correlated with white mold disease incidence. Benefit Cost Ratio was higher (2.61) in both packages. BCR increased over farmers' practices was about 39.38 to 39.81% in IPM package using field.

O34-8. Investigations on *Ustilaginoidea virens* causing false smut of rice in India

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Ustilaginoidea virens causes rice false smut. The yield losses to the tune of 0.2-49% have been reported in India. Morphological characterization of *U. virens* isolates from PB showed creamy white, grey black, fluffy mycelium, undulated, compact, ring pattern growth of colonies. Spores were, circular to ovate, echinulated, double walled. While, the isolates from Delhi and UP showed creamy dull white-grey, cottony, undulated colonies. Spores were circular to ovate, highly echinulated, double walled, mass of spores covered with silvery membrane. The conidia (3-5µm) of *U. virens* were globose to irregularly rounded and ornamented with prominent spines (200-500nm). Out of the 20 tested culture media for the growth of *U. virens*, 4 media (Corn meal dextrose agar, Yeast malt agar, Potato dextrose agar, and Potato carrot agar) showed cultural growth (1cm in 10 days) which was at par with the standard PSA (Potato sucrose agar). A greenhouse trial was conducted to standardize the inoculation technique in false smut of rice (CV. Swarna) during the 2018 Kharif season by using syringe and spray inoculation methods at boot, early flowering and grain filling stages of the crop. Syringe inoculation of spore suspension ($4X10^6$) of *U. virens* at early flowering stage of the rice crop was most successful method in producing the disease as compared to the spray method. Syringe inoculation produced 10.0% disease incidence and 0.4% disease severity at early flowering stage of the crop respectively. The disease was not produced at boot and grain filling stages of the crop by either method.

O34-9. Effect of fungicides as seed dressers on seedborne infections of soybean

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Maintenance of seed viability and vigour during storage seems to be a challenging task in soybean. One of the important reasons for this is seed associated pathogens that cause rapid deterioration in seed especially during storage under ambient conditions. To avoid seed borne infections that occur during storage or carried through field, a set of fungicides were tested for their efficacy against seedborne infections in soybean. After receiving kharif produce, before placing the seeds in storage, the soybean seeds were treated with 8 different fungicides and were subjected to seed health and quality parameters by adopting standard procedures. The results indicated that, at 14 months after storage, the fungicide Carboxin + Thiram (76.63%) followed by Pyraclostrobin + Metiram (74.50%) recorded germination at above IMSCS when compared to that in control (31.88%). The study also revealed that, all the fungicides offered complete protection against seedborne infections from 10 months after storage onwards. As the storage period extended, there was gradual increase in per cent seed rot and is vice- versa in case of seedling vigour. At 16 months after storage, the fungicide Carboxin+ Thiram (34.25%) recorded significantly lowest per cent seed rot when compared to control (85.25%). Similarly, with respect to seedling vigour, the same fungicide was found significantly superior.

O34-10. Protection of *Beta vulgaris* subsp. *maritima* against the root-knot nematode using some weed plants

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Beet root (*Beta vulgaris* L. subsp. *maritima*) is an economically important leafy vegetable crop in many countries. The root-knot disease caused by *Meloidogyne incognita* is highly damaging and yield reducing factor of beet root throughout the world. Chemical nematicides, though effective and working instantaneously, are now being reappraised in respect of environmental hazard, high costs and limited availability. Plants appear to be a source of cheap and effective pesticidal compounds, having low plant and human toxicity and being easily biodegradable. Therefore, a greenhouse experiment was carried to test the efficacy of some weed plants against *Meloidogyne incognita* (Kofoid & White) Chitwood, attacking beet root. All applied treatments significantly ($p \leq 0.05$) enhanced the growth parameters of beet root and inhibited nematode multiplication compared to inoculated control. However, the maximum reduction in root-knot development was observed in the plants treated with *Ricinus communis* L. followed by *Achyranthes aspera* L. while minimum in plants treated with *Coccinia grandis* L. From the foregoing experimental results it may be concluded that these weed plants can be exploited for the crop protection as well as sustainable management of the pathogen.

O34-11. Carvacrol inhibit biofilms produced by *Dickeya zeae*

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Dickeya zeae is the causal agent of devastating banana soft rot disease, resulting in serious worldwide economic losses. The formation of a biofilm is an important virulence and pathogenesis factor for *D. zeae*. The following study aims to determine the inhibitory effects of carvacrol on biofilms produced by *D. zeae*. We found that the minimum inhibitory concentration (MIC) and the minimal bactericidal concentration (MBC) values that Carvacrol exhibited against planktonic *D. zeae* MS1 were 0.1 mg/mL and 0.2 mg/mL, respectively. Quantitative crystal violet staining of biofilms showed that the biofilm formation was inhibited by 79.07%, 48.05%, 28.37% and 8.06% with all four concentrations (1/2MIC, 1/4MIC, 1/8MIC and 1/16MIC) of carvacrol after treatment at 32 °C for 24 hours, respectively. And the scanning electron microscopy (SEM) images clearly showed the three-dimensional biofilm morphology of the *D. zeae* and the resulting anti-biofilm effect. Carvacrol reduces the formation of *D. zeae* biofilm under sub-inhibitory conditions. Based on these results, Carvacrol, as a natural substance, may play an important role in t the prevention and control of soft rot diseases.

O34-12. Evaluation of the efficacy of *Trichoderma* species, used in combination, to control basal stem rot disease of oil palm (*Elaies guineensis* Jacquin)

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The oil palm industry in Malaysia and Indonesia is being severely affected by *Ganoderma* species which cause basal stem rot disease. The disease not only causes a loss in oil palm yield but results in death of trees. Research on discovering a sustainable and eco-friendly solution to this disease is increasing. Current control methods make use of synthetic fungicides. *Trichoderma* species have been recognized as effective biological control agents against a wide range of plant diseases. Thus, in this study, oil palm seedlings inoculated with *G. boninense* were treated with three *Trichoderma* species (single and in combination) to evaluate their effects on the growth and suppression of *G. boninense*. The combination of *Trichoderma* species was found to be the most effective treatment in suppressing the severity of the disease by 83% and 89% with regards to the foliar and bole symptoms, respectively. Vegetative growth of treated oil palm seedlings was significantly improved. Peroxidase, polyphenol oxidase and total phenolic content were enhanced in the treated seedlings. Disease development was slower in the seedlings treated with the combination of *Trichoderma* species compared to the control, which exhibited the highest percentage disease severity. The combination of these *Trichoderma* species could potentially be used as an effective control option.

O34-13. Evaluation of *Trichoderma* and *Bacillus* species in the management of pathogenic nematode and fungi on tomato

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Tomato production is constrained by many pathogens. The present study was carried out to verify the effects of biological control agents (*Trichoderma harzianum*, *Bacillus subtilis*, *B. thuringiensis* and *Bacillus cereus*) on *Fusarium oxysporum* f. sp. *lycopersici* and root-knot nematode of tomato. The pot experiment was carried out at Ladoke Akintola University of Technology Ogbomoso, Nigeria during 2017 planting season. The treatments were *T. harzianum*, *B. subtilis*, *B. thuringiensis* and *B. cereus*, with or without the pathogens as control 1 and 2, respectively, in a Completely Randomized Design in 3 replicates. Incidence of the disease complex recorded the least height (48.52 cm) and number of leaves (87.73) while infection of root-knot nematode had the highest values of 55.95 cm and 108.09, respectively. Among the biological control agents, there was no significant difference ($p \geq 0.05$) in the height and number of leaves/ plant while control 2 had tallest plants (74.13 cm) and the highest number of leaves/plant (142.33). Control 1 had the least plant height and leaf number, respectively (57.91 cm and 71.3). There was no significant difference in number of fruit and fruit weight of the biological control agent treatments but was higher in the Control 2. Galling index, root and soil nematode population were significantly lower in *B. subtilis* with 1.54, 543 and 370, respectively, while *B. cereus* had 2.00, 1101 and 524, and *B. thuringiensis* had 2.01, 1044 and 510, respectively. In conclusion, the application of *Trichoderma* and *Bacillus* mixture significantly improved the growth and yield of tomato.

O34-14. Status of *Fusarium* wilt infecting Cavendish banana in India and possible strategies for its sustainable management

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Of late, Fusarium wilt particularly Tropical race 4 (TR4) strain is becoming a major threat to banana industry in almost all the banana growing continents of the world affecting livelihood of millions of the people. In India too, this lethal disease was recorded in Bihar and Uttar Pradesh and there is a possibility of movement of this deadly strain to other neighboring states which may cause huge yield loss and un-employment problems. To characterize this devastating strain of Fusarium wilt, samples were collected from different states of India and identified the presence of VCG 01213/16 as well as VCG 0124 which infect Cavendish group of bananas in Bihar, UP, MP, Maharashtra, Gujarat, West Bengal and Tamil Nadu. The incidence recorded was up to 60%. Immediately after the confirmation of the presence of TR4, an array of sensitization and awareness meetings were conducted in different parts of India involving all the stakeholders of banana mainly to contain further spread of the disease. In order to identify resistant sources, a total of 325 germplasm accessions were screened in hot spot areas and identified about 30-35 resistant accessions which may be useful for distribution to the farmers as well as for the improvement of susceptible commercial cultivars through breeding approaches. Besides, consortia of native bioagents possessing multiple functions and cost effective and farmer friendly mass production and delivery system have been developed for the effective management of the disease. The details of findings are discussed in this paper.

35. Remote sensing and machine learning for determination of spatio-temporal distribution of invasive species

Organizers: R Muniappan and Pramod K Jha

Lead

O35-1. Modern AI techniques to understand the spatio-temporal spread of invasive alien plants: approaches and challenges

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In recent years, deep learning has emerged as an effective tool for discovering patterns in imagery data, with application in diverse domains, from medical imaging to remote sensing. Epidemiological modeling is another successful approach that is being increasingly used to study the spatiotemporal spread of diseases, pests, and plants. Here, we propose a generic framework that combines these modern data-driven techniques to understand the dynamics of invasive alien plant spread, a problem that has enormous environmental and social impact. To this end, we use historical high-resolution satellite imagery, ecological data, and plant presence/absence information due to extensive surveying. There are several challenges that need to be overcome in order to realize such a system; data inadequacy, model complexity, and heterogeneity in data formats are just a few of those obstacles. We apply this to study the spatiotemporal spread patterns of invasive alien plant species in the Chitwan Annapurna Landscape (CHAL) region of Nepal, a biodiversity hotspot. The primary focus is on understanding the roles of human activities and climate change on the rate and pattern of spread.

Invited

O35-2. Spatial distribution of *Lantana camara* in Chitwan Annapurna landscape area Nepal using satellite imageries

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Remote sensing has been an important tool to detecting large scale distribution of invasive alien plant species. We used knowledge based classification to determine the spatial and temporal distribution of *Lantana camara* in Chitwan Annapurna Landscape (CHAL) area, Nepal. The spatial knowledge was combined with spectral knowledge in the mapping. Multispectral and medium spatial resolution data (Landsat 8) was preferred to maximum likelihood classification for identifying land use categories. ERDAS Imagine 2014 software was used for knowledge based classification where different inputs like aspect, slope, elevation, maximum temperature, minimum temperature, rainfall and reflectance in addition with land use were hypothesized in knowledge engineer of ERDAS imagine. In addition to these six digital globe images of high resolution (2*2m), different districts were used as reference data to map the spatial distribution of *Lantana*.

Knowledge based classification of Landsat and Digital Globe image was done. The suitable distribution area of the weed in CHAL was found to be 12.02% and the actual distribution (using reflectance value) of the weed in the same area was found to be 1.138%. The suitable distribution area of the weed in Digital Globe images i.e Chitwan, Tanahau and Myagdi was found to be 4.8%, 3.35% and 0.11%, respectively. Similarly, the actual distribution of the weed in the digital globe images i.e. Chitwan, Tanahau and Myagdi was found to be 2.65%, 0.38% and 0.0013%, respectively.

O35-3. Spatial distribution of an invasive weed *Ageratina adenophora* in Chitwan-Annapurna landscape, Nepal using knowledge based approach

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Rapid spread of invasive species is a significant threat to native biodiversity and ecosystem functioning. We used knowledge-based image classification approach using remotely sensed images to map current potential distribution of the invasive weed *Ageratina adenophora* (Sprengel) R. King and H. Robinson in Chitwan-Annapurna Landscape (CHAL), Nepal, and four different patches within different districts (Kaski, Myagdi, Ramdi and Tanahun). For CHAL, multispectral and medium spatial resolution satellite data (LANDSAT 8 TM) was subjected to supervised classification for determining land use categories, whereas for four small patches of districts, high spatial and spectral resolution satellite data from Digital Globe Imageries were assessed. This land use image subjected to supervised classification in integration with other sources of georeferenced information such as elevation, aspect, environmental variables as minimum temperature, maximum temperature and rainfall and reflectance value assessed from the corresponding satellite imageries was used for building up rules for knowledge engineer and knowledge based classification in ERDAS Imagine 2014. Knowledge based classification showed that 21.74% (6967.62km²) of CHAL area is found to be suitable for *Ageratina adenophora* in current condition (2018), middle mountain being highly invaded. For small patches, knowledge based classification with Digital Globe imageries exhibited 0.72%, 8.42%, 3.45% and 0.01% of area of Kaski, Myagdi, Ramdi and Tanahun invaded by the weed respectively in current condition. As high resolution Digital Globe Imageries exhibited lesser area of invasion by the weed when compared to Landsat -8 images, further field verification would predict the accuracy of the process and actual area of invasion.

O35-4. Spatial distribution of an invasive weed *Chromoleana odorata* in Chitwan-Annapurna landscape area, Nepal using knowledge based approaches

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Multispectral satellite imagery can facilitate identification and assessment of invasive plant species distribution. The objectives of this study are to map the habitat distribution of *Chromolena odorata* in

Chitwan Annapurna Landscape (CHAL) and to identify the high potential spatial location for *Chromoleana odorata* ((L.) R. M. King & H. Robinson) through satellite imageries. Multispectral and medium spatial resolution satellite data (Landsat 8) was used for supervised classification of land use in ArcGIS 10.3 and the classification was incorporated with slope, aspect, elevation, temperature (minimum and maximum) and rainfall range of the species to set rules for knowledge engineer and knowledge based classification in ERDAS Imagine 2014. Two high spatial and spectral resolution satellite data from Digital Globe for Nawalparasi and Chitwan districts was used for mapping actual spatial distribution of the weed. Knowledge based classification of LANDSAT 8 showed that 5.4% of CHAL was found to be suitable habitat of *C. odorata*, whereas species level distribution on the basis of reflectance of species showed about 0.91% actual distribution of the weed in CHAL. Knowledge based classification of Digital Globe Imageries of Chitwan and Nawalparasi district showed 2.46% and 3.80% area as suitable habitat for the weed, respectively, whereas the same location in Chitwan and Nawalparasi districts under Knowledge based classification showed 2.8% and 8.36% of the area as suitable habitat for the distribution of the weed, and species distribution on basis of reflectance in area of Digital Globe images was found to be 0.74% in Chitwan and 0.15% in Nawalparasi.

O35-5. Mapping the distribution of invasive alien plant *Parthenium hysterophorus* in Chitwan Annapurna landscape (CHAL), Nepal using knowledge based approach

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Parthenium (*Parthenium hysteorphorus* L.) is a rapidly spreading neo-tropical invasive weed. This study aimed to detect and map parthenium in Chitwan Annapurna Landscape (CHAL), Nepal with knowledge-based approach by assessing the freely available open source Landsat-8 image. Knowledge-based approach allows integration of remotely sensed data with information such as land use, climatic, and digital elevation models (DEMs). Supervised classification was done to provide a land use map including forest, agricultural land and other classes in ERDAS Imagine software. Further reclassification was done in iso-clustered unsupervised classified image of Landsat 8 image based on occurrence locations of parthenium. Variables that likely affect the distribution of the weed – temperature, rainfall, elevation, slope and reflectance value – were used for knowledge-based classification to get spatial distribution of parthenium in CHAL. Similar process was done in four high spatial resolution Digital Globe imageries (Chitwan, Myagdi, Nawalparasi and Tahanun) that lie within CHAL to get current distribution. Potential suitable distribution in above four Digital globe image boundaries were extracted from knowledge based classified map of Landsat 8 image for comparison. Knowledge based approach used in Landsat 8 image showed parthenium is found in 5% (1669 km^2) of total area of CHAL in current condition (2018). Extracted Digital Globe images boundary from Landsat 8 classified image showed 38%, 35%, 7% and 32% area invaded by parthenium but knowledge-based classification done in Digital Globe images showed parthenium invaded in 45%, 1%, 1% and 3% area of Chitwan, Myagdi, Nawalparasi and Tahanun, respectively.

Oral

O35-6. Extraction of onion fields infected with anthracnose-twister disease using object based image analysis

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Remote sensing is one of the advanced technologies that can be used in early detection, mapping and spatial tracking of pests and disease infestations. This technology can give an updated information on the geoinformation and plant health status of the areas by conducting image analysis and classification processes using imageries captured by satellites and Unmanned Aerial Vehicles (UAV). Anthracnose-Twister disease is one of the destructive diseases of onion in the Philippines caused by fungi Colletotrichum gloeosporioides and Gibberella moniliformis. The manifestations of this disease in onion areas are very visible in aerial imageries captured by UAV's, thus, these imageries were utilized in extracting infected onion areas in the fields. To map out the affected areas, Object Based Image Analysis (OBIA) was performed in aerial imageries captured by the UAV's. Vegetation indices generated from the RGB and NIR bands were used as image layers and the Support Vector Machine as the classifier. The Support Vector Machine (SVM) was used to generate geophytopathological maps showing the actual picture and health status of onion fields with 85+% accuracy. The OBIA using SVM was effective in extracting infected onion areas using different vegetation indices, thereby, creating geophytopathological maps pin pointing the infected and the non-infected fields in the areas. These, maps were turned over to the decision makers and extension workers to raise the level of awareness on the infestation and used as monitoring tool in disease spread prevention as well as in planning for disease and pesticide management and environmental protection.

O35-7. Modelling climate change impacts and scenario variations on forecasting the potential endangered areas for the establishment of fall armyworm in India

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The Fall Armyworm (FAW) or *Spodoptera frugiperda*, is an endemic and agriculturally important insect pest in tropical and subtropical regions of the Americas causing severe impact estimated at millions of dollars. FAW has been recently identified for the first time in India and is also a first record in Asia threatening food security and livelihoods of millions of farmers. The insects are affected by climatic factors, and climate change may affect geographical distribution, abundance, growth rate, survival, mortality, number of generations per year and other characteristics. These effects are difficult to project due to the complex interactions among insects, hosts and predators. Moreover, agricultural pest management may become more challenging under future climate change and variation. The present study aims to project the impact of climate change on future suitability for the expansion of FAW as well as highlight the high risk probability areas due to the pest under current and future conditions. The modelling was carried out using CLIMEX model, GIS, the known distribution of the species and the CliMond meterological database. The potential endangered areas for the FAW establishment are studied for the major maize growing states in India. The climate change projection with temperature variations and scenario variations using two general circulation models (GCMs), CSIRO MK3.0 and MIROC-H, for 2030 and 2050 under the A2 Special Report on Emissions Scenarios (SRES) are also studied. This kind of analysis assessing the possible impacts of FAW under future climate conditions is essential for the future economic production of crops.

O35-8. Development of a decision support system for control of Northern corn leaf blight (*Exserohilum turcicum*) and Kabatiella eyespot disease (*Kabatiella zeae*) in corn under European conditions

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In recent years, an increase in fungal leaf diseases in corn has been observed under Central European conditions. Among others, two diseases have appeared to be most important: Northern Corn Leaf Blight (NCLB) (caused by *Exserohilum turcicum*) and Kabatiella Eyespot Disease (KED) (caused by *Kabatiella zeae*). In the meanwhile, two fungicides have been registered in the EU for chemical control of corn leaf diseases. However, a lack of knowledge about the damage potential of the diseases has hampered an IPM-guided application of fungicides based on economic damage thresholds so far. This has prompted field studies with the main objective to develop a threshold-based decision support system (DSS) for effective control of the two diseases. Field trials were conducted at two different locations in Germany over three years (2017-2019). Through artificial inoculation at different growth stages and subsequent yield analysis (silage biomass/grain yield), disease-yield loss relationships and economic damage thresholds have been established in corn for the first time. As a result, the economic threshold for NCLB was found to be lower (5% diseased leaf area at flowering stage) than the one for KED (20%). In further field trials, the impact of agronomic cultivation factors such as tillage, pre-crop or cultivar was assessed in order to establish a solid DSS in corn under Central European conditions.

O35-9. Image processing as a tool to identify the insecticidal effects in rice yellow stem borer eggs

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Effects of two diamide insecticides, Tetraniliprole and chlorantraniliprole on eggs of yellow stem borer, *Scirpophaga incertulas* was studied along with an untreated control. Bromophenol blue stains the periplasm and ooplasm in an insect embryo to blue color. Based on this concept, insecticide treated eggs were stained with bromophenol blue (10%w/v). Areas with active protein stain blue and the other areas remain unstained. The images of the eggs were captured under a stereozoom microscope attached to a camera (Optika Pro V). The stained areas attaining blue color in both the treatments were quantified through an image processing program in MATLAB R. The images of the embryos were processed and through centroid method, the blue colored portion in each of the embryo was estimated. The percentage of blue colored portion in the treatments was estimated and compared through t-test. Analysis revealed that there was significant difference in size of the embryos and protein content in the insecticide treated eggs. Identification of activity of insecticidal molecules in insect tissues through staining and imaging could serve as an important tool in the years to come.

O35-10. Banana bunchy top disease surveillance using remote sensing satellite imagery and machine learning algorithms in West Africa

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The banana bunchy top virus (BBTV, genus Babuvirus) severely reduces plant growth and prevents banana production. BBTV outbreak in West Africa was first recorded in Benin Republic in 2010 and has spread to the adjoining border communities of Nigeria. As part of the effort to contain the disease spread in the region, regular surveillance is being conducted that includes field surveys and diagnostic testing of suspect samples. Banana farm holdings are generally small and fragmented in the area, it is therefore impracticable to assess all banana farms using field survey methods alone. In this study, we have used medium resolution satellite imagery to identify banana fields in the BBTV endemic area using a remote sensing approach to aid in targeted surveillance for BBTV control and to delineate areas of possible infestation. Vegetation indices derived from multispectral and multi-temporal Sentinel 2 and Landsat 8 image data were used to classify landcover and to identify banana farms using four machine learning algorithms (Random forest, Support vector machines, Boosted decision trees and K-nearest neighbours). Results suggest that the four algorithms performed comparatively well in classifying landcover with an overall accuracy of about 0.95 and Kappa coefficient of 0.91. Specifically, the banana class was predicted with balanced accuracies of above 0.90 with support vector machine exhibiting the highest performance. Our results suggest that the use of satellite imagery such as Sentinel 2 and LANDSAT 8 in combination with machine learning algorithms are useful in the detection of banana farms to increase BBTV surveillance.

O35-11. Arthropod community associated with okra and eggplant in Sri Lanka: an initiative for a bio-surveillance programme

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Eggplant (*Solanum melanogena*) and okra (*Abelmoschus esculentus*) are grown in commercial scale targeting export markets. Few major crop pests were identified to cause economic damages however comprehensive studies are lacking on associated arthropod communities. There might be other crop pests which may have naturally managed through biotic and abiotic conditions prevail. In addition, there might be associated insect species, which might not damage said crops but other crops potentially grown by importing contracting parties (ICPs). Being a contacting party to IPPC, managing pest records is vital which possibly include pests, disease vectors, agriculturally beneficial organisms as well as natural enemies of pests, as such data would assist ICPs in performing pathway initiated pest risk analysis (PRA). Further, pest information along with taxonomic identifiers would assist the quarantine regulatory functions while the commodities are exported. Therefore, present study aims at collecting and compiling a comprehensive list of insect species associated with crop ecosystems, where the taxonomic identities are confirmed through DNA-barcodes. Approximately 900 arthropod specimens were collected from export oriented farmer fields in Sri Lanka during one crop cycle and 93 unique taxa were delimited with DNA-barcodes of 658 base pair fragment in COI gene, using LCO1490/HCO2198 primers. The DNA-barcodes were deposited in BOLD systems V.3 and the specimens were deposited at the National Plant Quarantine Service of Sri Lanka. Continuous observations made during the crop cycle has resulted population dynamics of major crop pests revealing integrated pest management opportunities.

36. Host plant × pest interaction (HPR 2)

Organizers: R P Thakur and Philip C Stevenson

Lead

O36-1. Utilizing host plant resistance to manage blast: An emerging threat to dryland cereals

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In recent years, blast disease incited by *Magnaporthe grisea* (Herbert) Barr [anamorph: *Pyricularia grisea* (Cooke) Sacc.] has emerged as an important foliar disease of pearl millet in India. The disease also affects other dryland cereals such as finger millet and foxtail millet. A thorough understanding of resistance mechanisms is essential for crop improvement programs aiming at the development of cultivars with stable and durable resistance. Identification of resistance sources is the first step towards understanding resistance mechanism and utilization of resistance genes in the crop improvement. Resistance sources to diverse pathotypes of *M. grisea* adapted to pearl millet have been identified. Similarly, sources of blast resistance were identified in finger millet and foxtail millet. It is important to identify diverse resistance genes existing in crop species to breed for durable resistance. Therefore, allelic relationship among gene(s) governing blast resistance in different lines of pearl millet was studied. An investigation into the biochemical defense features in pearl millet genotypes having resistant and susceptible reaction to blast pathogen was also conducted. In addition, comparative transcriptome profiling of compatible and incompatible *Magnaporthe grisea*-pearl millet interaction was conducted for the functional classification and identification of novel genes or gene family members involved in plant–pathogen interactions, the expression pattern of which could help in the development of disease control strategies. The results of these studies will be discussed in this presentation.

Invited

O36-2. Mutations in Asc1 gene determining susceptibility/resistance to stem canker disease in wild tomatoes in Peru

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Tomato is the most produced vegetable worldwide, accounting for 14% of the world's vegetable production (FAO 2010). The origin of tomatoes is in the Andes, however, with the development of modern cultivation of tomato and urbanization in the area, wild tomatoes are rapidly losing their original diversity. Maintaining genetic resources in wild tomatoes is important for the present and future breeding of tomato. *Alternaria alternata* tomato pathotype causes Alternaria stem canker on several susceptible cultivars (e.g. *Solanum*

lycopersicum cv. Aichi First) of tomato by producing AAL-toxin, one of the well-known host-specific toxins (Bas 2000). AAL-toxin causes apoptotic cell death in tomato, but ceramide avoids it in standard tomato cultivars. Ceramide synthesis in tomato is conferred by Asc1 gene, and susceptible cultivars and the wild tomato, Solanum cheesmaniae and *S. galapagense*, in the Galapagos islands are susceptible to AAL-toxin. We made a hypothesis that the wild tomatoes in the Andes have diversed mutations in Asc1, and in order to verify the hypothesis, we made a collection of endemic wild tomatoes in Peru and analyzed susceptibility/resistance to AAL-toxin and sequence of Asc1. We have found 2 accessions, a *S. pimpinellifolium* and a *S. lycopersicum* var. cerasiforme, which are susceptible to AAL-toxin and carrying mutation in Asc1.

O36-3. Feeding by the bean bug *Riptortus pedestris* induces green stem syndrome and trans generational changes in pod maturation phenology and seed traits of *Glycine soja*

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Plants have various defences against insect infestation, including constitutive, induced, and even transgenerational defences. Some insects manipulate host plants morphologically and physiologically to confer an adaptive advantage. Therefore, the physiological changes of plants in response to insect infestation may be either adaptive defence mechanisms or maladaptive changes resulting from manipulation by infesting insects. Various stink bugs, such as the bean bug *Riptortus pedestris* (Hemiptera: Alydidae), induce green stem syndrome, or green soybean syndrome, in soybeans, characterized by delayed senescence in stems, leaves and pods. To understand the ecological significance of green stem syndrome for plants and insects and assess transgenerational effects of stink bug feeding, we studied the effects of *R. pedestris* infestation on the domesticated soybean and its ancestral wild species *Glycine soja*. Field surveys revealed that the occurrence of the autumn *R. pedestris* generation coincided with *G. soja* pod maturation in both lowland and mountainous sites. Besides, *R. pedestris* contained the phytohormones auxin (IAA) and cytokinins. Following infestation by *R. pedestris*, pod maturation was significantly delayed in domesticated soybeans and *G. soja*. When *G. soja* seeds obtained from infested and non-infested plants were cultivated, the progeny of infested plants exhibited much earlier pod maturation than that of control plant progeny, indicating that *R. pedestris* feeding induced transgenerational changes.

O36-4. Characterization of race non-specific adult plant leaf rust resistance genes and their effect on stem and stripe rust resistance in Indian conditions

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Host resistance is the most widely employed method for rust disease management. Leaf rust resistance genes viz., *Lr34*, *Lr46*, *Lr67* and *Lr68* confer race non-specific adult plant resistance (APR) against many pathotypes of leaf rust. They confer non-hypersensitive, slow rusting resistance which is characterized by the slow progress of the disease with less terminal disease severity. The wheat genotypes showing leaf tip necrosis ('ltn') phenotype were (198 genotypes) screened with molecular markers. Wheat genotypes were evaluated at multi-locations to ascertain their effect on leaf, stem and stripe rusts diseases as well as their stability across locations. The four resistance genes were identified in 127 bread wheat genotypes. Many of

these genotypes were carrying multiple rust resistance genes. A total of 71 genotypes were not found to be associated with leaf rust resistance genes indicating that they may be carrying unidentified APR genes. It was observed that susceptible genotypes usually lacked the seedling resistance. Many of the genotypes studied were resistant to multiple rust diseases across locations over two years. It was observed that genotypes with seedling resistance and APR genes were highly resistant and their resistance was stable across locations and over the years. Several genotypes had high leaf rust resistance than the ones with known APR genes indicating the presence of unidentified APR genes. These genotypes with stable resistance to two or more rust diseases can serve as stable sources of rust resistance.

O36-5. Combined transcriptome and metabolome analysis revealed jasmonic acid mediated defence in *Zea mays* against *Chilo partellus* Swinhoe

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Maize defend whorl feeding pests by activating jasmonic acid (JA) mediated signalling pathway, which lead to production and/or elevation of defence metabolites. To elucidate the mechanisms of defence against *Chilo partellus*, transcriptome and metabolome of susceptible parent BML6, resistant parent BML7, and their hybrid were analysed 48 h after infestation by the pest. Differential expression analysis of transcriptome found 396 highly significantly expressed transcripts and non targeted analysis of soluble metabolome found 28 significantly expressed metabolites in all genotypes. Fourteen transcripts were tested by qPCR. The up-regulated genes in decreasing order of their log2 fold change in BML7 were *Terpene synthase 4 (TSP4), TSP 10 (TSP10), Lipoxygenase 3 (LOX3), putative Cysteine proteinase inhibitor (CPI), Alpha-dioxygenase 1 (AD1), Salicylate carboxyl methyltransferase (SBMT), Linoleate 9S-lipoxygenase 1(LOX1), Anthranilate synthase 2 (AS2), Endoglucanase 2 (EG2), Lipoxygenase 5 (LOX5)* and *Cellulose synthase 6 (CS6)*. Down regulated transcripts were, *Sucrose synthase 1 (SS1)* and *Shikimate kinase 1 (SK1)*. In hybrid, all transcripts were up-regulated, which in decreasing order of their log2 fold change are *LOX1, (E)-beta-caryophyllene synthase, TSP4, ASI, LOX5, CPI, SBMT, TSP10, AD1, LOX3, SK1, SS1, EG2* and *CS6*. This suggests that JA mediated defence is activated while salicylic acid mediated defence and primary metabolism are down regulated in resistant parent, whereas, the hybrid not only defend the pest but also maintain its vigour by channelizing primary metabolism to growth. In line with the pattern of transcript regulation, the aromatic amino acids were down regulated in BML 7, whereas up regulated in hybrid.

O36-6. OsWAKL21, a putative receptor of rice cell wall damage activates alternate signalling in rice and *Arabidopsis* to induce immunity

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Xanthomonas oryzae pv. *oryzae* (Xoo) causes the serious bacterial blight disease of rice. As part of its virulence repertoire, Xoo secretes various cell wall degrading enzymes (CWDEs) such as cellulases,

xylanases and a lipase/esterase (LipA). Conversely, treatment of rice tissues with any of these purified enzymes activates immune responses. Plants sense this cell wall damage as a mark of infection and induce immune responses. Very little information is available about the plant functions that are involved in the elaboration of cell wall damage induced immune responses. Transcriptome analyses revealed a rice cell wall-associated receptor kinase, OsWAKL21 that is up-regulated following treatment with either LipA or Xoo. VIGS mediated down-regulation of OsWAKL21 attenuates LipA induced immune responses. Over expression of OsWAKL21 in rice mimics LipA treatment in induction of immune responses, activation of JA pathway and enhanced expression of defence related genes, indicating that it plays an important role in elaboration of LipA induced immune responses. Ectopic expression of OsWAKL21 in Arabidopsis also activates plant immune responses. OsWAKL21 is a moonlighting kinase having in vitro kinase and guanylate cyclase activities. Interestingly, OsWAKL21 needs kinase activity to activate immune responses in rice while in Arabidopsis it needs the guanylate cyclase activity. Thus, OsWAKL21 is activating similar immune responses in two different species but via different mechanisms.

O36-7. Proteomic analysis of defence response in aphid resistant wild crucifer *Rorippa indica*

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Startling feeding and reproductive strategies enable aphids infest crop plants and cause significant yield loss. Mustard aphid *Lipaphis erysimi* (L.) Kaltenbach is a prominent pest of Indian mustard *Brassica juncea* (L.) Czern. Toxic insecticides are the currently practised remedies to get rid of the infestation. A few wild crucifers have been reported to show resistance to *L. erysimi*. *Rorippa indica* (L.) Hiern is one of them. Somatic hybrid between *R. indica* and *B. juncea* has manifested the resistance trait of the wild parent. The cDNA-AFLP (complimentary deoxyribonucleic acid-amplified fragment length polymorphism) analysis has identified active defence response in *R. indica* against this annoying pest. Among the identified defence response candidates, defensin and a nematode resistance protein homolog from *R. indica* on over expression have shown to induce tolerance in *B. juncea*. In the present study, a comparative proteomic analysis by LC-ESI-MS/MS (Liquid Chromatography-Electrospray Ionization-Tandem Mass Spectrometry) method at 24-, 36- and 48-hour post infestation was carried out to understand the defence response at the protein level in *R. indica* aerial tissues in response to mustard aphid infestation compared to un-infested control samples. The concordance between protein and gene expression data (cDNA-AFLP) was analysed as well. The work has implication in developing sustainable pest management methods in mustard cultivation. It also provides important insight about biological processes involved in incompatible plant aphid interaction in a non-host.

O36-8. Re-analysis of RNA-Seq data of a FHB susceptible hexaploid wheat NIL revealed rolesof methylation-related genes and a microRNA in response to pathogen stress

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Epigenetics plays a definitive role in the adaptation of organisms to adverse environmental conditions. In plants epigenetic mechanisms, including DNA methylation and sRNA accumulation regulates gene expression. Hence, next-generation sequencing studies should focus on exploring the role of epigenetic

mechanisms in environmental adaptations. In a previous study, the response of wheat to *Fusarium graminearum* causing Fusarium head blight (FHB) was investigated through transcriptome analysis of lines differing for 2DL FHB resistance QTLs. However, comprehensive analysis of methylation-related genes in response to pathogen was not performed in that study or any other studies. We re-analyzed RNA-Seq data of said study to reveal roles of methylation-related genes in response to *F. graminearum*. Sixteen methylation-related genes were down-regulated in a susceptible line, 2-2890. GO associated these genes with L-methionine salvage from methylthioadenosine and S-adenosylmethionine and steroid biosynthesis (p-value 0.001). Co-expression analysis of this NIL with methionine S-methyl-transferase gene (MSM; *TraesCS1A02G013800*) resulted in 3-hydroxy-3-methyl-glutaryl coenzyme A reductase (HMGCR; *TraesCS5A02G269300*). HMGCR was negatively correlated (-1.00) with genes encoding pathogenesis-related and detoxification proteins and xylanase inhibitors. GO analysis associated these genes with methionine S-methyl transferase (p-value 0.001). Expression levels of HMGCR were higher (Log2 levels from 3.25 to 4.00) in pathogen inoculated compared to MSM (Log2 levels from 1.25 to 3.25) in mock-inoculated samples. Forty-three genes were down-regulated by miR9678. These genes are associated with responses to biotic stimulus and glucan endo-1,4-beta-glucanase in GO.

O36-9. Brown planthopper, *Nilaparvata lugens* (Stal) (Delphacidae: Hemiptera) resistant manipur and odisha rice landraces: morphological and biochemical characterization and mechanism of resistance

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Ten Manipur rice landraces and one Odisha landrace (Salkathi) along with standard checks (Ptb33 – resistant; TN1 – susceptible) were selected to study the brown planthopper (BPH), *Nilaparvata lugens* response. Resistance mechanism of BPH on these landraces was evaluated for the possible use of these landraces in BPH management. The present study revealed that all the resistant MRA as well as one Odisha landrace, Salkathi and resistant checks Ptb33 had significantly lower BPH nymphs settling, honeydew production, fecundity, feeding rate, nymphal survival, plant dry weight loss per mg of insect dry weight and higher unhatched eggs, nymphal developmental period, days to wilt, functional plant loss index (FLPI) compared to the susceptible check TN1. Similarly, BHP resistant accession had significantly low total soluble sugar and higher phenol and silica content than TN1. Resistant and moderately accessions of MRA, Salkathi and Ptb33 expressed significantly more amount of defence enzymes such as peroxidase and polyphenol oxidase upon BPH infestation. Interestingly, all the observed BPH response parameters of Salkathi were on par with Ptb33. Odisha landrace, Salkathi and MRA accessions, AC-9053(A) and AC-9074(A) performed better in the tested parameters. Hence, these accessions can be effectively used as promising donors for developing BPH resistant varieties, which would ensure food security by reducing losses under field conditions.

O36-10. Micro-Tom: A new model system for plant-pathogen interactions

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Tomato is a versatile vegetable used world-wide in different forms and serves as an ideal model plant to study plant-pathogen interactions with promising prospects. *Arabidopsis thaliana* although a prominent model plant, it lacks significant developmental traits such as multicellular trichomes and compound leaf suggesting

the necessity for alternative plant models for plant-pathogen interaction studies. *Solanum lycopersicum* L. cultivar Micro-Tom, a miniature dwarf tomato has notable advantages to study molecular biology and physiology of plants due to small size (up to 1357 plants/m^2), short life cycle (70-90 days from sowing to fruit-ripening), relatively small genome size (950 Mb) and transformability. It also harbours distinctive mutations like *Stemphylium* resistance (Sm) and immunity to *Fusarium* wilt (I). Micro-Tom is susceptible to various fungal, bacterial, viral pathogens and insect pests with typical symptoms in comparison with other plant model systems. Micro-Tom and its mutants have been exploited for interaction studies in pests like *Tuta absoluta, Frankliniella occidentalis, Tetranychus utricae* and *Liriomyza sativae*. Micro-Tom is convenient for systemic acquired resistance (SAR) or induced systemic resistance (ISR) studies using microbes and plant activators. Transgenic Micro-Tom has potential post transcriptional gene silencing mechanism i.e., RNA interference (RNAi) in controlling tomato leaf miner (*T. absoluta*) where hairpin sequences are expressed for target genes which resulted in a significant reduction of foliar damage. Along with pest and pathogen interaction studies in Micro-Tom, hormonal interactions especially BR-JA (Brassinosteroid-Jasmonic Acid) interaction showed anti-herbivory traits. Micro-Tom, when employed with genetic manipulation tools, helps in determining genetic components that regulate resistance.

37. Integrated pest management (1)

Organizers: Govind Gujar and Anitha Koduru

Invited

O37-1. Biological hypovirulence by hypovirus - CHV1: A Success story of chestnut blight biocontrol in Portugal

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The European chestnut (*Castanea sativa* Mill.) is a very important tree on mountain regions in Portugal. Chestnut Blight is associated with the fungus *Cryphonectria parasitica* (Murrill) Barr. This pathogen is an A2 quarantine organism that was introduced in 1989 and is establishes in all regions of *C. sativa* in Portugal. In some places, the incidence of the disease may reach the dramatic values of 100%. Hypovirulence is a biological process in which the aggressiveness of *C. parasitica* is reduced by fungal virus infection (Hypovirus), which has been shown to be effective to control the disease by promoting canker healing and chestnut recovery. Based on the rationales of hypovirulence, a program for chestnut blight biocontrol was applied in Portugal. The program lays in a first stage, on the study of the *C. parasitica* population related with vegetative incompatibility system (vic type), and in a second stage, on the application of the compatible hypovirulent strain to each active canker. The program for the chestnut blight biocontrol includes several entities such as the Polytechnic Institute of Bragança, the Chestnut Treatment Organizations and the chestnut producers. Since 2015, the program had the participation of 907 chestnut producers, which treated 32053 chestnut trees in 1813 chestnut orchards. The results obtained in this program, that needs to be continued for a more extended time, point forward for a success story and chestnut blight disease has been controlled by this selective and efficient hypovirulence biological method.

O37-2. Copper, chitosan and *Trichoderma* synergy for effective and safe plant protection

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Late blight caused by *Phytophthora infestans* is one of the most important diseases affecting organic and conventional production of vegetables like potato, tomato and capsicum etc. The disease can spread very rapidly and cause severe crop losses under favourable environmental conditions. Perilous effects of copper (Cu) containing chemicals for management of late blight of potato (LBP) alarms development of safe and widely adopted novel fungicides. Combination product involving lower doses of Cu, Cu-tolerant *Trichoderma* and Chitosan (Chi) was found highly effective against LBP with improved yields and quality. Investigation revealed higher efficacy of the combination of copper and *Trichoderma* against late blight of potato. Field trials were conducted at GBPUAT, Pantnagar to validate the efficacy of a triple combination of copper, chitosan and chitisanolytic *Trichoderma*. Plant emergence was found maximum in the treatment involving triple combination of the COH (500ppm) + Chitosan (500ppm) +Trichoderma (98%) which was significantly higher than treatment having Mancoceb (89%) and control (60.4%). The lowest disease severity (10%) was observed in COH + TCMS-36 + chitosan treated plots followed by Mancozeb (11%). A significant difference was observed in terms of quality and tuber yield among treatments. The plots treated

with the triple combination yielded 40-50 per cent more yield over control and around 20 per cent over the recommended mancozeb application rate. Thus, Cu tolerant *Trichoderma* strains and plant defence inducer chitosan could be developed as combination products with Cu- based fungicides in the safe and effective management of late blight.

O37-3. Female tephritid fruit fly suppression *via* male feeding on insecticide-laced semiochemicals

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Many tephritid fruit flies in the tropical and subtropical area are serious pests of fruit commodities. Male annihilation using a combination of methyl eugenol or cue-lure laced with broad-spectrum pesticides, i.e. organophosphate and carbamate was one of the integrated pest management tactics. Reduced-risk pesticides were introduced as killing agents in recent years due to the environmental concerns for broad-spectrum pesticides and increasing pesticide resistance of the pests. In contrast to the contact poison of broad-spectrum pesticides, many reduced-risk pesticides have strong bioactivity. Male flies fed and regurgitated insecticide-laced lure shortly after feeding on the attractant. The female population can be suppressed via female flies picking up insecticide in the male regurgitated content. Field trials conducted in Hawaii demonstrated significant reduction of female melon fly, *Zeugodacus cucurbitae* (Coquillett), at the area where fipronil-laced cue-lure was deployed. Laboratory studies demonstrated a significantly higher mortality among female flies fed on regurgitated fipronil-CL droplet compared to regurgitated fipronil sugar droplet treatment. Four reduced-risk pesticides, chlorantraniliprole, acetamiprid, thiamethoxam and spinosad were evaluated in the laboratory to determine the potential of insecticide horizontal transfer when combining with methyl eugenol. The results show secondary male oriental fruit fly, Bactrocera dorsalis Hendel, mortality in spinosad and thiamethoxam were significantly higher than chlorantraniliprole and acetamiprid. In addition, regurgitated droplets collected from ME-spinosad fed males caused significantly higher female mortality than other treatments at 48 h. The results from this study demonstrated male annihilation technique with reduced-risk pesticides expands the suppression effect from male to the female population.

O37-4. Biological properties of a novel insecticide, cyclaniliprole, cyclapryn against agricultural pests on vegetables

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A wide spectrum insecticide, Cyclapryn™ found by Ishihara Sangyo Kaisha Ltd., and now being registered in Korea in 2017, followed by approval in the United states, Canada, Japan, Australia. We introduce the characteristics of this compound in this report. 1. Target pests inhibit feeding behavior immediately after the treatment of this compound, then got a muscle paralysis, finally gradually dead within 4 days. 2. Although this compound belongs to IRAC 28 (Ryanodine receptor modulator), it demonstrated to exhibit high insecticidal activity against the diamides-resistant-pests such as diamondback moth *Plutella xylostella* and the smaller tea tortrix *Adoxophyes honmai* to other existent diamides under the recommended dose rate. 3. The main target pest are Lepidopteron insects in all diamide, in addition, other labelled target pest are Hemipteran insects in some diamides. Beside of these pests, Cyclapryn is effective against adults of Coleopteran pests and

Dipteran pests that most diamides difficulty control in labelled dose rates. 4. This compound show long-lasting activity and high rainfastless on crops. These biological properties of Cyclapryn could contribute to built up an IPM strategies without affecting natural enemies and beneficial.

O37-5. Competition of two whitefly parasitoids under microhabitat in plastic houses

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Eretmocerus hayati and *Encarsia formosa* are two species of important parasitoids of the whitefly *Bemisia tabaci*. In order to use the parasitoids more effectively, evaluation of the effects of intraspecific competition and interspecific competition on parasitism rate per female and the potential to control *B. tabaci* was conducted in plastic houses. The results showed that parasitism rate per female of *En. formosa* was significantly reduced due to interspecific competition, whereas *Er. hayati* was not affected significantly. Intraspecific competition showed no significant effect on parasitism rate per female in each of the two parasitoids. No significant differences in whitefly mortality were observed among the treatments with one or two female parasitoids in a cage, indicating that competitive interference between the two parasitoids.

O37-6. Sequential sampling plan for *Tuta absuluta* (Meyrick) with and without the effect of predator, *Nesidiocoris tenuis* (Reuter) in tomato

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Sequential sampling plan provides action thresholds for pest management decisions. Sequential sampling plan was developed for *Tuta absoluta* with and without the effect of its predator, *Nesidiocoris tenuis* (Reuter) in tomato (cv. Solan Lalima) both in open and polyhouse conditions. Both the pest and the predator followed negative binomial distribution and the data fitted well the Taylor's power law and Iwao patchiness regression. Within plant *T. absoluta* larvae were distributed on all the three plant strata with slight preference for the middle stratum (open field: 33.5-46.8%; polyhouse: 30.3-43.2%) than the bottom (open field: 22-36.4%; polyhouse: 28.8-36.9%) or the top (open field: 21.7-36.2%; polyhouse: 21.8-34.4%). The mine count was reliably used to estimate larval density and to predict the possible fruit damage one week later. The optimum sample size decreased with the increase in density and decrease in the precision level and vice-versa. Control decision lines the leafminer were developed on the bases of larval density and the mine density in the presence and absence of *N. tenuis*. Presence of *N. tenuis* pushed the decision lines up indicating that in the presence of the predator control measures are required at higher pest densities than in its absence. The maximum numbers of sampling units in case of sequential sampling were less as compared to stratified random sampling. Present study provides useful information for effective monitoring and taking suitable pest management decision against the pest, especially to avoid unnecessary insecticide sprays when the predator is active.

O37-7. Bio-efficacy of ReklemelTM active for the management of root-knot nematode, *Meloidogyne incognita* in capsicum under protected cultivation

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Capsicum (*Capsicum annuum* L) is a widely cultivated annual crop. Currently, grown in protected cultivation in India is being severely attacked by plant-parasitic nematodes, particularly the root-knot nematode (*Meloidogyne incognita*). Reklemel active (chemical name: fluazaindolizine) is a new molecule formulated by Du Pont, India specifically for the management of plant parasitic nematodes. Two seasons of experiments were carried out on the efficacy of Reklemel (formulated as 500SC) on root-knot nematod in capsicum grown under protected cultivation. Reklemel was evaluated at concentrations of 0.0125% (equivalent to 25 mg ai/plant), 0.025% (50 mg ai/plant) and 0.0375% (75 mg ai/plant), which was applied to the transplanting holes as a drench (200 ml solution/hole) before transplanting. Carbofuran 3%G at 2.00 kg ai/ha was used as the standard check. The following assessments were made; initial nematode population in 200 cc soil, final nematode population in 200 cc soil at the final harvest, root-knot (galling) index (RKI) at 30, 60 and 90 days after transplanting, plant stand at 30, 60 and 90 days after transplanting, marketable yield (t/ha) and phytotoxicity symptoms, if any observed. Reklemel at a concentration of 0.025%, equivalent to 50 mg ai/plant, was the most effective treatment and superior to other treatments in reducing nematode parameters and increased crop yield. No phytotoxicity was observed in the capsicum crop and following rotational crop, cowpea. Reklemel appears to be a promising new tool for control of plant-parasitic nematodes in capsicum.

O37-8. Efficacy of insecticides, biopesticide and dormant oil against peach leaf curl aphid, *Brachycaudus helichrysi* (Kaltenbach) based on pruning levels

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Peach leaf curl aphid, *Brachycaudus helichrysi* (Kaltenbach) is a regular pest affecting quality peach production. The management of the pest is solely based on the application of insecticides that too the OP and carbamates. The increasing concern among the environmentalists has forced scientists to search for integration of various pest management strategies including new insecticides. Winter pruning reduces the carryover of the aphid population. Therefore, in the present study, different pruning levels (1/4, 1/2 and 3/4) were coupled with application of neonicotinoids namely imidacloprid and thiamethoxam (both @ 0.008 %), biopesticide and hydrocarbon oil (dormant oil) for the management of peach leaf curl aphid. The results revealed both the neonecotinoids at 3/4 level of pruning efficacious (<10% infestation and <35 aphids/whorl) in managing the aphids and were superior over the recommended insecticides i.e. oxy-demeton methyl (0.025%) and dimethoate (0.03%). The oil and biopesticide treatments did not prove effective at any of the pruning level and were even inferior to the recommended insecticides. 3/4 pruning level alone without any insecticide application resulted in only 30.83 per cent infestation in comparison to 65.00 per cent at 1/4 pruning level. The avoidable loss values of 50.96 and 50.30 per cent were calculated for imidacloprid and thiamethoxam, respectively, at 3/4 pruning level. These insecticide treatments were also found economical when the benefit cost ratio was worked out, with BCR of 24.00:1 and 21.42:1, respectively, at 3/4 pruning level. The neem formulation and dormant oil though found superior over control were not much effective.

O37-9. Susceptibility status of cotton mealybug parasitoid, *Aenasius arizonensis* (Girault) (Hymenoptera: Encyrtidae) to different insecticides

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Cotton mealybug, *Phenacoccus solenopsis* Tinsley is a key sucking pest of cotton and became a serious threat to cotton cultivation in India. Solitary endoparasitoid *Aenasius arizonensis* (Girault) was found to be dominant and aggressive parasitoid on cotton mealybug. Adult females parasitize the third instar nymphs of *P. solenopsis.* Insecticides belonging to different groups have been recommended for the management of *P. solenopsis* in cotton crop. Indiscriminate application of insecticides on cotton negatively influences the performance and activity of parasitoids. It is essential to study the safety of most frequently used insecticides with biological control of mealybugs and the possibility of their integration in IPM strategies. Hence, the present experiment was aimed to know the level of susceptibility of *A. arizonensis* against different insecticides which are most commonly used in the cotton ecosystem. The ascending order of toxicity was as follows: clothionidin (9.258 ppm) < diafenthiuron (189.22 ppm) < spiromesifen (242.01 ppm) < pyriproxyfen (248.13 ppm) < pyriproxyfen + fenpropathrin (250.32 ppm) < flonicamid (263.53 ppm). Toxicity of different insecticides on parasitized (mummified hosts) mealybug on emergence of adults of *A. arizonensis* clothionidin (18.849 ppm) < pyriproxyfen (142.145 ppm) < spiromesifen (431.241 ppm) < flonicamid (459.220 ppm) < diafenthiuron (509.027 ppm). The survived adults were selected and stored in -20ºC for further study on biochemical basis of tolerance to different insecticides. Since *A. arizonensis* is an important parasitoid of *P. solenopsis* in terms of suppressing the mealybugs population, spraying insecticides having lower LC50 values should be avoided in the cotton ecosystem.

O37-10. Antifungal potentials of some medicinal plants against *Macrophomina phaseolina* (Tassi Goid) root rot *of Sesamun indicum* L. in Benue State, Nigeria

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Systemic fungicides and fumigants, which are generally used to inhibit the growth of fungi, have become popular targets of conservationists because they are important man-made pollutants. It was against this background that thirty medicinal plants were screened for their fungitoxity against *Macrophomina phaseolina* the causal agent of charcoal root rot of *Sesamum indicum* L., using Czapeck- Dox agar plant extracts media. Out of these, the extracts of pulverized bark of *Prosopis africana* and leaves of *Nuclea latifolia* significantly ($p \leq 0.05$) inhibited both radial mycelia growth and sclerotial formation. These findings represent the first step to identifying plants with antifungal potentials against *M. phaseolina* in Nigeria. In vivo and in vitro activities of the *P. africana* and *Anacardium occidentale* extracts were evaluated against charcoal rot of *S. indicum* L. all the leaves extract showed significant reduction of the mycelia growth of the pathogen as both significantly ($p \leq 0.05$) reduced the incidence on the development of *M. phaseolina*. Phytochemical analysis of the two plants extracts *P. africana* and *A. occidentale* showed the presence of alkaloids, saponis, tannins, flavonoids and anthraquinones in petroleum ether, ethyl acetate, methanol and water extracts. The effect of plant leaf extract on mycelia growth of the test organism shows that both plant extracts reduced the mycelia growth significantly as compared to the control. The antifungal property of these plants makes them potential interest for control of *M. phaseolina*.

O37-11. Management of pod sucking bug, *Clavigralla gibbosa* (Spinola) using botanical insecticides in pigeonpea

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Insect pests, particularly those feeding on the flowers, pods, and seeds of pigeonpea, constitute the most important biotic constraint affecting the yield of the crop. Among the pod damaging insect pests of pigeonpea, next to pod borers, pod sucking bug, *Clavigralla gibbosa* (Spinola) is one of the most important pests in India inflicting heavy loss to seed yield. In recent years, this insect has assumed the status of a major sucking pest in Punjab and is a real threat to quality grain production in pigeonpea. The pest has the potential of causing major economic losses in early and medium-late pigeonpea cultivars. The pest damage results in shrivelled or deformed seeds. The bioefficacy of some botanical insecticides was evaluated for the management of pod sucking bug in pigeonpea during 2018. Foliar spray was given at the seed filling stage upon pest appearance in all the treatments except untreated control. Among the different botanical treatments, the mean population of pod bugs was significantly lower in neem seed kernel powder (NSKP) @ 10% being 8.67, 9.00 and 9.78 bugs per plant after 1, 3 and 7 DAS, respectively. It was followed by treatment with homemade neem leaf and fruit extract (NLFE) @ 1000 ml/acre, which recorded 9.67, 9.89 and 10.11 bugs per plant after 1, 3 and 7 DAS, respectively. As compared to pest population before spray, both the treatments registered 41.72 and 38.50% reduction in pest population, respectively after 7 days of spray.

O37-12. Lethal and sublethal effects of bioinsecticides on lepidopteran pests

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Lepidopteran insect pests are a polyphagus group of insect pests such as Egyptian cotton leafworm, *Spodoptera littoralis* Boisd, black cutworm, *Agrotis ipsilon* Hufnagel, and cabbage moth, *Mamestra brassicae* L. These pests attack field and several vegetable crops. Frequency of chemical pesticides applications have been used as a rapid method for control these pests. However, important non-target effects and health-related issues have required the search for alternatives, and more sustainable control methods. Bio-pesticides could represent and play a useful rule as an alternative approach in crop protection because of their safety to humans and non-target organisms. Studies related to the effect of bio-pesticides on insect pests are examine by lethal effects through mortality data, but recently, several studies are estimating the sub lethal effects of insecticides onto biological traits of insect pests. Generally, the sub lethal concentrations of an insecticide can affect on insect biology, behavior, and physiology parameters, which decrease the populations of insect in next generations. So, our project investigates the lethal and sub lethal effects of different bio-insecticides formulations on development, reproductive activity in different insect species of order Lepidoptera.

38. Climate change effects on pests and pest management

Organizers: H C Sharma and S C Dubey

Lead

O38-1. Impact of climate change on pest management and food security

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Global warming and climate change will have a major implication for pest associated losses, and effectiveness of pest management technologies. Climate change may result in breakdown of host plant resistance to certain insect pests, and thus, there is need to develop crop cultivars with stable resistance to insect pests. Climatic change may also disrupt the balance between insect pests and their natural enemies. Temperature, relative humidity, elevated atmospheric CO_2, and UV radiation also alter effectiveness of of entomopathogenic fungi and nematodes for controlling insect pests. Insect viruses are also inactivated by high temperatures, sunlight and ultraviolet rays. High rainfall also reduces the effectiveness of insecticides. Therefore, there is a need to have a concerted look at the likely effects of climate change on the efficacy of different crop protection technologies, and devise appropriate strategies to mitigate the adverse effects of climate change on the bio-efficacy of IPM technologies for sustainable crop production and food security.

Invited

O38-2. Degree-day based phenology model for predicting the developmental events of cotton pink bollworm *Pectinophora gossypiella* (Saunders) in field under changing climate scanario

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Lower and upper developmental temperature thresholds of 13.0 and 34.0 ºC were determined for cotton pink bollworm (PBW), *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechidae) using a coefficient of variation (CV) technique of degree-day (DD) accumulations. Eight years field data (2009, 2012-2018) on pheromone trap catches of male moths recorded at Nagpur (Maharashtra) were used for DD accumulation between the consecutive moth peaks starting from the beginning of the emergence, employing a sine wave method with horizontal upper cut-off. The combination of lower and upper developmental thresholds with the lowest CV of DD between events was accepted. The estimated thresholds and DD were validated at four different locations across the North (Faridkot, Haryana), Central (Surat and Junagadh, Gujarat) and South (Dharwad, Karnataka) cotton growing zones of India. Two weeks prior to rosette appearance was used as the starting point for DD accumulation assuming peak in-field infestation. Using 13.0/34.0 °C thresholds, the mean heat units (HU) accumulated between the consecutive moth peaks (one in-field generation, adult to adult) were estimated at 504.05 ± 4.84 DD. Asynchronous moth peaks of eight years coincided when plotted on HU scale. Seven generations were determined for PBW in a cropping season, the length of which varied between 35 - 73 days in response to temperature. Validation of the model provided closer estimates across the tested locations. In the context of climate change, the present findings are crucial in predicting the dates of

moth emergence, oviposition and egg hatch in PBW, which will aid in undertaking timely management actions.

O38-3. Species diversity of fruit flies in different varieties of mango in Ranga Reddy district of Telangana State, India

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India is the largest producer of mangoes (*Mangifera indica*) with 44.14% of total world production and continues to dominate fruit production by contributing 36% to total fruit area. In Telangana State, mango is cultivated on 1.2 million hectares and occupies 22% of the total area under fruits. Fruit flies are the major constraints of mango export. In India, out of 176 species under Family Tephritidae, 34 belong to the genus Bactrocera. Studies were carried out in Ranga Reddy district of Telangana State, India during 2018 to find out species diversity of fruit flies in important mango varieties, Banginapalli, Dashehari and Himayat. The surveillance was conducted using methyl eugenol in white and yellow bottle traps. 50 traps were placed in each variety and observations were taken from fruit set to harvest. The results revealed that all the varieties are damaged by two species, *Bactrocera dorsalis* and *B. zonata*. The highest mean number (272.28) of fruit flies were trapped Banginapalli followed by 96 in Dashehari and 89.42 in Himayat. Banginapalli was found to be more susceptible to fruit flies compared to the other two varieties. The oriental fruit fly, *B. dorsalis* was found dominating other species in Banginapalli, whereas, *B. zonata* was found dominating in Dashehari and Himayat varieties. There was no significant difference in the number of fruit flies trapped in white and yellow bottle traps. Timely management through cultural, chemical and by using para-pheromone lures as an area-wide management strategy can reduce the damage by fruit flies in mangoes.

O38-4. Biological parameters and functional response of *Aphelinus asychis* Walker on *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) in bellpepper

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The relative preference, biological parameters and functional response of *Aphelinus asychis* Walker, a parasitoid of *Myzus persicae* (Sulzer), was investigated under laboratory conditions at the Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. The study revealed that the parasitoid was able to parasitize all the nymphal instars of the aphid with preference to second instar (51%) followed by first instar (46%). The population growth parameters of parasitoid, *A. asychis* i.e., egg to adult emergence period, pre-oviposition period, oviposition period, post -oviposition period, fecundity and sex ratio (F: M) on second instars of the host was 16.23±0.45, 1±0.00, 6.6±0.40, 1.6±0.40 days, 58.8 eggs/female, 1:0.97, respectively. The true generation time (T), the true intrinsic rate of increase (rm), doubling time, finite rate of increase (λ) and the net reproductive rate of the parasitoid was 22.02, 0.16, 2.52, 1.17 and 33.32 days respectively. The densities of 10, 15, 20, 25 and 30 of second instar nymphs of green peach aphid were exposed to individual mated females of *A. asychis* with ten replications for 24 h. *Aphelinus asychis* exhibited Type-II functional response to the second instar of *M. persicae* with attack rate (a) of 0.034±0.004 h^{-1} and handling time (Th) of 1.32±0.23 h. Theoretically, *A. asychis* could parasitize a maximum of 18.25 aphids

over a period of 24 h. Hence, *A. asychis* can be utilized as one of the components in the integrated pest management programme of green peach aphid, *M. persicae.*

O38-5. Effects of climate change on sucking pests of potato: Indian perspective

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Potato is a cool climate-loving crop. Climatically, there is a short window in which potato has been fitted with appreciable use realized even 80 to 90 days old crop. All climate change projections are based on simulations and therefore involve uncertainties. However, climate change not only affects the cultivation system but also changes the pressure of sucking pests on potato. Pests such as whitefly, aphids, thrips, hoppers and mite have become more serious in last two decades on potato crop because they not only suck the sap from tender parts but transfer number of viral diseases, resulting in degeneration of crop. The three years pooled data revealed that the highest thrips and whitefly population was recorded in a September planted crop with a high incidence of stem necrosis and apical leaf curl disease, respectively. The high temperature (30-35 ^{0}C) and dry weather during early October are favorable for the development of stem necrosis disease. Similarly, whitefly activity was also triggered on early crop due to high temperature and moderate humidity. At present, most of the potato seed is grown in Northern plains under no or low sucking pest pressure to keep it virus free but due to change in climate, in certain regions, aphids/whiteflies/thrips will occur in more virulent forms, resulting in threat particularly to virus-free seed production in India. The best economic strategy for Indian farmers is to use IPM practices, monitor pest occurrence and their build-up on the potato crop.

O38-6. Biology of new invasive pest, fall armyworm *Spodoptera frugiperda* (J.E. Smith) on maize

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Maize as a food, fodder and industrial crop is one of the most important cereal crops in India's agricultural economy. Recently, a new invasive lepidopteran pest, fall armyworm [*Spodoptera frugiperda* (J.E. Smith)] has become the most important whorl-feeding insect pest of maize in India since its report in May 2018. This pest caused serious damage resulting in 15-50% leaf and whorl damage. The current importance of the fall armyworm warrants multi-pronged management options. The biological aspects of fall armyworm were studied under laboratory conditions on maize at ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad during August-September 2018 to January-February 2019. The average pre-oviposition, oviposition and post-oviposition periods of fall armyworm were 3.66 ± 0.14, 2.66 ± 0.14 and 2.08 ± 0.14 days, respectively. The number of eggs laid per female varied from 21-85 with an average of 48.16 ± 6.24 and the hatching percentage was found to be 73.3 ± 1.95. The average incubation, larval and pupal periods were 4.60 ± 0.23, 15.53 ± 0.31 and 7.66 ± 0.31 days, respectively. The total life period was 32.8 ± 1.63 days for adults. Sexual dimorphism in pupa and adults was observed. Sex-ratio of male to female was 1:1.28. The shortest life cycle was observed in August-September 2018 and January-February 2019, while the longest life

cycle was observed in December-January 2019. Cannibalism was observed in larvae from third instar onwards. Development of effective, eco-friendly integrated approaches are necessary for its management to achieve sustainability in maize production.

O38-7. Effect of temperature on biology and population growth parameters of *Bactrocera dorsalis* and *Bactrocera zonata* on mango

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Insects being exothermic are mainly affected by the change in the environmental temperature. In the present study, the biology and population growth parameters of *Bactrocera dorsalis* and *B. zonata* were studied at fixed temperature of 25 ºC and average room temperature of 28.8 ºC on mango. The data revealed that the time for the completion of the immature development on mango at the average room temperature of 28.8 ºC (17.17 ± 0.31 and 17.25 ± 0.17 days for *B. dorsalis* and *B. zonata*, respectively) was lesser as compared to the time taken at the fixed temperature of 25 ºC (20.00 ± 0.18 and 24.39 ± 0.26 days, respectively, for *B. dorsalis* and *B. zonata*). The population growth parameters of *B. dorsalis* and *B. zonata* with a true generation time of 42.00 and 37.32 days and with a finite rate of increase of 1.09 and 1.10 females/day, respectively, at room temperature, indicate that the population will multiply at a higher rate within a shorter period of time in comparison to the true generation time of 55.00 and 53.47 days and finite rate of increase of 1.08 and 1.07 for *B. dorsalis* and *B. zonata*, respectively, at a fixed temperature of 25 ºC. The study reveals that as the global temperature will increase, the fruit flies will be able to complete more generations per year, thereby, increasing the damage being caused by the pest.

O38-8. Climate change effects on chilli pest incidence and management in Andhra Pradesh

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Chilli, *Capsicum annuum* is a major commercial crop grown in Andhra Pradesh. Global warming causes a significant effect on the incidence of pest, natural enemies, new insect pests, insect-virus interactions and pest management practices. The study was conducted at the Horticultural Research Station, Lam Farm, Guntur, Andhra Pradesh from 2005 to 2012 by recording the weather parameters and the population dynamics of pests. The results revealed that climate change has a major impact on chilli production. The rise in temperature due to greenhouse gases resulted in increasing sucking pest incidence (thrips, *Scirtothrips dorsalis* (R^2 = 0.79), whitefly, *Bemisia tabaci* (R^2 = 0.44 for nymph 0.76 for adults), minor pests became major (Aphid, *Myzus persicae* (R^2 = 0.46), mite, *Polyphago tarsonemuslatus* (R^2 =0.74), flare up of vector transmitted viral diseases (Gemini (0.75), CMV, PNBNV). The temperature also plays an important role in diseases occurrence in chilli. The elevated temperature along with the elevated CO_2 significantly increased the incidence of bacterial wilt, bacterial spot and anthracnose, whereas, the incidence of Phytophthora blight was reduced at the elevated temperature. The frequent occurrence of weather extremes such as drought and floods, and uneven distribution of rainfall leads to early flowering, thus, favours the new flowers pests (bud borer R^2 =0.78 and midge R^2 = 0.74). The increased use of pesticide lead to residues in the produce, thus, affects human health. Hence, there is need to change pest management strategies as per the climatic change to protect the crop as well as the natural enemies.

O38-9. An insight of *Alternaria* leaf blight of peanut in India

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Peanut (*Arachis hypogaea* L.) is an important oilseed and ancillary food crop of the world. The biotic and abiotic stresses are major factors which hamper the productivity of peanut in India. Alternaria leaf blight caused mainly by *Alternaria alternate* occurs severely in summer peanut crop. The disease occurs also on peanut grown in rainfed conditions; however, the severity is less. Temperature above 37 °C for few days, deficiencies of nitrogen and micro nutrient, damage of peanut by jassids and thrips, water stress about 30 days or more, and peanut grown in the saline soil at 4 dsm^{-1} or above are predisposing the peanut to Alternaria leaf blight. Existence of differential infection by *A. alternate* on peanut genotypes and genetic differences among its isolates were confirmed in the present study.

O38-10. Addressing *Phytophthora* blight disease: an emerging threat to pigeonpea expansion and production

Raju Ghosh and Mamta Sharma

Phytophthora blight (PB) caused by *Phytophthora cajani* is an emerging disease of pigeonpea affecting the crop irrespective of cultivars, cropping systems and soil types. Limited information is available on the biology, epidemiology and management of PB. We standardized zoospore screening technique for PB and screened many pigeonpea germplasm and breeding lines to identify resistant sources. A total of 16 *P. cajani* isolates were characterised through culturally, morphologically and at molecular level. In PB resistant screening in pigeonpea, 1 × 105 zoospores/ ml suspension of *P. cajani* was standardised as optimum. A total of 4000 pigeonpea lines were screened, and through repeated confirmation, only 30 lines were found with resistant/moderately resistant reaction to PB. To develop IDM strategy, six different fungicides were tested in vitro to determine efficacy dosage. Out of six fungicides with different doses, acrobat @ 0.75 µg/ml was found most effective to inhibit mycelial growth of *P. cajani*. The selected fungicides with specific dosage from in vitro experiments were further validated in the greenhouse on PB moderately resistant (ICPL 99010, ICPL 20135, ICPL 99048) and susceptible (ICP 7119) lines via a combination of seed treatment and soil drench. The results indicated that Ridomil Gold (25 µg/ml), Indofil M 45 (10 µg/ml), Acrobat (0.45 µg/ml) and Curzate M8 (50 µg/ml) were equally effective in minimizing the disease incidence in pigeonpea with seed treatment followed by soil drench applications.

39. Extension education and technology transfer

Organizers: S Sithanantham and Henry Creissen

Invited

O39-1. Entrepreneurial efforts for popularization of bioagents

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Biocontrol are increasing popularity because of demand for low-residues and organic foods, heightened focus on environmental protection, desire to preserve biodiversity, a revival of academia's interest in biocontrol and interest from the investment community and traditional plant protection companies. The commercial success of the bioagents formulations depends up on the bioefficacy of bioagents, shelf life and quick knock down effects and cheapest multiplication on the suitable readily available and economical substrate. Screening of efficient strains isolated from natural sources. Bioagents further development w.r.t. high temperature, saline, alkaline tolerance, development of fungicide-insecticide-biofertilizer compatible strains as well as cost effective at mass production. Development of innovative thermostable, long shelf life, sustained release polymer matrix based bioformulations for better efficacies and wide adaptability on different agro climatic conditions. Development suitable formulation for drip compliant system and user-friendly formulation for large scale application in short time to save labour cost to farmers. Registration guideline of formulations need to be defined clearly for hassle-free, easy to adopt and time-consuming registration process. There are tremendous scope for basic fundamental research on development of user friendly formulations and extension activities for enhancement of biointensive, environmentally sound, economically viable, user friendly, socially acceptable disease and resistance management systems with the help of biocontrol agents. Biocontrol could represent a new green revolution without pesticides residue by understanding how products interact with plants and pathogens. There is an opportunity for us to change the way of agriculture works around the world. Increasing awareness of use of bioagents program at farmers and easily available quality product of bioagents at village level.

O39-2. The beneficial insect community of Moroccan citrus groves: assessment of their potential to enhance biocontrol services

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The aim of this work was to assess the biodiversity of natural enemies in citrus orchards in Morocco to facilitate future investigations on their potential as biocontrol agents in citrus orchards. More than two-thirds of beneficial species identified in citrus groves of Morocco (105 species) are indigenous (>70%). Both groups represent only a small fraction of the introduced species. They mostly attack scale insects (Diaspididae) and Aphids (Aphididae). The ladybeetle *Rodolia cardinalis* is the first beneficial species introduced in 1921 in the Moroccan citrus orchards to control the cottony cushion scale *Icerya purchasi*. Major introductions of this beneficial species have been made during the ninetieth century to control the main pests which were accidentally introduced. These purposely introduced species mainly belong to Aphelinidae, Encyrtidae, Eulophidae, Coccinellidae and Phytoseiidae. Whereas a high proportion of the introduced beneficial species

was established, no species has been reported to be harmful to this date. Among all the introduced beneficial species, insects belonging to Aphelinidae, Encyrtidae, Eulophidae, Coccinellidae and Phytoseiidae are the most effective biocontrol agents. Considering only introduced species used in classical biological control context, about 20% and 40% of the species are considered as effective or partially effective, respectively.

O39-3. Measuring the un-measurable? a method to quantify adoption of integrated pest management practices in arable farming systems

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The ability to practically monitor and measure IPM adoption across arable farms is crucial to the success of programmes aiming to improve IPM adoption. The project reported here aimed to establish a universal metric for quantifying adoption of IPM in temperate arable farming. This was achieved by; identifying a set of key activities that contribute to IPM; weighting these in terms of their importance to the achievement of IPM in order to create the IPM metric; surveying arable farmers in the UK and Ireland about their pest management practices; and measuring level of farmer adoption of IPM using the new metric. The survey results showed that, while the level of adoption of IPM practices varied across the sample, all farmers had adopted IPM to some extent (min. 27.2 points, mean score of 65.1), but only 13 of 225 farmers (5.8%) had adopted more than 85% of what is theoretically possible. We believe that this new metric would be a viable and cost-effective system to use to facilitate the benchmarking and monitoring of national IPM programmes in countries with large scale arable farming systems.

O39-4. Pink bollworm management in India with area wide approach and community participation: a success story

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Pink bollworm (PBW) (*Pectinophora gossypiella* Saunders) outbreak in Bt cotton in central and south India caused widespread damage with infestation ranged between 8 – 92% and yield losses to the tune of 10-30% during 2017. Considering the bio-ecology and spread of PBW in Indian cotton ecosystem, it was practically impossible to control this pest in a season or two with the field-by-field approach in isolation. In this context, ICAR-Central Institute for Cotton Research (ICAR-CICR), Nagpur, has taken timely steps of adopting area-wide approach (village level) with community participation to tackle this issue. The role of ICAR-CICR was instrumental in bringing together all the cotton production stakeholders. The approach involved essentially the large-scale dissemination and implementation of integrated pest management strategy devised with long term research efforts of ICAR-CICR through joint efforts of extension agencies of State Agriculture Departments, State Agricultural Universities, Krishi Vigyan Kendras, cottonseed producers, the seeds and ginners associations, agrochemical companies, NGOs, etc. with cotton farmers at the centre of decision-making process. Sizable efforts were concerted upon creating mass awareness through periodical field visits and on-site diagnostics, organizing farmer trainings, farmers' fair and exhibitions. The activities were publicised through mass media (print, electronic, social, etc) for greater visibility and creating mass awareness. With concerted and focused efforts of all the stakeholders, the PBW infestations could be brought

down to <30% in the following season of 2018. The continual efforts in this direction will ensure a long-term solution.

O39-5. Real time pest managemnet services through mass media – a scalable strategy of Professor Jayashankar Telangana State Agricultural University

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Professor Jayashankar Telangana State Agricultural University, a pioneer in the "Service of the Farmers" strives to deliver the latest technologies developed in the University to the farming community through different means of communication. The Electronic wing is one such tool, which is most sophisticated and reaches to a large group of audience most productively in the quickest possible time with maximum accuracy (Prashanth et al., 2019). Electronic wing is providing timely and real-time weather based agro advisory services through electronic, print, radio and social media continuously in the form of video modules, radio scripts, press notes, news prompts, voice messages, YouTube modules and WhatsApp messages to the middle-level extension workers and extension scientists. Proper information at the proper time to farmers results in enhancing the productivity and profitability, thereby, increasing the income of farmers. To access the information, Electronic wing has created several platforms for the farmers like audio, video, text, voice and multimedia messages. The Electronic wing has been immensely useful in the production of video capsule programmes, Digital Video Discs, Quickies, Jingles, Information Kiosks and Agricultural Portals. The Electronic wing has evolved as an ICT hub of the university over a period and reached to the level of National level training centres on the digital extension. Electronic wing, as one of the major ICT platforms, its impact in pest management has been analysed for the past five years from 2014 to 2019.

O39-6. A frontline extension initiative on education of stakeholders on the management of the invasive fall armyworm, *Spodoptera frugiperda* on maize in South India

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In India, infestation of the invasive fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) on maize was reported from Karnataka during mid-2018. The pest rapidly spread to other maize growing states in South India. It causes more than 50% crop damage. To disseminate the authentic information on the pest, its damage and control measures to the farmers, ICAR-Agricultural Technology Application Research Institute (ATARI) initially shared literature from 'Feed the Future' initiative on the management of FAW in Africa with Krishi Vigyan Kendras (KVKs) responsible for frontline extension education of stakeholders in agriculture at the district level. The extension staff was trained on various aspects of the pest to immediately respond to the farmers' queries. IPM trial on maize was formulated by ICAR-ATARI and laid out in 15 x 10 m plots in the instructional farm of KVKs by extension entomologists during post rainy season in 19 districts across three states. IPM treatments were compared with insecticide applications in terms of the plant stand, crop damage and yield. Scouting, monitoring with sex pheromone traps, application of neem oil, application of entomopathogenic nematodes and *Metarhizium* in leaf whorls and insecticidal applications were found most effective. Implementation of the push-pull technique with *Desmodium* and *Brachiara* spp. was challenging. The data generated on IPM options within the district along with farmer field surveys was used by the KVK scientists to understand, interact and educate farmers and the state department of agriculture officials on monitoring and management of the invasive FAW on maize.

O39-7. Novel initiatives of NIPHM for plant health promotion in India

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National Institute of Plant Health Management (NIPHM) established in 1966 as the Central Plant Protection Training Institute (CPPTI) plays a crucial role in enhancing agricultural production addressing the emerging challenges in the field of plant health management by assisting the Government of India, the States, and other stakeholders through core role of teaching, training, research, certifications & accreditation, and policy support within National and International contexts. The institute has designed custom made training module for low-cost on-farm production of bio-pesticides, bio-fertilizers, bio-agents (parasitoids and predators), EPN's, Agro Ecosystem analysis and Ecological Engineering, Traps and lures preparation and simple methods for removal of pesticide residues from fruits and vegetables which are most popular. The technology transfer is being systematically carried out for promotion and adoption across different states in the country. There were around 175 training programmes on capacity building with more than 5000 trainees are being trained on capacity building programmes which include a custom-designed module for International participants. The institute also gives handholding training for the experts from biocontrol laboratories and there were 318 bio-control laboratories are in operation in India. The paper deals with the capacity building modules of NIPHM that has a prime focus on empowering farmers to produce their own biorational inputs for IPM adoption, livelihood and environmental sustainability.

O39-8. Farmer field school on outstanding traditional knowledge-based insect pest management: a single means with many ends

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The humongous challenge faced by the scientists globally is to ensure quality and abundance of food, feed, and fibre with effective, economical and eco-friendly pest management. The losses incurred by pests multiply exponentially in the changing climate, causing pest resurgences in newer regions, thereby, threatening food and nutritional security. With over 310,000 technological ideas, innovations and traditional knowledge (TK) practices from all over the country in its database, the National Innovation Foundation – India (NIF), an autonomous body of the Department of Science and Technology, Government of India, provides complete end to end incubation support to grassroots innovators and outstanding traditional knowledge holders. To provide eco-friendly, cost-effective pest management solutions, the Value Addition Research & Development (VARD) – agriculture division of NIF initiated Farmers Field School on through Outstanding Traditional Knowledge-based open source technologies. The program trained over 1000 farmers from 8 states on the use of local biodiversity and other resources for pest management, thus, reducing chemical usage and the cost of cultivation. Based upon the Land to Lab and back to Land (LLL) model, farmers were trained in identification of local insecticidal plants, knowhow of herbal preparations, identification of pests, beneficial insects, damaging stages, economic threshold levels of pests, hazards of chemicals; the program was very well received by the farmers and more training were demanded for skill upgradation. Training the farmers, not only revives the eroding outstanding TK but also equipped to utilize low-cost, locally available resources for insitu pest management along with sensitization towards the conservation of such resources for sustained agriculture ensuring food security.

O39-9. Impact of field demonstrations on integrated crop management in tomato among tribal and hilly region of Dehradun, Uttarakhand, India

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Tomato is widely cultivated in the tribal and hilly region of Dehradun, Uttarakhand, India. However, its productivity is low in the region due to the incidence of late blight disease and fruit borer. Besides, poor nutrient management and lack of adoption of high yielding hybrids also affect its productivity. Accordingly, under Tribal Sub Plan project of ICAR, KVK, Dehradun has taken an initiative during 2014-2018 to uplift the economy of the tribal families through technological interventions in tomato. Demonstrations were organized in 30 ha area in three adopted villages (10 ha in each village) in Dehradun. In demonstrations, Abhinav hybrid was demonstrated. Besides, need-based application of profenophos + cypermethrin @ 2 ml/l of water gave quite satisfactory results in the management of fruit borer. However, for the management of late blight disease, 3 sprays of cymoxanil + mancozeb @ 2 g/l of water were found most effective. Water-soluble NPK 18:18:18 and NPK 0:0:50 were applied by the farmers at weekly interval @ 5 g/l of water on the rotation basis and continued till the end of the crop. The impact of field demonstrations revealed that 71.55% increase in yield and 80.42% enhance in net income as compared to the farmers' practice. The average yield was 473.90 q/ha with an average net income of Rs. 643140.00/ha in the demonstrated crop while it was 276.23q/ha and Rs. 356466.00/ha in the farmers field. Demonstrated practices are being followed by the farmers, which has increased the productivity and quality of tomato.

O39-10. Survey on pesticide use in basmati rice for management of diseases and pest by the farmers of Western U.P. and pesticide residue analysis

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A survey was conducted in 19 districts of Western Uttar Pradesh on Basmati rice from 2014 to 2018. During the survey, four farmers field (2.0 ha each) were selected in each district with four spots (1 m^2 each) in each field. The objective of the survey was to provide an analysis of data trends on the type of pesticides, diseases and pest status in Basmati rice and the pesticide-related concerns among the Basmati rice growers. During the survey, average disease incidence was recorded as sheath blight (25.22%), black kernel (17.72%), blast (3.99%), bacterial leaf blight (1.00%), false smut (0.19%) and insect-pests infestation/damage were recorded *viz*. stem borers (4.73m-2), leaf folders (4.48 m^{-2}), gandhi bugs (0.05 m^{-2}) and grasshoppers (0.35 m^{-2}). The survey also showed that the intensity of diseases and insect-pests varied from district to district and variety to variety. To overcome these problems, farmers use pesticides at different crop stages that resulted in the rejection of Basmati rice export to USA and UK during 2012-14 due to the presence of pesticide residue. Data recorded during survey were analysed which revealed farmers of Saharanpur district used the maximum number of pesticides i.e., 20 followed by Meerut (18) and minimum number of pesticides were used by the farmers of Hathras and Pilibhit (04). The maximum residue of Tricyclazole was found in samples from Aligarh (0.38 ppm) and minimum in Bijnor (0.01 ppm), while the residue of Carbendazim was found maximum (0.03 ppm) in G.B. Nagar and minimum (0.01 ppm) in Mathura.

O39-11. Development, registration and commercialization of smart ag-biologicals for sustainable pest management and improving soil health

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Ag-Biologicals are gaining increasing acceptance from farmers worldwide as a fundamental tool for enhanced crop production (soil nutrient mobilization and acquisition) and Bio-intensive plant protection (managing pests and diseases with eco-friendly bio inputs). Biological crop protection agents offer highly targeted ways of controlling pests and diseases and provide new resistance management strategies. More and more Novel Smart Ag-biological products are reaching the marketplace with greater investment in proof of efficacy, broader testing across geographies and with advanced technology for fine-tuning to meet the grower's needs for sustainable food production. Successful commercialization of Ag-Biologicals hinges on the outcome of the development process and is often limited by a lack of knowledge and experience with biological control agent production, formulation techniques and regulatory approvals. Critical steps in development, registration and commercialization of successful Smart Ag-Microbial Bio-control Agents (Bio-pesticides)/Bio-stimulants for sustainable pest management and improving soil health would be deliberated at length.

40. Post-harvest pests and their management

Organizer: D R Thakur

Lead

O40-1. Biointensive management of *Callosobruchus maculatus* and *C. chinensis* (Coleoptera: Bruchidae) stored pests of legumes worldwide

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Insects belonging to the family Bruchidae (Coleoptera) commonly called "pulse weevils" or bruchids are cosmopolitan in distribution and cause serious loss to legumes both in fields and stores worth million dollars every year. *Callosobruchus maculatus* (F.) and *C. chinensis* (L.) infest *Phaseolus mungo*, *P. aureus*, *Vigna sinensis* and many more legumes in stores. But reproductive strategy and life history traits of *Dinarmus basalis* (Rondani) a larval-pupal parasitoid and an egg parasitoid, *Uscana femoralis* Pajni and Tiwari (Hymenoptera: Trichogrammatidae) interrupt the life cycle stages, thus, stop the progeny expansion of the pest population in between. Egg endoparasitoid, *U. femoralis* parasitized 0-84 hours old eggs and rendered them unviable for future development. Similarly, koinobiont parasitoids, *D. basalis* synchronized its development with larval development of host insect. Female parasitoid has long ovipositor for placing eggs into host eggs and larval body. In case of larval parasitoids, the most preferred and susceptible stage for oviposition and development were fourth instar larva and pre-pupa of both the host insects. The larval pupal development of parasitoid was 7.8 ± 1.4 and 17.2 ± 2.4 on *C. chinensis* and 6.8 ± 0.8 and 13.4 ± 1.4 days on *C. maculatus* and total development period was 29.7 ± 2.3 and 27.3 ± 1.3 days, respectively. Parasitoid larva completes its development at the cost of host larva and pupa and kills them while transforming into adults. Both idiobiont and koinobiont parasitoids could be exploited as potential bio-controlling agents for legume and other stored grain pests after detailed investigations and field trials. Botanicals and their derivatives are one of the best alternatives to control pest species. Both methanol and acetone extracts in different concentrations were used to reduce adult longevity, F1 emergence and improved adult mortality and oviposition deterrence in both the pest species.

Invited

O40-2. Management of postharvest black rot of potato incited by *Rhizoctonia bataticola* using extracts of plant origin

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Aqueous and ethanol solutions of leaves of *Azadirachta indica*, *Cymbopogon citratus*, and *Ocimum gratissimum* were evaluated against post harvest black (charcoal) rot of potato (*Solanum tuberosum* L.) caused by *Rhizoctonia bataticola* (IMI 298277). The extracts were each tested separately against the spore germination and mycelia radial growth of the rot causing organism in vitro and the natural infection of potato tubers by the pathogenic organism in vivo. Alcohol extracts of the plant materials were more effective than water extracts in the percentage inhibition of spore germination and mycelia radial growth of the fungus in culture which increased with period of incubation as well as in the percentage rot reduction in both artificially infected unwounded and wounded potato tubers after 1 h and 6h dip. The least disease incidence and severity was recorded in unwounded tubers treated with extracts of *A. indica* after 6h dip. Extracts of *A. indica* were

the best followed *C. citratus* and *O. gratissimum* in controlling the growth of the pathogen in culture and in rot development and spread in potato tuber. These plant materials are readily available and cost effective when compared with the synthetic pesticides which are not only scarce and very expensive when available but difficult to obtain by resource poor farmers who produce over 98% of food consumed in developing countries. Extracts of these plant materials can suitably be exploited as potent bio-pesticides in the control of black rot of stored potato tubers caused by *R. bataticola* to increase food production.

O40-3. Effect of nanocides on rice weevil [*Sitophilus oryzae* (Linnaeus)] and seed quality enhancement in maize seeds

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An experiment was conducted to study the efficacy of different Nanocides viz, Nanosilica, Nanoalumina and Nanoclay, each at three different concentrations @ 500, 250, 125 ppm kg^{-1} seed, diatomaceous earth @1000 ppm kg^{-1} seed and an untreated check against rice weevil and their impact on seed quality parameters at Seed Research & Technology Centre, Rajendranagar during 2016-17. All the eleven treatments were replicated thrice and statistically analyzed by using completely randomized design. The data on adult emergence, seed damage per cent, weight loss per cent, germination percentage, seedling vigour index were recorded at every three months interval. Nanosilica @500 and 250 ppm gave complete protection to maize seed from development and seed damage caused by *Sitophilus oryzae* (Linnaeus) and maintained the germination above IMSCS > 90% up to nine months of storage as compared to the control (25%). Nano silica @ 500 ppm and 250 ppm outperformed in enhancing the germination (90.67% and 90.00%) and seedling vigour index (2630 and 2010.67) compared to control (25% and 943), respectively. The three nanoparticles along with diatomaceous earth used for the management of *S. oryzae*, were also studied for their effect on the abrasion of cuticle and other parts of *S. oryzae* adults by using scanning electron microscope (SEM).These studies confirmed the adverse effects of Nano silica on the *S. oryzae* followed by Nano alumina, while Nano clay was found to be least effective among the three Nanocides.

O40-4. Studies on biochemical parameters of chickpea (*Cicer arietinum* l.) genotypes against *Callosobruchus chinensis* (Coleoptera: Bruchidae)

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The present investigation aims to analyze bio-chemical (nutrient & antinutritional) parameters of 15 different accessions of chickpea (*Cicer arietinum* L.) seeds in relation to total protein, sugars, tannins, phenols, flavonoids and trypsin inhibitors per cent content for bruchids *Callosobruchus chinensis* were carried out in the Department of Entomology, ICRISAT, Hyderabad. These results indicated that the biochemical compounds such as proteins and sugars make the accessions/cultivars to susceptible while the phenolic compounds such as phenolic acids, flavonoids, tannins seemed to impart a degree of host plant resistance to

the *C. chinensis* infestation in chickpea. Based on contents of various parameters of the cultivars were found a higher levels of total sugars and protein in KAK 2 and ICCV 2 respectively. Whereas PI 599066 was found to be higher content of phenols, while NBeG 47 showed highest amount of flavonoids and trypsin inhibition were found to be least damage cultivars/accessions. Therefore the aforesaid biochemical parameters would be useful in crop improvement program with biochemical traits which may protect the chickpea grains during storage against the pulse beetle attack.

O40-5. Evaluation of novel control release formulations of *Eucalyptus globulus* (Labill) essential oil against *Sitophilus oryzae* (Linnaeus)

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Post-harvest loss caused by insects, rodents, microorganisms etc., reach colossal propositions with the damage caused by insect pests being one of the major contributors. Among them, *Sitophilus oryzae* (L.) is a serious pest. Management of these insects relies heavily on the use of synthetic insecticides and fumigants, which has led to serious environmental issues. Phyto-insecticides have long been touted as attractive alternatives for pest management. However, commercial formulations of phyto-insecticides for stored product pest management need to developed with special attention towards effectiveness over longer periods. Control release formulations achieved through utilization of naturally occurring polymers such as chitosan and sodium alginate, envelope the active ingredients leading to controlled release, improved stability and effectiveness. The present study investigated *Eucalyptus globules* (L.) essential oil control release formulations against *S. oryzae*. The essential oil was formulated as microcapsules and nanocapsules and bio-assayed under laboratory condition. Chitosan microcapsules and nanocapsules recorded 88.33 and 93.33 per cent mortality respectively whereas chitosan- sodium alginate nanocapsules recorded 95 per cent mortality. Chitosan micro and nanocapsules were effective even after 60 days when compared with pure essential oil treatment which was effective till 48 hours only. The morphology and chemical structure of microcapsules and nanocapsules were characterized by SEM and FTIR. Essential oil entrapment efficiency, storage stability and release kinetics were studied. Hence, natural polymers like chitosan possess attractive applications in active ingredient delivery because of their non-toxic, biodegradable and biocompatible nature and offer ample scope in the development of novel control release formulations.

O40-6. Application of leaf extract of *Lantana camara* coated with maize starch based edible coat on fresh-cut fruits of *Ananas comosus* and *Musa sapientium*

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The increase in the consumption of quality fresh fruits has led to wider acceptance and rise in its sales. Plant extracts have been used for thousands of years, serving many purposes, such as food preservatives and medical therapeutic agents. The preservation potentials of ethanolic extract of leaf of *Lantana camara* (1% and 3%) incorporated in maize starch-based edible coat was assayed on *Ananas comosus* and *M. sapientium*. The quality of the coated fruits, non-coated fruits and sodium benzoates respectively were determined at 8oC (82% RH), using the following quality properties: pH, total carotenoid content, ascorbic acid, total phenolic content, microbial load, total antioxidant activity, total soluble solids, overall visual quality and potential browning, at intervals for 12 days. The quantitative phytochemical analyses of the extracts were analysed. The quantitative phytochemical analysis of the extract of *L. camara* leaves shows the high yield of tannin,

flavonoid, and anthraquinones, with low yields of alkaloid and cardiac glycosides. The assessment of the shelf-life quality parameters revealed that the fruits coated with maize starch-based edible coat, and the extract at 3% showed the most significant effect on the enhancement of the shelf-life of *A. comosus* and *M. sapientium* for 12 days based on the overall visual quality, physicochemical and microbial properties. This study was able to establish the use of *L. camara.*

O40-7. Potential of microwave irradiation on the postharvest control of cowpea bruchid

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Cowpea Weevils are serious threats to Cowpea production and storage in Nigeria. The use of synthetic chemicals in their control poses to health and environmental safety. Hence, there is need to explore environmentally safe and sustainable control measures. Consequently, experiments were conducted at the Crop Protection Research Centre, St Xavier's College (Autonomous), Palayamkottai India, under laboratory conditions (28 ± 2 ºC, 70 – 75% RH and 11:13 h photoperiod) to determine the effect of microwave irradiations on the postharvest control of Cowpea bruchid, *Callosobruchus maculatus*. Five pairs of 2-day old *C. maculatus* collected from stock culture were kept in a Petri-dish containing 50 healthy seeds (Ife brown variety) and exposed to microwave irradiation at 300 power level for 0, 4, 6, 8, and 10 minutes. The experiment was conducted using completely randomized design (CRD) replicated five times. Results showed that microwave irradiation significantly ($P \leq 0.05$) increased the mortality of *C. maculatus* compared to control without adversely affecting the viability and proximate composition of the seeds. Hence, microwave irradiation could be in cooperated into the integrated pest management strategy of *C. maculatus*.

O40-8. Effect of powder preparation of clove, ginger, garad (babul) and galangal on the infestation of sorghum grains caused by khapra beetle larvae *Trogoderma granarium*

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Sorghum is the most important cereal crops in the Sudan, used for both human and animal diet. Khapra beetle is the major storage pest of Sorghum grains. This study was conducted to reveal the efficacy of clove *Syzygium aromaticum*, ginger *zingiber officinale*, Babul, *Acacia nilotica* and galangal *Alppina officinarum* on Khapra beetle larvae. The experiment was carried out in the laboratory to rear Khapra beetle larvae on sorghum grains treated with powder of the above botanical crops. Ten Khapra beetle larvae were added to each treatment. Five treatments replicated five times arranged in complete randomized design. The treatments were consisted of sorghum treated with powder of clove, ginger, bubal and galangal, and untreated sorghum grains taken as a control. Five parameters (weight losses of sorghum grain, Khapra beetle larvae mortality, adults emerged, seed germination and seed damage) were used to show the effect of these botanical crops on Khapra beetle larvae. Khapra beetle larvae mortality and weight losses were counted every week, adults counted after their emergency (after ten weeks), seed damage and seed viability were done at the end of the experiment. The result indicated that these botanical crops significantly ($p < 0.05$) reduced the damage level of Khapra beetle larvae on sorghum grains. Clove powder showed the lowest weight losses, highest mortality, highest seed germination, and lowest seed damage, followed by ginger, garad, galangal and untreated Sorghum grain. From this study we can conclude that clove crop is the most important crop to control Khapra beetle larvae.

O40-9. Antifungal effects of leaf extracts of three plant species against *Colletotricum musae* the causal agent of anthracnose postharvest disease of banana fruit

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Anthracnose is a postharvest disease of banana caused by the fungus *Colletotrichum musae* that results in major economic losses during transportation and storage. For the management of banana anthracnose, antifungal effects of three medicinal plants (*Azadirachta indica*, *Calotropis procera* and *Anacardium occidentale*) were assessed in this study. The extracts of the plants were prepared using water, the phytochemical constituents were determined and agar well diffusion method was used to assess the toxicity of each extract at 50 mg/mL, 100 mg/mL and 150 mg/mL. The pathogen was isolated from banana infected with anthracnose disease. The results revealed the presence of one or more phytochemicals in each of the plant extracts. Among these were alkaloids, saponnin, tannins, anthocyannin, phenol and flavonoids. All the extracts inhibited mycelia growth of *C. musae*. The inhibition of mycelia growth of the pathogen increased with increase in concentration and days of incubation. At the end of day 5 of incubation, the inhibition at 150 mg/mL of all the extracts was significantly different ($P<0.05$) from other concentrations. However, among all the treatments, *C. procera* extracts gave the highest percentage growth inhibition of the pathogen at all levels of concentrations tested, while *A. indica* extracts though effective was the least but not significantly different from *A. occidentale*. Therefore, since these plants are cheap, easy to obtain and extract with a simple process of maceration or infusion, more trials on the dosage and formulation on the control of banana anthracnose disease are recommended.

41. Integrated pest management (4)

Organizers: S Gopalakrishnan and Rethinasamy Velazhahan

Invited

O41-1. Efficacy of native microbial antagonists in the ecofriendly management of *Monosporascus* root rot and vine decline disease of muskmelon in Oman

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Monosporascus root rot and vine decline (MRVD) disease caused by *Monosporascus cannonballus* is a major constraint in muskmelon cultivation worldwide and effective control measures are currently lacking. This study aimed to develop an ecofriendly method to manage this disease by using native antagonistic rhizobacterial strains. Thirty-eight native bacterial isolates from the rhizosphere soil of muskmelon and cucumber were screened for their ability to inhibit the growth of *M. cannonballus* in dual culture assay. Among them, five strains viz., *Bacillus amyloliquefaciens* (B4), *Pseudomonas mendocina* (B7) and *Bacillus endophyticus* (B10), *Pseudomonas resinovorans* B11 and *P. aeruginosa* AT3, identified based on the 16S rRNA gene sequence analysis, were found to inhibit the mycelial growth of *M. cannonballus*. Scanning electron microscopic observation of the hyphae of *M. cannonballus* at the margin of the inhibition zone revealed morphological abnormalities. These bacterial isolates showed compatibility among them and with *Trichoderma viride*, a well-known fungal antagonist. The efficacy of the microbial antagonists in the management of MRVD disease of muskmelon was evaluated under greenhouse conditions. The results indicated that *P. resinovorans* B11 was the most effective among the bacterial antagonists in controlling MRVD in melon. Seed treatment and soil application of P. resinovorans B11 significantly reduced the incidence of MRVD. The strain *P. resinovorans* B11 showed both temperature and salt tolerance and could form biofilm. This study revealed that *P. resinovorans* B11 has great potential to be used as a biocontrol agent for the control of MRVD of muskmelon under the desert farming system.

O41-2. *Mentha piperita* essential oil on *Sitophilus zeamais* adults: acute toxicity and effects on associated gut microbiome

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Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae) is a destructive pest of stored grains, especially maize. The insect is characterized by high biotic potential and ability to infest the standing crops also. Infestation causes a massive reduction in weight of seeds as well as impairs their viability. Currently, the insect control management primarily depends on synthetic pesticides, but their use is limited due to the high risk of residues on food stuff and insect resistance development, and to their negative impact on the environment. Alternative and more sustainable control strategies are thus necessary. Plant essential oils are promising eco-friendly alternatives to harmful chemicals. The internal synergy among their complex

constituents imparts insecticidal activity and delays resistance development. The present study investigates the effect of *Mentha piperita* essential oil on *S. zeamais* and its associated gut microbiome. To identify the microbiome of maize weevil, next-generation sequencing of fungal internal transcribed spacer (ITS) region and bacterial 16S rRNA gene was performed after seven days of incubation with or without *M. piperita* essential oil treatment. In addition to a direct adult's toxicity, the essential oil may modify the bacterial community of the model pest. The research findings will provide a deep insight into the microbiome and favour the development of a novel pest management strategy.

O41-3. Suppression of rice blast disease by phyllosphere adapted bacterial communities

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Phyllosphere is one of the important plant niches that support diverse microbial communities. A study was conducted to explore the bacteriome composition of phyllosphere of two rice genotypes, PRR78 and Pusa 1602. Bacterial communities were isolated using culture-based methods and characterized up to the species level by comparing16S rRNA sequence. A total of 40 distinct bacterial isolates obtained were further subjected to in vitro interaction with *Magnaporthe oryzae*. Fourteen of bacterial communities were found fungicidal against *M. oryzae* and five of them showed fungistasis action. In planta assay on the effect of bacterial interaction on rice seeds revealed their significant impact on germination and other growth parameters. While few bacterial species suppressed germination and seedling growth, others accelerated the germination and promoted the growth indicating specific interaction behaviour. Individual bacterial species were re-introduced on rice phyllosphere and challenged with blast fungus to evaluate their effect on blast disease in climate-controlled greenhouse. Blast disease severity was found significantly reduced by isolates Pv30B3 (82.1%), MtL15 (77.9%), Pa30B17 (77.3%), SmL7 (74.7%), Mt30B1 (66.7%) and Af30B4 (58.2%) in planta assay. qRT-PCR based gene expression analysis further revealed altered expression of several defence related genes in rice indicating specific interaction of phyllosphere bacteria with rice leaf. The study culminated in the identification of a diverse group of phyllosphere adapted bacterial communities with potential for rice blast management in organic rice farming.

O41-4. Structural and functional characterization of rice endophytic microbiome

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Endophytic bacterial communities of rice cultivars were characterized by NGS based culture independent metagenomic and culture dependent microbiological tools. A total of 117 endophytic bacterial morphotypes were isolated from rice cultivars, Pusa Basmati 1, BPT 5204, P-1401 and HPR 2143 grown at Almora, Uttarakhand, India, and subjected to in vitro and in planta antagonism-assay against rice blast caused by *Magnaporthe oryzae*. Morphotyping and highly discriminatory DNA finger printing by BOX-PCR revealed 75 distinct bacterial types among the collection that was further identified using 16S rDNA sequence comparison. When evaluated against *M. oryzae*, endophytic bacteria showed non-volatile metabolite (14 endophytic isolates) and volatile metabolite (32 endophytic isolates) mediated antagonism in vitro. The shortlisted antagonistic endophytic isolates were further evaluated against blast disease in controlled

greenhouse trials under artificial epiphytotic conditions. Average disease severity in un-treated and tricyclazole (0.01 %) treated rice seedlings recorded 53.5 % and 9.6 %, respectively. Percent reduction in blast severity for the endophytic bacteria treated seedlings were recorded as Ms-Alm-A12 (47.2 %), Ct-Alm-B4 (48.7 %), Bs-Alm-B34 (43 %), Bs-Alm-B18 (41.1 %), As-Alm-B20 (40.5 %), Ps-Alm-B23 (41.4 %), Ls-Alm-B9 (42.5 %), Ps-Alm-C3 (40.5 %), Sh-Alm-D2 (39.2 %), Cc-Alm-D3 (41.4 %), Bf-Alm-D28 (39.2 %), and Ma-Alm-D33 (39.5 %) which clearly revealed the potential of endophytic microbiome for ecofriendly blast disease management. Mode of action of endophytes against blast fungus in rice is being deciphered.

O41-5. Role of microbiomes in multitrophic interactions: from fundamental approaches to biopesticide conception

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Insect pests occur in crops to be included in agro-ecosystems. A very broad range of feeding behaviours is associated with insect adaptations and contributions in food webs in a diversity of ecological processes. Their interactions with plenty of micro-organisms are more increasingly observed. In many situations, the adaptative processes are thought to be more related to the associated microbiomes than the pest species itself. Considering plant – aphid models, a broad range of interactions between micro-organisms and insects revealed the differential roles and impacts of the latter, from symbiosis to pathogenicity. At laboratory scale, different approaches can be developed to investigate multi-trophic interactions: (1) direct defences from plants or entomopathogen micro-organisms and subsequent uses of various biotechnologies, (2) indirect defences focusing on semiochemicals and their role in multitrophic interactions either as attractive or repellent toward aphids. Moreover, each kind of protagonist, plants and aphids, should not be considered alone but associated with their related microbiomes. Particularly, oral secretions such as saliva and digestive residues such as honeydew also include different components related to microorganisms for further effects on predators and parasitoids. Also, some Plant Growth Promoting *Rhizobacteria* (PGPR) inducing systemic resistance (ISR) impacts aphids. Several inter-specific interactions related to plants and aphids induce changes in aphid behaviour. The results of several microbial – plant – aphid assays were discussed with the perspectives to switch from the laboratory to the fields by developing bio-pesticides and complementary approaches to sustainably control pests.

O41-6. Management of *Fusarium* complex Pokkah Boeng disease of sugarcane through application of *Trichoderma* strains

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Sugarcane is considered as multi-utility crop and being cultivated in diverse climatic conditions in India. The five sugarcane producing zones have been identified in the country but mainly country is identified as tropical and sub-tropical regions. Sugarcane research and development programme is being carried out by government organizations, private companies and others. ICAR- All India Coordinated Research Project on Sugarcane is a platform for validation of sugarcane varieties and technologies. Sugarcane crop is attacked by several insect pests and diseases. Sugarcane diseases are caused by a diverse group of pathogenic microbes among them fungal sugarcane diseases are more economic importance that causes reduced cane productivity and juice quality. At present Pokkah Boeng disease of sugarcane is a new emerging fungal disease. The

present study was undertaken to explore the fungal bio-control agents especially *Trichoderma* spp., for the management of Pokkah Boeng disease because the use of different groups of pesticides has increased 30 times over fifty years in India, which proves to be fatal for the human health, environment and safety. A total of 51 Trichoderma strains were isolated from the sugarcane rhizosphere. The isolated Trichoderma strains were screened against *Fusarium moniliformae* adopting Dual Culture Plate, Volatile Diffusion techniques, Mini plot and Field conditions. It observed that application of *Trichoderma* strains reduces disease incidence and disease severity while enhancing cane yield and juice quality as well. For the sustainable sugarcane production and environmental concerns, the use of *Trichoderma* strains as bio-control agents for managing Pokkah Boeng disease is suggested based on the experimental results.

O41-7. *Bacillus* species: the multifaceted bioagent for the management of *Xanthomonas citri* pv. *malvacearum*, the causal agent of cotton bacterial blight

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Bacterial antagonists against plant pathogens are widely exploited for the biological management of plant diseases. In this study, antagonistic bacterial species were isolated from different cotton ecosystem such as endophytes (74 isolates), phylloplane (32 isolates) and cotton rhizosphere soils (48 isolates). Their efficacy against *Xanthomonas citri* pv. *malvacearum* (Xcm) were evaluated under in vitro by agar well diffusion technique. Among the isolates, the endophyte *Bacillus amyloliquefaciens* strain ETL2 was very effective in inhibiting the Xcm growth with an area of 983.76 mm^2 followed by *Bacillus velezensis* strain ELS2 with an area of 944.41 mm^2. PCR amplification of antimicrobial peptide (AMP) genes revealed that *B. amyloliquefaciens* strain ETL2 had maximum of 8 antibiotic biosynthesis genes namely, ItuC, bacA, bacD, bamC, fenCEA, sfrA, spaCS and mycC that produced antibiotics Iturin, bacilysin, bacillomycin, fengycin, surfactin, subtilin and mycosubtilin. Further, *B. amyloliquefaciens* strain ETL2 associated with Xcm inhibition was identified as aromatic hydrocarbons, phenols and fatty acids by Gas chromatography and mass-spectrometry (GC-MS). Delivery of *B. amyloliquefaciens* strain ETL2 and *B. velezensis* strain ELS2 as seed treatment and foliar spray was found promising for the management of bacterial blight of cotton in pot and field experiments. In pot and field experiments, the maximum plant growth promotion and seed cotton yield were observed in the plants treated with *B. amyloliquefaciens* strain ETL2 followed by *B. velezensis* strain ELS2 with better disease control efficiency compared to chemical control agents and chemical plant defense inducers.

O41-8. Plant growth promoting *Rhizobacteria* as a biological control agent against *Tuta absoluta* in tomato

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Plant growth promoting rhizobacteria (PGPR) effectively suppress the plant pests and diseases and increase the yield of the crop. Bio-pesticides offer an alternative option to chemical pesticides because of their low environmental pollution and low toxicity to human health. *Pseudomonas fluorescens* and *Bacillus cereus* show insecticidal activity against insect pests. Certain strains of PGPR display insect suppression activity promote plant growth and induce systemic plant defenses. This study aimed to evaluate the effectiveness of

entomopathogenic PGPR viz. *P. fluorescens* strain NBAIR-PFDWD and *B. cereus* strain NBAIR-BCTP against the *Tuta absoluta* in tomato. Larvicidal bioassays were performed with different dosages of PGPR strains (10^9, 10^8, 10^5, 10^3 and 10^2 cfu/ml) with appropriate control. Both the strains and its combination were pathogenic to larvae of *T. absoluta*. LC50 value 2.31 x 10^3 cfu/ml of NBAIR-BCTP, 3.78 x 10^3 cfu/ml of NBAIR-PFDWD and 1.73 x 10^3 cfu/ml of consortia of both strains. Under field conditions, consortia treated tomato plots showed highly significant reduction of *T. absoluta* pest (74.15%) followed by PFDWD (63.44%) and BCTP (60.67%) on 14th day after treatment of the second spray. Yield of cabbage increased significantly in P. fluorescens strain NBAIR-PFDWD treated plants compared to untreated control. These results may suggest that both PGPR strains have the potential to be used for management of *T. absoluta*.

O41-9. Biochemical and molecular characterization of *Bacillus* spp. microbiome from different parts of vanilla and its efficacy against major pathogens

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Vanilla planifolia popularly known as Prince of Spices a fleshy perennial liana grown in and around Western Ghats for its natural compounds used in several ice creams, chocolates and beverages. *Fusarium oxysporum* f.sp. *vanillae* (FOV) is one of the most destructive pathogens causing severe loss to yield and during the survey conducted in 2016, maximum incidence of 25 % was noticed in Coorg district. Forty bacterial isolates have been test evaluated under in vitro conditions against *F. oxysporum* f.sp. *vanillae*, maximum inhibition of 53.33 % was recorded in VREN1. Thirteen fungal isolates have been tested and FVLEP3 showed maximum percentage inhibition of 68.89%. IAA production, siderophore production, GA production by bacterial antagonist VREN1 tentatively identified as *Bacillus amyloliquefaciens* recoded higher growth promotion activity. Amplification of lipopolysaccharides genes such as Iturin, Sarfactin, Bacillomycin, Zwittermycin and ACC deaminase also showed positive. Aqueous formulation with different amendments for assessing survival ability were tested for *B. amyloliquefaciens*; NA medium amended with Glycerol 100 mM showed higher cfu of 8X10 9 60 days post inoculation. Induction of defense enzyme was also recorded upon challenge inoculation, the activity of peroxidases, polyphenol oxidase, catalase, superoxide dis mutase and phenol were high during five days of post inoculation of pathogen in plants were soil application and foliar spray with *B. amyloliquefaciens* was incorporated.

O41-10. *Trichoderma* and plant probiotics in suppression of soil-borne pathogens and in increasing yield of vegetable crops

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Attempts were made for the suppression of major soil-borne pathogens and improvement of plant growth and yield of tomato (*Solanum lycopersicum* L.) using *Trichoderma*. Before setting the experiments, a series of preliminary experiments were conducted to select a virulent isolate of *Sclerotium rolfsii*, *Rhizoctonia solani* and *Fusarium oxysporum*, an effective antagonistic isolate of *Trichoderma* spp. Besides, those composts were also screened to select the best one to prepare *Trichoderma* fortified compost. A total of 102 isolates of fungi were identified as *Trichoderma harzianum*. Among the promising antagonist, *T. harzianum* isolate PABT-22 showed the highest radial growth inhibition of 76.27%, 79.46% and 76.93%, respectively against *S. rolfsii*, *R.*

solani and *F. oxysporum*. Poultry refuse compost was the best among the selected six compost based on tomato production in the field experiment. The dose of *Trichoderma* fortified compost @ 3.0 x 108cfu's/ml (T7) showed the best performance on root length, root fresh and dry weight and shoot height, shoot fresh & dry weight 18.75 cm, 11.22 g, 4.43 g and 55.00 cm, 28.93 g and 4.22 g, respectively. In the field experiment, the performance of *Trichoderma* fortified compost (TFC) showed the lowest post-emergence seedling mortality, collar rot and southern blight, root rot and *Fusarium* wilt. Percent disease index (PDI) was observed lowest in the treatment T7. The highest yield 63.65 t ha^{-1} was also found in the treatment T7. Total yield in the treatment T7 where *Trichoderma* fortified compost @ 3.0 x 108cfu ml^{-1} was applied was increased 59.07% over control.

O41-11. Biocontrol potential of rhizosphere bacteria of Zingiberaceae plants

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Association between micro-organisms and plants begins from their existence. Microbes exist in the environment as decomposers, nitrogen fixers, phosphorous solubilizers, bio-stimulants, defenders and as well defense inducers against pathogens. The rhizosphere region which acts as an interface between soil and plant system is the battleground in which plant recruits its own micro-organisms, which seems to beneficial for them through directed secretions. A study was attempted to explore the bio-control potential of rhizosphere bacteria of cultivated and non-cultivated Zingiberacae crops. Rhizosphere soil from cultivated Zingiberaceae crops like cardamom, ginger and turmeric from Karthok and Dikling region of Pakyong, East Sikkim, and uncultivated Zingiberaceae crops like wild cardamom, wild ginger and wild turmeric from Zoological park, Bulbuly, Gangtok, East Sikkim were collected. From the rhizosphere soil, bacteria were isolated by serial dilution method. Around 150 bacterial isolated from different crops and regions were screened against a soilborne and a foliar pathogen of orchids using dual plate technique. In vitro study revealed bacteria from turmeric rhizosphere collected from Karthok region inhibited mycelial growth of two important pathogens of orchid. The experiment is taken further for characterization of the bacteria to exploit its bio-control potential.

42. Food safety: Mycotoxins and pesticide residues

Organizers: Hari Sudini and Dimitrios Tsitsigiannis

Invited

O42-1. Discovery to delivery of biological control for aflatoxin mitigation to improve health and income in Africa

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Aflatoxins pose a significant public health risk, decrease productivity and profitability of animal industries, and hamper trade. To minimize aflatoxin contamination in several crops, a biocontrol technology based on atoxigenic strains of *Aspergillus flavus* that do not produce aflatoxin is used widely in the United States. Similar technology, with the generic name Aflasafe, has been improved and adapted for use in Africa by IITA in partnership with several national and international institutions. Aflasafe application prior to crop flowering in the field displaces toxin producing *Aspergillus* strains, thereby reducing aflatoxin crop content. Country-specific Aflasafe products have been developed or are currently being developed in 20 African nations. Using incentivization mechanisms (AgResults: https://agresults.org/projects/nigeria) and commercialization approaches (www.aflasafe.com), Aflasafe is being scaled up for use in several African nations through a mix of public, private, and public-private partnership interventions. During the last two years, manufacturing and/or distribution rights of Aflasafe have been licensed to the private sector (in Nigeria, Senegal, The Gambia, Tanzania, Mozambique, Ghana and Burkina Faso) and to a public institution (Kenya). Farmers in several African nations have commercially treated more than 250,000 ha of maize and groundnut crops achieving >90% reduction in aflatoxin contamination. We recommend use of biocontrol as one of the main components of integrated management of aflatoxins. This presentation will provide information on the long road from development to large-scale deployment of biological control for improving food security, promoting trade, contributing to healthier farm families, and creating wealth.

O42-2. Agricultural interventions to better manage aflatoxin contamination of groundnut

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Aflatoxins are produced by the *Aspergillus flavus* group fungi, i.e., *A. flavus* and *A. parasiticus*, following invasion of groundnut pods during pre-harvest and post-harvest stages. Aflatoxin production in groundnuts is influenced by the toxigenicity of *A. flavus*, soil moisture stress especially terminal drought, high soil temperatures besides genotype susceptibility. Devising integrated management strategies for tackling this problem are important worldwide since reliable resistant sources are not available currently. Aflatoxin management strategies mainly include blocking the infection process of *A. flavus* by host-plant resistance; biological control; managing environmental factors; proper pre-and post-harvest management practices. Under the present scenario, genetic resistance seldom can eliminate this problem and so needs to be used in conjunction with pre-and post-harvest management practices. Pre-harvest management include following water management techniques that avoid moisture stress at critical crop growth stages. Cultural practices like gypsum application, calcium amendment are proved effective. Further, manuring also reduces aflatoxin

contamination. Application of atoxigenic *A. flavus* strains significantly reduces aflatoxin contamination. Proper drying of pods after harvest to 7% moisture levels is ideal to prevent growth of fungi including aflatoxigenic strains. Hermetic storage of groundnut pods offers a sustainable solution in managing post-harvest aflatoxin problem by creating airtight conditions with reduced oxygen levels through insect, fungal and seed respiration. Our research at ICRISAT on use of Purdue Improved Crop Storage (PICS) bags proved to safeguard seeds/pods against *A. flavus* infection and lowered the aflatoxin contamination during storage.

O42-3. Species diversity and mycotoxin contamination associated with *Fusarium* ear- and stalk rot on maize in Central Europe

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Fusarium species are common pathogens on maize and can lead to contamination with toxic metabolites which reduces the quality and safety of both animal feed and human food products. A monitoring of *Fusarium* infected maize cobs and stalks was conducted in Germany to determine the range of *Fusarium* species present in field and to assess the impact of tillage, previous crop and weather conditions on *Fusarium* population. To this end, in year 2016, 2017 and 2018, a total of 387 infected cobs and 190 stalk segments from 58 locations in Germany were collected. For each sample, site-specific agronomic data on tillage and previous crops as well as meteorological data such as precipitation, air temperature and humidity during the vegetation period were recorded. Based on morphological characters and species-specific PCR analysis, 14 different Fusarium species were identified. The predominant *Fusarium* species in maize cobs were *Fusarium graminearum, F. verticillioides* and *F. temperatum.* Whereas, *F. graminearum, F. equiseti, F. culmorum* and *F. temperatum* were the predominant species infecting the maize stalks. Differences in the local *Fusarium* species composition were mainly associated with climate variations between the years and the microclimate at the different locations. The previous crop had no significant effect on cob infection with different Fusarium species. Ploughing significantly reduced cob infection with *F. graminearum* and *F. temperatum*, however, it favored infection with *F. verticillioides*. The results demonstrate a key role of temperature and precipitation in determining the local range of *Fusarium* spp. and the severity of infection.

O42-4. Acute toxicity of the aqueous plant extract of *Eragrostis Tremula* (Teff)

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Acute Toxicity of the aqueous plant extract of *Eragrostis Tremula* (Teff) was conducted in laboratory. The plant was collected at Tangaza Local Government Area, Sokoto State. Plant was dried at room temperature, grinded and sieved to fine powder. Using OECD guideline for limit test, the test was carried out in two phases. In the first phase, five female Albino Wister Rats of average weight 164kg and after acclimatization for 2 weeks fasted for 3 hours, each is administered 2000mg/kg using oral cannula observed for signs of toxicity for 3 to 4 hours after administration. The second phase include another five albino Wister rats of average weight 164kg and after acclimatization for 2 weeks fasted for 3 hours, each was administered 5000mg/kg using oral cannula. No mortality in animals at all doses of extracts up to 5000mg /kg. The absence of death at doses up to 5000 mg/kg of crude extract showed that LD50 of extracts of *E. tremula* is greater than 5000mg/kg; calmness was the only behavioral signs of toxicity shown by the animals, these disappeared within 24 hrs of extracts administration. The acute toxicity study of aqueous extract *of E. tremula* at doses of 2000 and 5000 mg/kg showed no signs of toxicity on hematological or histological parameters. Results showed that *E. tremula* does not cause toxicity at the doses studied.

Oral

O42-5. Mitigation of aflatoxin contamination in groundnuts using *Trichoderma viride*

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Groundnut is an important legume crop that serves as a good source of protein. India stands second in groundnut cultivation. The international demand for groundnut production has been alarmingly increased in the recent years. The factor that hinders the groundnut cultivation is aflatoxin contamination. Aflatoxins are Mycotoxins produced by *Aspergillus flavus* and *A. parasiticus*. They are potent hepato- carcinogens. The current paper deals with mitigation of aflatoxin contamination in groundnuts using *Trichoderma viride.*

O42-6. Acute toxicity of commercial chemicals and plant-borne essential oil on the behavior and development of earthworms, *Eudrilus eugeniae* (Kinberg) and *Eisenia fetida* (Savigny)

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Comparative toxicity of two chemical pesticides (Temephos and Monocrotophos) versus a plant-derived betel leaf oil *Piper betle* (L.), to earthworm *Eudrilus eugeniae* (Kinberg) and red worm, *Eisenia fetida* (Savigny 1826) were evaluated. The mortality rate was more prominent in Temephos at 100 µg concentration to both the earthworms in filter paper test (FPT) as well as 10 mg concentration in artificial soil test (AST). In contrast, P. betle does not displayed much mortality rate to both the earthworms even at 1000 mg of treatment concentrations. The lethal concentration (LC50) value was observed at 3.89 and 5.26 mg/kg for Temephos and Monocrotophos against *E. eugeniae* and 3.81 and 5.25 mg/kg to *E. fetida* respectively. Whereas, LC50 value of betel leaf oil was only observed at 3149 and 4081 mg/kg to *E. eugeniae*and *E. fetida* respectively. The avoidance or attraction assay also displayed that earthworms were more sensitive to the soil containing chemical pesticides. Chemical pesticides significantly reduced the earthworm weight and growth rate. However, *P. betle* oil did not change the development in 2, 7 and 14 d even at 4000 mg treatment. Enzyme ratio of CAT and SOD was also affected after exposure to the chemicals. Hence our study implied the risk associated with the chemical pesticides and recommends plant-derived harmless alternative pest control.

O42-7. Bioefficacy and persistence of chlorantraniliprole for the management of top borer in sugarcane

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Bioefficacy and residue of chlorantraniliprole was evaluated in sugarcane under sub-tropical climatic conditions. Ferterra (chlorantraniliprole) was tested at different doses i.e. @ 15, 20, 25 and 30 kg ha^{-1} along with other insecticides i.e. phorate and carbofuran @ 30 kg ha^{-1} in commercial sugarcane variety Co 0238. Cumulative per cent incidence of top borer with treatment of chlorantraniliprole @ 30 and 25 kg ha^{-1} was

significantly less (0.68 and 1.00 %) as compared to other treatments and both the treatments were found at par with each other. The net returns after excluding insecticide and labour cost, in treatment of chlorantraniliprole @ 30 was highest (Rs. 51,462/-) closely followed by 25 kg ha^{-1} (Rs. 49,909/-), although it was lowest in chlorantraniliprole 15 kg ha^{-1} (Rs. 15,769). The population of natural enemies viz. *Apanteles flavipes*, *Isotima javensis* and *Stenobracon* sp., with the application of chlorantraniliprole at different doses viz. 5, 20, 25 and 30 kg ha^{-1} was found to be safe and comparable to the control treatment, while the use of phorate and carbofuran @ 30 kg ha^{-1} insecticides were found to be non-selective and vicious on the natural enemies. On the basis of results of top borer management and economics chlorantraniliprole @ 25 kg ha^{-1} was found better in sugarcane and also proved superlative, in respect of maximum cane and sugar yield along with other physiological growth parameters.

O42-8. Standardization and validation of multi-residue analytical method for simultaneous determination of 34 chemical pesticides in red chilli powder using GC-MS/MS

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A simple, sensitive and reproducible multi-residue analytical method for quantitative determination of 34 pesticides in red chilli powder was developed using GC-MS/MS and validated. Modified QuEChERS method of sample extraction with acetonitrile recorded the acceptable recoveries (within 70- 120 %) at fortification level of 0.01, 0.05 and 0.1 $mgkg^{-1}$ for tested pesticide standards with relative standard deviation (RSD) ranging from 0.10 -14.94 %. The calibration curve for each analyte was linear over the concentration range of 0.01 to 0.1 µg mL-1 and coefficient of determination (R2) ranged from 0.995 to 0.999. The LOD and LOQ were ranging from 1.70 to 6.20 and 5.00 to 16.00 µg kg-1, respectively. The intra-day precision with respect to recovery at 0.05 mgkg-1 fortification level recorded the recoveries from 70.23 of 119.89 % with RSD of 0.10 to 14.76 %. The inter day precision with respect to changed date of analysis recorded the recovery from 70.31 to 110.87 % (first day analysis) and 71.88 to 114.89 % (second day analysis) with % RSD of 0.33 to 11.87. This method could be used for monitoring of 34 pesticides in red chilli through GC-MS/MS.

O42-9. Effect of fermentation isolates from idli batter as a promising agent for controlling aflatoxigenic *Aspergillus flavus* and its AFB1 production

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Aflatoxins are produced by soil borne pathogen *Aspergillus* spp. as their secondary metabolites and classified as group-I carcinogen by IARC. This class of mycotoxin poses a serious threat throughout the food chain infecting up to 25% of world Agricultural produce. *Aspergillus flavus* is very notorious plant pathogen and reported to infect a diverse group of plants, owing to the negative impacts of *A. flavus* and its aflatoxin, many countries have set their regulation to harmonize the mycotoxin level in food and feeds. Recently there has been a lot of emphasis on utilizing the microbes of GRAS nature, to mitigate these toxins. In this study, we have screened the potential strains from fermented foods to inhibit *A. flavus* and its aflatoxigenic effects. The primary screening carried out using selective coumarin medium and coumarin-degrading isolates were subsequently grown on MRS agar. The selected strains were evaluated for antifungal potency using agar well diffusion method and *Aspergillus* sclerotia formation, sporogenesis potential were evaluated by zone

exhibition methods. Effect of isolates on *A. flavus* biomass production, hyphal morphology, and AFB1 production were carried out in YES medium. Two isolates showing maximum inhibition of 38 mm and 32 mm, respectively as compared to *Lactobacillus plantarum* (24 mm) and control (MRS broth) were further checked for their antifungal effect on groundnut seeds and have shown promising effect.

O42-10. Development of methodology for detection of different insecticide residues in rice grains

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A reverse phase high performance liquid chromatography (RP-HPLC) method was standardized and developed for simultaneous estimation of residues of thiamethoxam, flubendiamide and endosulfan in rice grains. Extraction and clean-up process was done by modified QuEChERS method. The final extracts were concentrated with vacuum evaporator and made up the volume with HPLC grade acetonitrile. Detection of thiamethoxam, flubendiamide and endosulfan residues were estimated by using HPLC coupled with UV-VIS detection system, C18 column. Mobile phase of acetonitrile and water (90:10, v/v) @ 0.5 mL min-1 flow rate was operated. Thiamethoxam, flubendiamide and α-endosulfan and β- endosulfan presented distinct peaks at retention times of 1.95 min, 2.40 min, 3.39 min and 3.90 min, respectively. Constant recoveries were observed above 80% for all the three insecticides when samples were fortified at different levels of 0.05, 0.10, 0.25, 0.50 and 1.00 mg kg^{-1} levels.

O42-11. Comparative efficacy of two mycotoxins from *Beauveria bassiana* (Bals.) Vuill. and *Metarhizium anisopliae* (Metchnikoff) Sorokin against *Spodoptera litura* Fab. and their non-target activity against the earthworm, *Eudrilus eugeniae* Kinb.

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We investigated two widely accepted entomopathogens (*Beauveria bassiana* and *Metarhizium anisopliae*), against the destructive pest Spodoptera litura (Fab.) through the assessment of larval tolerance and regulation of antioxidants as well as potential impact on the non-target earthworm, E. eugeniae, in comparison with commercial pesticides. Exposure to entomopathogenic fungi resulted in the modification of the levels of detoxification enzymes as well as significant increases in catalase and superoxide dismutase activity. Bioassay results showed that *B. bassiana* and *M. anisopliae* induced larval mortality of third and fourth instars. Correspondingly, sub-lethal dosage of *B. bassiana* showed slightly higher alterations in larval development compared to *M. anisopliae*. Histological examination of the alimentary tract revealed that showed significant changes in the midgut tissues compared to control larvae. The non-target screening through artificial soil assay on beneficial earthworm *E. eugeniae*, with *B. bassiana* (5×108 conidia/ml/kg) and *M. anisopliae* (5×108 conidia/ml/kg) showed less toxicity as compared to monocrotophos (10 ppm/kg). Current results suggest that the fungi *M. anisopliae* and *B. bassiana* significantly reduce the development of lepidopteran pests, while having only lesser impact on beneficial earthworms.

Poster presentations

Poster session I: Integrated pest management (IPM 1)

IPM1 P1. Shelf life assessment of aqua suspension formulations of the entomopathogenic fungi *Beauveria bassiana* (Balsamo) Vuillemin

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Studies on the effect of storage of developed *Beauveria bassiana* (Balsamo) Vuillemin 7% AS formulations B40G2/1H1/1 and B40S1/1C1/2 with adjuvants and control containing only *B. bassiana* aqua suspension on viability of the fungus was undertaken in the Biological control laboratory, Dept. of Entomology, MPKV, Rahuri. At 10 DAI, surface coverage by the fungus varied from 100 to 8.00, 100 to 12.00 and 100 to 0.00% in formulation B40G2/1H1/1, B40S1/1C1/2 and control, respectively, from 0 to 300 days storage samples. The samples of formulation B40G2/1H1/1 and B40S1/1C1/2 stored up to 90 days showed the cent per cent surface coverage against 30.00 per cent in control. The cfu count varied from 27.9 to 0.61x108, 29.6 to 0.85x108 and 27.7 to 0.00x108 cfu/ml in formulation B40G2/1H1/1, B40S1/1C1/2 and control, respectively from 0 to 300 days storage. Formulation B40G2/1H1/1 and B40S1/1C1/2 maintained their superiority over the control for viability of the inoculums, while formulation without adjuvants recorded decline in viability. The reduction in viability (cfu ml^{-1}) was rapid after 240 days in developed formulations and that merely after 30 days of storage in control with *B. bassiana* alone. Considering surface coverage (%), biomass produced and viability (cfu ml^{-1}) the *B. bassiana* 7% AS formulations B40G2/1H1/1, B40S1/1C1/2 and control could be stored up to 9, 9 and 2 months, respectively to get minimum cfu count of 1x108 ml-1 for AS formulation

IPM1 P2. Seasonal incidence and management of cotton aphid and whitefly on okra (*Abelmoschus esculentus* (L) Moench)

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Okra (*Abelmoschus esculentus* (L.) Moench.) is an important vegetable crop cultivated all over the world including countries like India, Bangladesh, Pakistan, Nepal, China, Sri Lanka, Germany, etc. Many sucking insect pests have been reported for attacking and infesting the okra crop and responsible for deteriorating its quality in terms of marketing and nutrition. Among all sucking insect-pests, aphids, *Aphis gossypii* (Glover) and whiteflies, *Bemisia tabaci* (Gennadius) are reported to be the most important sucking pest responsible for huge economic crop loss. Incidence of Aphids on okra starts after fortnight interval of sowing crop and huge incidence was observed in late September-October period (>50-60 aphids/leaf). In the case of whiteflies, it is observed that whitefly incidence starts from fortnight interval of sowing crop and more incidence was observed up to 60 DAS and then their population starts to decline. The appearance of aphids and whiteflies in the field is positively correlated with relative humidity. In the present study, the field efficacy of different eight treatments including untreated control was also checked against cotton aphid and whiteflies in field of okra at Entomological Research Farm, Institute of Agricultural Sciences, BHU, Varanasi. Among different treatments, Acetamiprid followed by Imidacloprid was found to be most effective against sucking insect pests

under study. The order of effectiveness of different insecticides against aphids and whiteflies was found as Acetamiprid 20 SP > Imidacloprid 17.8 SL > Acephate 75 SP > Dimethoate 30 EC > Fipronil 5 SC > Buprofezin 25 SC > Azadirachtin 0.03% WSP

IPM1 P3. Seasonal incidence of predatory coccinellids and efficacy of selected insecticides against it in okra (*Abelmoschus esculentus* (L) Moench) agroecosystem

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The present field experimental study was conducted at Entomological Research Farm, BHU, Varanasi to estimate the seasonal incidence of predatory coccinellids (*Coccinella septumpunctata*) in the field of okra in response to the incidence of sucking insect pests on okra crop responsible for causing huge economic loss to the farmers. The predatory coccinellids were reported natural enemies of almost all sucking insect pests particularly aphids, whiteflies, etc. So, they are helpful in reducing crop damage from the attack of sucking insect pests and therefore reduced down the input cost required to protect the crop. In this study, the data of two consecutive years of experiments taken into consideration to estimate the incidence of coccinellids in field of okra during its cultivation period. It was observed that the appearance of coccinellids starts just after the 14-20 DAS of the crop and their number found to be increased in the month of late September to mid-October of Kharif season. The population dynamics of predatory coccinellids were positively correlated with the number of host insects and observed to fluctuate with the population dynamics of the host insect pests i.e. sucking insect pests of the crop. The chemical treatments were found to be hazardous as compared to that of biological one. In present study, the order of insecticides found relatively safe against predatory coccinellids in field condition was Azadirachtin 0.03% WSP > Buprofezin 25 SC > Dimethoate 30 EC > Fipronil 5 SC > Acephate 75 SP > Acetamiprid 20 SP > Imidacloprid 17.8 SL

IPM1 P4. Biological control of fungal plant pathogens using the local microbe *Trichoderma* spp. for a sustainable environment through integrated pest management

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Today, the environmental losses due to chemical pesticides used for combating the infestation of fungal pathogens on various crops is not only affecting the nutritional quality of these crops but is also resulting in the destruction of the environment due to recycling of these hazardous chemical substances. In the present biological control experiment, the locally isolated microbe *Trichoderma* spp. fungi were used to combat these infestations through the integrated pest management. The local *Trichoderma* species were isolated from the local soil samples and were inoculated on nutrient media using the serial dilution technique. After a series of inoculations, 18 different *Trichoderma* isolates were obtained and identified using authentic manual of fungi for morphological, microscopic and molecular techniques using D1/D2 region of LSU (Large SubUnit:28S rDNA). The isolates of *Trichoderma* having a higher radial growth at optimum temperature were selected for screening their antagonistic potential against the potent fungal pathogens, isolated from rotten fruits collected from local markets of Bihar. The biological control potential was tested using three techniques namely Dual culture, Culture filtrate Assay and Slide culture Assay along with the biochemical characterization of culture

filtrates. In all the techniques, the local *Trichoderma* isolates showed substantial growth inhibition of the fungal pathogens. The significant result confirmed the antagonistic potential of the local *Trichoderma* isolates which may be exploited further to minimise the environmental losses. This eco-friendly biological control practice can be explored as best practice for the integrated pest management so that to make an efficient and sustainable environment.

IPM1 P5. Identification of effector protein from generalist herbivore, *Spodoptera litura* and finding their targets in plants

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The common cutworm, *Spodoptera litura* is a leaf and fruit feeding generalist insect pest of the order Lepidoptera and among the most destructive pests in agriculture. Plant defense mechanisms against this prolific feeder are not well understood. The identity of insect elicitors that activate defense and effectors released by *S. litura* to modulate/attenuate defenses is largely unknown. The current study aims to identify genes encoding effector proteins in salivary glands of *S. litura* by bioinformatics based analysis. Head and salivary glands of *S. litura* were used for de-novo transcriptome analysis and effector prediction. 1328 proteins from the head and 641 from salivary gland were identified as secretory proteins. Out of which, 808 from the head and 267 from salivary gland proteins were predicted to be potential effector proteins, and some of their orthologues play important roles in plant-pathogen interactions. This study provides the first insight of potential effectors from *S. litura* salivary glands, which might be crucial in broad host specificity of the herbivore. However, to know the effector protein function in planta and their targets, further study needed to be done.

IPM1 P6. Characterization and evaluation of antagonistic activity of fluorescent *Pseudomonas* isolates against *Sclerotium rolfsii* causing chilli root rot disease

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Root rot of chilli caused by *Sclerotium rolfsii* is a soil borne plant pathogen has attained the economic importance and causing disease in agricultural and horticultural crops. Bacterial antagonists such as *Bacillus*, *Pseudomonas* are widely used for the management of *Sclerotium rolfsii*. *Pseudomonas* spp. received great attention as biocontrol agent because of their catabolic versatility, excellent root-colonizing abilities and production of broad range antifungal metabolites. Therefore, present investigation was undertaken to isolate different strains of *Pseudomonas fluorescens* from various agro ecological zones for the control of root rot of chilli. Totally twelve isolates of *Pseudomonas fluorescens* were isolated from the crop rhizosphere soils of Uttar Pradesh (India). Isolates of fluorescent *Pseudomonas* were tested for their biochemical activity. All the isolates have been found positive response for catalase production test, gelatin hydrolysis, citrate utilization, oxidase test and showed negative response to indole production test. Their antagonistic activities were assessed against *S. rolfsii* under in vitro conditions. *P. fluorescens* isolate FP-12, resulted in highest inhibition of *S. rolfsii* through dual culture technique (94.20% inhibition) which was significantly quite higher than the other isolates. The next most effective isolate against *S. rolfsii* found was FP-29 (92.76% inhibition) followed

by FP- 34 (89.13% inhibition), FP-3 (88.4%), FP-28 (79.8% inhibition) and lowest percentage of inhibition was recorded in FP-14 (36.24% inhibition)

IPM1 P7. Weed seed bank dynamics under different land use systems of the semi-arid condition of Vindhyan region, Eastern Uttar Pradesh

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Weed seed bank (WSB) dynamics is a crucial component of the "associated" diversity in agro ecosystems. As it regulates the communities of weed species and predict the degree to which crop-weed competition will affect crop yield and quality. So the present study were undertaken at RGSC farm, BHU, Mirzapur and nearby area, during rainy season 2017, to understand the effect of the Land Use Systems [6-LUS: Agri-horti system (AHS): guava and mango based; pure orchard (PO): guava, mango and aonla; and annual crop system (ACS)], altitudinal ranges (2-altitudes: lowland and upland) and soil depths (2-soil depths: 0-15 and 15-30cm) on WSB dynamics. On June 30, 2017 soil sample were drawn and placed on the perforated aluminum trays and maintain soil moisture close to field capacity. Seedling emergence method was used for observation. Results showed the lowest and highest densities of the broadleaved and sedges WSB under the mango PO and guava AHS respectively. Although, guava PO and ACS recorded the lowest and highest grasses density, respectively. Lowest density of weeds in PO may be attributed to reduced light penetration caused by the dense canopy formation. Altitudinal ranges did not affect the density of grasses and broadleaved weed. However, the lowest sedges density recorded under upland might be due to low soil moisture content which didn't favor the growth of purple nutsedge. All the weeds showed higher density in the top layer might be due to higher organic carbon, available nitrogen and available phosphorus and low bulk-density than sub surface soil

IPM1 P8. Defense induction by antifungal microbial-volatile, 2-methyl pyrazine, against rice blast caused by *Magnaporthe oryzae*

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Bacterial volatile compounds (BVCs) are molecules with low molecular weight and high vapor pressure that can readily evaporate and diffuse. Plant-associated endophytic bacteria *Pseudomonas putida* BP25 was shown to suppress the plant pathogen rice blast fungus *Magnaporthe oryzae* Isolate 1637 by BVCs. BVCs were found to inhibit all developmental stages of the fungus in vitro. 2-Methyl pyrazine (MP) is one among the many BVCs released by *P. putida* BP25. We have evaluated 2-Methyl pyarazine for its antimicrobial activity against rice blast fungus and the disease. Series of in vitro and in planta experiments were conducted on rice seed and seedlings. Blast disease incidence and disease severity on volatilized seedlings were significantly reduced as compared to un-primed seedlings. Besides direct antifungal activity, 2-Methyl pyrazine was found to activate defense pathway associated genes in rice. Analysis of transcripts of candidate defense genes, OsPAD4, OsEDS1, OsPDF2.2, OsPR3 and OsPR1.1, by quantitative real time PCR (qPCR) with reference to a housekeeping gene, actin, revealed differential expression in volatilized seedlings. Among

the defense-related genes, OsEDS1, OsPDF2.2, OsPR3 and OsPR1.1 were found to be either non-responsive or slightly repressed at high concentration of volatile molecules. Significant induction of OsPAD4 gene up to 6.0 to 7.0 folds was observed in volatilized seedlings. This is the first report of salicylic acid mediated defense activation by induction of OsPAD4 in rice plants by 2-Methyl pyrazine. This technique can be incorporated in the Integrated Pest Management programme in rice farming by seed treatment methods

IPM1 P9. Wolbachia and the biological control of mosquito-borne disease

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Vectors are living organisms that can transmit infectious diseases between humans or from animals to humans. Many of these vectors are blood-sucking insects. With the resurgence of vector-borne disease, some have been pessimistic that conventional control measures, such as using insecticides for long-term periods will be effective. In an environment heavily impacted by the use of chemical insecticides, environmentally friendly methods for controlling pest populations and disease vectors must be seriously considered. The prospects of using *Wolbachia* to control insects are promising. *Wolbachia* is maternally inherited intracellular rickettsiae-like bacteria belonging to the α-Proteobacteria whose attributes, and more importantly, whose spreading capability can be exploited for various applications. *Wolbachia* have evolved intriguing ways to interfere with key reproductive processes of their arthropod hosts. *Wolbachia* behaves more like a reproductive parasite by inducing: feminization of genetic males, parthenogenesis, male-killing, and cytoplasmic incompatibility (CI). However, a major obstacle for *Wolbachia* based strategies lies in the ability to transfer *Wolbachia* infections to novel hosts. This obstacle has been overcome by using microinjection technique for a successful transfer of cytoplasm into embryos of novel hosts. Although they are still at an experimental stage, *Wolbachia*-based interventions are a powerful tool for the control of insect pest populations and disease vectors on a large scale, However, given advances in recent years particularly in the areas of genomics, cell biology, and molecular biology, we are optimistic that results of ongoing and future research will expand opportunities to use Wolbachia and similar endosymbiotic bacteria in biocontrol programs.

IPM1 P10. Effectiveness of integrated pest management strategies against brinjal shoot and fruit borer *Leucinides orbonalis* (Lepidoptera: Crambidae)

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Field experiments were carried out in two consecutive cropping seasons i.e. 2017-18 and 2018-19 to evaluate the effectiveness of IPM strategies against brinjal shoot and fruit borer *Leucinides orbonalis* (Lepidoptera: Crambidae) in the farmers field under on farm trials of Krishi Vigyan Kendra-Khowai, Tripura. By adoption of IPM strategies the fruit damage on an average was reduced by 16.42 per cent compared to 31.55 per cent in farmers practice. The shoot damage was also reduced on an average by 4.02 per cent compared to 9.19 per cent in farmers practice. The average yield levels improved by 12.94 per cent compared to farmers practice (35.7 qt/ha). This has resulted in reduction in the average cost of cultivation by Rs. 17089.00 per hectare and the average net income was improved by Rs. 51009 per hectare compared to the farmers practice and gives a clear message that adoption of IPM strategies helped in reducing the pest levels, damage and improving yield

IPM1 P11. The substrate specificity of *Nocardioides* sp. strain PD653 capable of degrading hexachlorobenzene

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Nocardioides sp. strain PD653, which is an aerobic actinobacteria isolated from an agricultural field contaminated with pentachloronitrobenzene ($C_6Cl_5NO_2$: PCNB), have been shown to degrade not only PCNB, but also persistent organic pollutants (POPs) including hexachlorobenzene (C_6Cl_6: HCB) and pentachlorophenol (C_6HCl_5O: PCP). The substrate range of *Nocardioides* sp. strain PD653 was investigated based on dissipation of substrates and liberation of halogen ions. In addition to several chloroaromatic compounds, the substrate specificity of this strain against α-, β-, γ-, δ-hexachlorocyclohexanes ($C_6H_6Cl_6$: HCHs), the ingredients of technical HCH (t-HCH) which is used world-wide as an insecticide, was also investigated. Strain PD653 dehalogenated 10 out of 18 halophenol congeners; however, it could dehalogenate only hexachlorobenzene out of seven halobenzene congeners tested. Moreover, apparent dehalogenation activities were shown for chloronitrobenzenes along with an increase in the number of substituted chlorine atoms except 2,3,4,5-tetrachloro-1-nitrobenzene. These results indicate that strain PD653 has a narrow substrate specificity toward chlorobenzenes, whereas it has a broad substrate specificity toward nitrochlorobenzenes and chlorophenols, in which highly chlorinated congeners are preferably recognized by this strain. Among the four HCH stereoisomers, strain PD653 could dehalogenate only β-HCH. Ten micro molars of β-HCH was completely dissipated and 18.94 ± 1.4 μmol L−1 of Cl− ions were liberated. This result clearly showed that strain PD653 prefers to dehalogenate β-HCH whose six chlorine atoms are all in equatorial positions. In conclusion, strain PD653 was expected to be applicable to bioremediation of soil contaminated with these compounds

IPM1 P12. Persistence of imidacloprid, lambda-cyhalothrin and spiromesifen on cauliflower

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Pesticides are considered a vital component of modern farming, playing a major role in maintaining high agricultural productivity. Consequently, in high- input intensive agricultural production systems, the widespread use of pesticides to manage pests has emerged as a dominant feature. The Central Insecticide Board (CIB) has taken a strong note of non-approved pesticide usage as it not only leads to environmental problems but also causes serious consumer health problems. Hence taken into consideration the issue of human health and related problems the study on persistence of imidacloprid, lambda-cyhalothrin and spiromesifen on cauliflower and cropped soil was conducted using Confidor (17.8 SL 140 and 280 mL ha-1) , Reeva 5 EC (300 and 600 mL ha-1) and Oberon 240 SC (419 and 838 mL ha-1) at single and double dose, respectively during 2016-2017 in the department of Entomology, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan. Imidacloprid, lambda-cyhalothrin and spiromesifen residues persisted in cauliflower curds upto 7 and 10 days at single and double dose, respectively. The residues of imidacloprid, lambda-cyhalothrin and spiromesifen in curds reduced to half in less than 4 days. The initial deposits of 0.102, 0.063 and 0.062 mg kg-1 at single dose and 0.191, 0.121 and 0.115 mg kg-1 at double dose were

observed for imidacloprid, lambda-cyhalothrin and spiromesifen, respectively, in cauliflower cropped soil. Safe waiting period of 12.28 days for imidacloprid, 11.33 days for lambda-cyhalothrin and 11.12 days for spiromesifen was suggested to harvest cauliflower safely.

IPM1 P13. Intraguild predation among two aphidophagus coccinellids of cabbage aphid, *Brevicoryne brassicae*

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Cabbage aphid, *Brevicoryne brassicae* is serious pest of cole crops grown in mid hills of Himachal Pradesh state of India and predaceous arthropods have been proposed as biological control agents against them. Cabbage aphid populations tend to build up quickly on infested plants because of its high reproductive capacity and results in stunted growth with deformation of plant. Spatial and temporal distributions of aphids promote interactions, such as intraguild predation (IGP), among natural enemies. *Coccinella septempunctata* and *Hippodamia variegata* was dominant predator of cabbage aphid but IGP can occur among these two aphidophagous predators thus reducing their efficacy in controlling pest. We investigated the IG interactions between these aphidophagous predators under laboratory conditions. Fourth-instars of the two species were isolated in test tube and starve for 18 hrs to maintain the hunger. The combinations of different stages of the heterospecific ladybird and different densities of *B. brassicae* were evaluated. The occurrence of IGP was recorded after 6 and 24 hours. *C. septempunctata* predated *H. variegata* at a higher rate than vice versa. Higher density of the aphid or grown-up larval stages of the IG-prey reduces the possibility of predation. The intraguild predation among the aphidophagous predators which was considered for the development of biocontrol strategy against aphid.

IPM1 P14. Management of fruit fly, *Bactrocera* spp. using insecticides, biopesticides and clay in bitter gourd

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Fruit flies are a major pest of agricultural commodities throughout the world, causing 30 to 100 per cent yield losses in vegetable crops, therefore, field trials were conducted to evaluate some insecticides, biopesticides and clay for the management of fruit fly, *Bactrocera* spp. infesting bitter gourd. Among insecticides, ƛ-cyhalothrin proved to be the most effective in managing fruit flies with least fruit infestation (13.80%) and maximum avoidable loss (48.72%). Among biopesticides, spinosad (15.86% infestation) and azadirachtin though inferior over the synthetic pyrethroid, were found effective over neem, pongamia oil, *Beauveria bassiana*, clay and also over the recommended insecticide i.e. malathion. Neem oil, *B. bassiana*, pongamia oil, clay and neemastra treatments were not foundeffective though these were superior over control. The benefit cost ratio (BCR) was highestin deltamethrin (26.56:1), followed by ƛ- cyhalothrin (22.21:1). The botanicals and microbials were not economically viable as the BCR computed was <1 except for *B. bassiana*, with a quite low BCR value (2.43:1)

IPM1 P15. Enhanced reproductive and biological potential of *Trichogramma chilonis* reared on eri silkworm eggs – a productive technology for tribal farmers and unemployed youth

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Trichogramma chilonis is mass multiplied on factitious host *Corcyra cephalonica* but one of the major obstacles preventing the successful production and utilization of this trichogrammatids is the availability and constant supply of host egg production at rapid and economically beneficial rates. Therefore, *T. chilonis* reared on the eggs of eri silkworm yielded trichogrammatids with superior biological attributes like Per cent female emergence of *T. chilonis* reared on eri silkworm was higher (81.81 %) as compared to *Corcyra* (62.93 %). Adult longevity of *T. chilonis* reared on eri silkworm was high (10.20 days) compared to *Corcyra* (3.63 days). Higher fecundity rate i.e.(300-350)eggs were laid by single eri silkworm adult when compared to rice moth (150-200), number of mean *Trichogramma* adults emerged from single eri silkworm egg was 9.20 as compared to single trichogrammatid emergence from a rice moth egg which showed that for field release of one-hectare , one trichocard made of 3500 eri silkworm eggs was economically beneficial as compared to 2.5 trichocards each made up of 16,000-17,000 rice moth eggs as larger egg size of eri silkworm accommodated more number(35,000-40,000) of trichogrammatids. For rearing rice moth larvae materials like maize, yeast, streptomycin sulphate, vitamin E tablets, protinex are required on the other hand only castor leaves are sufficient for eri silkworm larval rearing which is cost effective

IPM1 P16. Analysis of microbial community in soils suppressive to Chinese cabbage yellow

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Chinese cabbage yellow is the major disease caused by *Verticillium dahliae* and *V. longisporum* in Japan. Symptoms of this disease are wilting, stunting, chlorosis and vascular discoloration, leading to significant yield loss. In the fields of Chinese cabbage at production areas in Japan, several fields show no or less disease occurrence constitutively, implying that the fields harbor suppressive soil against the disease. Although presence of soils suppressive to Chinese cabbage yellow has been known for a long time in Japan, the suppressive mechanisms are not verified well. To uncover the mechanisms, we carried out comparative analyses on microbial community structures, as well as physical and chemical soil properties, between field soils occurring no (or less) and severe disease in Gunma prefecture in Japan. Consequently, no typical differences in physical and chemical properties, as well as Shanon-Wiener diversity indices of soil bacteria and fungi based on PCR-DGGE, were observed between the disease severities of the soils. However, a DGGE band in soil fungal community tended to specifically appear in the no or less diseased soils. Nucleotide sequencing analysis verified the fungus corresponding to the DGGE band was inferred as Chaetomiaceae, and we succeeded to isolate the fungus from the disease suppressive soil and identified as *Thielavia terricola* based on phylogenetical and morphological characteristics. From these results, inhabitancy of *T. terricola* in soils may function as a factor to explain soil suppressiveness against Chinese cabbage

IPM1 P17. Species richness and abundance of soil mites in different crop vegetation of Gangetic plain

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The study conducted on species richness of soil mites in different vegetations, correlation with inherent soil properties that affects diversity of mites at gangetic plains of Varanasi, Banaras Hindu University. The samples are taken from five different vegetations where all four orders of mites were found viz. Cryptostigmata, Mesostigmata, Prostigmata and Astigmata. Soil mites were extracted using Tullgren's Dry Funnel soil biota extractor and various soil characteristics were evaluated separately. Cryptostigmata group of mites were found abundantly in mango field. Under Mesostigmata, genus Arctoseius, Ololaelaps and Fuscuropoda were collected from pulse, vegetable and bamboo vegetation whereas Platyseius and Blattosocius were obtained from pulse field only. Family Cunaxidae was dominant among Prostimata order and maximum genera were found in vegetable field. Of order Astigmata, genus *Tyrophagus* was common in fodder field and bamboo plantation. Maximum species richness found from forest and vegetable field while minimum diversity of mites found from grassland areas. Soil pH (6.8 - 7.8) and EC of different vegetation was found neutral except fodder field. Texture of soils varied from sandy loam to loam with adequate water holding capacity ranging (WHC) within 30.40- 38.85%.Organic carbon content varied a lot with highest in mango field to lowest in bamboo grown areas. The bulk and particle density were found of 1.15 – 1.41 Mgm-3 and 2.53 – 2.71 Mgm-3 respectively. Nitrogen content was varied from 200.70 to 450.52 kg/ha. Available phosphorus (P2O5) 18.46 kg/ha to 37.44 kg/ha and available potassium (K2O) recorded was 164.16 – 371.52 kg/ha.

IPM1 P18. Abiotic stress tolerance of *Pseudomonas* spp. isolated from stressed ecosystems of Kerala

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Pseudomonas spp. are one among the most extensively exploited agriculturally important microorganisms (AIMs) in sustainable agriculture. However, reduction in field efficacy may result from poor survival of the isolates under prevailing abiotic stresses. In Kerala till now, very little effort has been taken in tapping microbial diversity from stressed ecosystems of Kerala. Thus, a study was undertaken to isolate native strains of *Pseudomonas* spp. having inherent stress tolerance. A total of 15 strains of *Pseudomonas* spp. were isolated from different stressed ecosystems of Kerala such as Thrissur, Palakkad, Vyttila and Moncombu representing areas of high temperature, drought, salinity and acidity. These isolates were subjected to various abiotic stresses viz., temperature (25, 37, 45 and 50°C), drought (10 % and 30 % PEG), salinity (1 M and 1.5 M NaCl) and acidity (pH 3.5, 4.5 and 5.5) under in vitro conditions. The stress tolerance was measured in terms of optical density at 600 nm. It was revealed that the strains P2, M4 and T5 showed tolerance to high temperature (50 °C) whereas M4 and V4 were found to be salt tolerant (1.5 M). At acidic pH of 3.5, two isolates viz., M4, and M5 survived. Only P4 and T4exhibited drought tolerance at 30 % PEG 6000 concentration. Hence, the isolates M4, M5, P2, P4, T4, T5 and V4 were selected as abiotic stress tolerant strains. The present study will be usefulin developing location specific bio control formulations to improve field performance under adverse environmental conditions.

IPM1 P19. Evaluation of fungicides for the management of rot diseases of small cardamom (*Elettaria cardamomum* Maton)

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Small cardamom (*Elettaria cardamomum* Maton.) known as the Queen of Spices is an economically important crop grown in Kerala, India. The diseases such as capsule rot and rhizome rot of *E. cardamomum* are major fungal diseases threatening the cultivation of cardamom results in 40 to 50 % of crop lose. The field trial was conducted at Indian Cardamom Research Institute, Myladumpara, Idukki District, Kerala for three years (2013 – 2015). The fungicides such as Dimethomorph 50WP (0.2%), Cymoxanil 8 + Mancozeb 64WP (0.2%), Hexaconozole 5EC (0.2%), Iprovalicarb 5.5 + Propineb 61.25WP (0.2%), Tebuconazole 25EC (0.2%), Potassium Phosphonate (0.3%), Fosetyl-Al 80WP (0.2%), COC 50WP (0.2%) + B.M, (1.0%) and Hexaconozole 2 + Potassium Phosphonate 16SC (0.2%) were used in this experiment. Before onset of the monsoon, plant sanitation work was completed. All the fungicides were applied in a monthly interval for three rounds except copper oxychloride. This copper fungicide was drenched in the plant base @ 2-5 Liters depends the size of the clump. The incidence of rot diseases such as capsule rot and rhizome rot of cardamom was recorded periodically. Results showed that the incidence of diseases was significantly reduced in the plot treated with fungicides as compared to control. However, it was also observed that highest reduction of capsule rot and rhizome rot were noticed in the plot treated with as Dimethomorph 50WP (0.2%), Fosetyl-Al 80WP (0.2%) and COC 50WP (0.2%) + B.M. (1.0%) followed by other treatments

IPM1 P20. Biological activity of solvent extracts of a potential red alga *Liagora ceranoides* (J. V. Lamouroux) on the life stages of *Spodoptera litura* (Fab.)

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Marine algae, as renewable resource, have widely distributed throughout the marine ecosystem, documented to possess colossal of secondary metabolites of varied biological activities against several organisms including insects. Such secondary metabolites offer an array of physico-chemical properties from which many bio-active compounds are derived for human welfare. The present study was conducted to assess the bioefficacy of solvent (Acetone, Hexane and Methanol) extracts of red alga, *Liagora ceranoides* for its insecticidal and IGR activities against *Spodoptera litura*. Different concentrations of solvent extracts (10µ/L, 30µ/L, 50µ/L, 70µ/L, 100µ/L and 200µ/L) were prepared and tested on the third instar larvae of *S. litura* with three replications under laboratory condition. Larval mortality was observed from day 1 to 5 whereas pupal malformation, pupal mortality and adult emergence were observed from 6 to 15 days. All the solvent extracts had exhibited larvicidal and Insect Growth Regulator activity. But, the acetone extract at 200µl/L excelled other solvents and exhibited larvicidal action (86.66%) followed by methanol 80.00% and hexane extract 66.66% and without larval mortality in untreated control and check. Results on IGR activity of acetone and methanol extracts of residual population of the larvicidal experiment showed pupal malformation (13.33%) except in hexane (0.00%) and all the solvent extracts have demonstrated pupal death but methanol extract exhibited insignificant effect (6.66%) compare to other two solvent extracts (13.33%) respectively. The phytochemical exploration of alga under GC-MS established the presence of 23 bioactive compounds that may be responsible for the toxic and IGR activity, which needs further investigation

IPM1 P21. *Rhynocoris marginatus* Fab. (Hemiptera: Reduviidae) - potent natural enemy for agroecosystem with multi-opponent assemblage

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Predatory potential of *Rhynocoris marginatus* (Fab.) (Heteroptera: Reduviidae) on *Aphis craccivora* Koch and *Spodoptera litu*ra Fabricius was assessed through two separate experiments. Cowpea variety, Anaswara raised in grow bags were caged and twelve such caged plants were kept each in experiment and control. Laboratory reared third instar nymph of the predator was released @1/cage, a day after artificial infestation with aphid, and repeated at 20 days interval till crop exhaustion. Second instar larvae of *S. litura* were released@5/plant, 26th DAS and the predator 48 hours later, after assessing *Spodoptera* population. Mean aphid density was significantly less at 4.75aphids/10cm stem in experiment as against 29.42 aphids/10cm stem in control, after a week of first release. Experiment cage supported significantly less aphid population at all intervals of observations till seventh week with a drastic fall at every immediate week of release. Green pod yield was significantly higher at 95.58 g/plant in experiment compared to 33.25g/plant in control. Mean aphid infested pods was significantly less at 1.54pods/plant in experiment as against 3.64pods/plant in control. Complete kill of the released *Spodoptera larvae* was observed within 4 days as against constant value of 5/plant in control. Leaf damage by *Spodoptera* was significantly less in experiment. Multiple release of the predator in cowpea field at 30, 50 and 70 DAS significantly reduced the aphid population. Though the incidence of pod borer, *Maruca vitrata* (Fab.) and pod bug, *Riptortus pedestris* (Fab.) were negligible to record, the number of pods damaged by *Riptortus* was comparatively less in predator released field

IPM1 P22. Screening of native *Pseudomonas* spp. for its antagonistic ability and for bio molecules imparting abiotic stress tolerance

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Pseudomonas spp. is one among the widely used biocontrol agent and plant growth promoter. However, there is a need to identify and characterize abiotic stress tolerant *Pseudomonads* which could survive under adverse environmental conditions. A total of seven abiotic stress tolerant strains which were earlier screened out from 15 native *Pseudomonas* isolates were evaluated for its antagonistic ability using bacterial ring method. The isolates P2, P4, M4 and M5 displayed strong antagonistic effect (growth inhibition ranging from 62.21 to 91.00 per cent) against five major soil borne fungal pathogens viz., *Phytophthora capsici*, *Pythium aphanidermatum*, *Sclerotium rolfsii*, *Fusarium oxysporum* and *Rhizoctonia solani*. These isolates were further screened for the ability to produce biomolecules imparting stress tolerance viz., exopolysaccharide and ACC (1-aminocyclopropane-1-carboxylate) deaminase as well as for the production of mycolytic enzymes viz., cellulase and ß-1, 3 glucanase. The isolates P4 and M4 were selected as exopolysaccharide producing when inoculated in the specific medium as per the procedure of Triveni (2000). Among the various isolates, P2 and M5 were found promising when spotted in Dworkin and foster salts medium supplemented with ACC as the sole nitrogen source indicating the ability to produce ACC deaminase enzyme conferring drought tolerance. When analyzed for mycolytic activity, M4 exhibited highest ß-1, 3 glucanase activity (0.98 U/ml) while, the bacterial strain P4 had the maximum cellulase production of 1.01 U/ml. Based on molecular characterization,P2 and P4 were identified as *Pseudomonas putida* while M4 and M5 as *Pseudomonas aeruginosa* with sequence similarities of 94.08- 99.84 %.

IPM1 P23. Antiviral priniciples for the management of a new viral disease in ginger

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Ginger is one of the earliest recognized oriental spices, which is being cultivated in India for both fresh vegetable and dried spice. A number of diseases are known to cause damage to ginger in India, among which the viral diseases are of very little knowledge. The viral diseases are nowadays increasing in spice crops because of their increase in area of cultivation. Economically significant and rhizome transmitted virus of ginger causing mosaic disease in ginger was observed in ginger growing tracts of Kerala. The characteristic symptoms were observed as small light green flecks on newly emerged leaves, which increased in size and eventually formed streaks. The streaks were arranged parallel to the veins, which led to severe chlorosis and necrosis in advanced stage. The present study was carried out with the objective of management of the disease using antiviral principles of plant, chemical and microbial origin. Perfekt (a botanical extract-76%) at 0.5 ml L-1 and 1 ml L-1, chemicals namely aspirin, salicylic acid, barium chloride at 100 and 150 ppm concentrations, botanicals namely 10% leaf extracts of *Mirabilis jalapa* and *Bougainvillea spectabilis*, 2% Neem oil- garlic emulsion and 2% PGPR mix II were used in the experiment. The treatments were given at fortnightly intervals. Before each spray the efficacy of treatments were evaluated using Vulnerability Index (V.I.) developed by Bos (1982). The treatments with Perfekt at 0.5 ml L-1 and 1 ml L-1 and 10% leaf extract of *M. jalapa* were found effective for the management of the disease

IPM1 P24. Evaluation of certain botanicals, bio-pesticides and insecticides against insect pests of brinjal

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The trial was conducted during kharif with nine treatments i.e., botanicals, bio-pesticides and insecticides. A total of six sprays were given at an interval of 10 days and data on jassids, whiteflies, fruit borer damage and yield was recorded. Among the treatments, spinosad 45 SC @ 0.3 ml/l and chlorfenapyr 10 EC @ 2 ml /l were significantly superior over other treatments in reducing the population of jassids (77.43% & 66.81 %) and whiteflies (74.54% & 69.76 %) respectively. Cartap hydrochloride 50 SP @ 2g/l and novaluron 10 EC @ 0.75ml/l with 55.72 and 50.73 percent mean reduction of jassid population were moderately effective. Novaluron 10 EC (63.02 %) and cartap hydrochloride 50 SP (60.55 %.) gave fairly good control of whiteflies. The treatments NSKE 5%, neem oil @ 5 ml/l and *Bacillus thuringiensis* @ 2g/l (38.42 %) did not show significant reduction of jassid (47.96%, 38.42 % and 34.83 %) and whitefly population (52.98 %, 49.85 % and 45.63 %) respectively. The incidence of fruit borer ranged between 15.32 (spinosad 45 SC) and 38.58 percent (*Beauveria bassiana* @ 5 g/l) on number basis in the treated plots as against 44.87 in the control. Among all the treatments, *Beauveria bassiana* was found to be least effective against jassid (27.82), whitefly (39.56 %) and fruit borer (38.58 %). Mean marketable fruit yield ranged from 32120 kg/ha (spinosad 45 SC) to 16500 kg/ha (Control)

IPM1 P25. Studies on geographical variation in the pheromonal components of *Spodoptera frugiperda* (fall army worm) new invasive pest in India

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A new entry of invasive pest *Spodoptera frugiperda* (J E Smith) (Lepidoptera:Noctuidae), commonly called fall army worm. Probably from Africa, is becoming a notorious pest in south India, causing major damage on maize. Pheromone components of *S. frugiperda* has been identified as Z-9-tetradecenyl acetate, Z-11-hexadecenyl acetate and Z-7-dodecenyl acetate. The pheromone formulation as an effective IPM tool had been used for the management of *S. frugiperda*. Past reports suggest that qualitative and quantitative variations occur in the pheromone blend composition of S.frugiperta between different populations. The present investigation was carried out to document the differences, both qualitative and quantitative, in pheromone components of *S. frugiperda*. Abdominal extracts from different geographical populations were analyzed through Gas chromatography coupled electroantennogram and Gaschromatograph-Mass selective detector. Dispensers with different blend ratios were prepared and evaluated at different geographical locations and the number of adults trapped were documented. Differences in the pheromone catches and pheromone components were observed and the probable causes for these variations are discussed

IPM1 P26. Effect of gamma irradiation on seed health and quality parameters of soybean

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Gamma irradiation treatment at 25Gy, 50Gy, 75Gy, 100Gy, 150Gy and 200Gy for the control of soybean seedborne diseases revealed that across dosages, the seed at immediately after exposure to irradiation had recorded germination above IMSCS with significant difference among the dosages. But with the increased dosages and storage period the per cent germination drastically reduced. However, untreated control had highest per cent germination (73.13%) upto six months after treatment. As the gamma irradiation dosages increased from 25Gy to 200 Gy, the Per cent Seed Infection (PSI) was decreased at all the storage periods under study and highest PSI was recorded in control (9.88%). There was an increase in per cent seed rot at increased dosages and extended storage periods. While least per cent seed rot was reported in untreated control (26.26%). It was also observed that gamma irradiation has drastically reduced the seedling vigour (1616-995) as the dosage increased from 25 Gy to 200 Gy and also with the extended storage. Overall, the gamma irradiation treatment was found to be ineffective in improving the seed health status of soybean.

IPM1 P27.Bio-efficacy of combined formulations of chlorpyriphos and cypermethrin against chilli thrips (*Scirtothrips dorsalis* Hood)

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India is one of the major producers of chilli (*Capsicum annuum* L.) in the world but the average productivity is very low in comparison to other chilli growing countries. The major limiting factor, responsible for low

yield in chilli, is the leaf curl disease which is mainly transmitted through insect vectors. However, thrips (*Scirtothrips dorsalis* Hood) play an important role in transmission of leaf curl disease. Looking to the seriousness of thrips infestation, the bio-efficacy of chlorpyriphos and cypermethrin was studied in chilli variety Kashi Anmol during 2018-19. Three dosages of chlorpyriphos 50% + cypermethrin 5% EC viz., 375 + 37.5, 500 + 50 and 625 + 62.5 g a.i./ha, along with three treated checks viz., chlorpyriphos 50% EC @ 600 g a.i./ha, cypermethrin 10% EC @ 60 g a.i./ha and indoxacarb 14.5% + acetamiprid 7.7% SC @ 111 g a.i./ha and an untreated check were evaluated with three replications under randomized block design. Foliar sprays of insecticidal treatments were applied when thrips population reached three nymphs per leaf. The population of thrips was recorded on fifteen leaves (top 5, middle 5 and bottom 5) of ten randomly selected plants per treatment & per replication. The observations were recorded at 3, 5 & 10 days after each spray. All the treatments were significantly superior over untreated check. The maximum reduction (94.47%) in population of thrips and the maximum yield (123.2 q/ha) were observed in the most effective treatment chlorpyriphos 50% + cypermethrin 5% EC @ 625 + 62.5 g a.i./ha.

IPM1 P28.Evaluation of insecticides against shoot and fruit borer (*Leucinodes orbonalis* Guenee) in brinjal

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Brinjal (*Solanum melongena* L.) is an important vegetable crop of the world and India has second rank after China. However, the yield and marketable quality of the brinjal severely affected by brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee), causes loss up to 70%. Brinjal crop protection pattern falls under crisis phase for the management of *L. orbonalis*, therefore, insect develop resistance against insecticides. To avoid resistance problem and reduce the pesticide application different insecticides were evaluated during Rabi 2014-15 and 2015-16. The study was carried out A-4 variety of brinjal. Total 10 sprays of various insecticides were applied at 10 days intervals. The admissible treatments were, Chlorantraniliprole 20 SC @ 0.4 ml/l, Emamectin benzoate 5SG@ 0.5gm/l, Spinosad 45 SC @ 0.5ml/l, Chlorpyriphos 20EC @ 2ml/l, Cypermethrin 25 EC @ 0.5ml/l, Rotational strategy (Chlorantraniliprole 20 SC @ 0.4ml/l followed by Emamectin benzoate 5 SG @ 0.5 gm/l, spinosad 2.5 SC @ 1.5 ml/l, chorpyriphos 20 EC @ 2ml/l, cypermethrin 25 EC @ 0.5ml/l), Mixture strategy (Chlorpyriphos 50 % + Cypermethrin 5 % EC @ 2ml/l) and control. The Spinosad 45 SC @ 0.5ml/l was best performed with lowest shoot damage (2.0%), fruit damage (10.62%) and highest yield (26.99 t/ha), followed by Chlorantrinileprole and lowest yield recorded with control. The study revealed that ten sprays of Spinosad 45 SC @ 0.5ml/l at 10 days interval was best for the management of *L. orbonalis* as well as maximum yield.

IPM1 P29.Abiotic stress tolerant isolates of *Metarhizium anisopliae* Sorokin from Kerala soil

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Insect pathogenic fungus *Metarhizium anisopliae* is one of most widely used biocontrol agent. However, *Metarhizium* fungi are prone to abiotic stresses which markedly reduce their potential as biocontrol agent. Hence it is important to screen isolates of *M. anisopliae* tolerant to such factors. From the survey conducted at different stressed areas of Kerala, three isolates of *M. anisopliae* such as MC 2, MC 4 and MC 7 were obtained and screened for drought, acidity and salinity tolerance. Screening for acidity tolerance revealed that

sporulation and mycelial growth of fungi were more at higher pH. Highest acidity tolerance was obtained for the isolate MC 7 with maximum mycellial biomass of 1.15 g at pH 2.5. Salinity tolerance trials revealed that the isolate MC 2 showed maximum growth and sporulation at 0.5 M where the other two isolates recorded more than 50 per cent growth inhibition. At higher concentration of 1.5 M, the isolate MC 2 thrived well with more than 40% growth where all other isolates showed only less than 11% growth and hence MC 2 can be considered as a saline tolerant isolate. Studies on drought tolerance showed that the isolate MC 2 recorded highest mycellial growth (0.93 g) in PDB broth amended with 30% PEG (Polyehylene glycol) showing highest drought tolerance. Isolate MC 7 is highly suited to acid soils and the isolate MC 2 records multiple stress tolerance and suited to both saline and drought prone areas.

IPM1 P30. Improved method for delivery of bio-inoculant and their use in management of rice BLB disease

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Agricultural production is constantly suffering from plethora of threats instigated by various groups of plant pathogens leading to huge economic losses. Rice being the second most important staple food for the world's population is prone to number of fungal, bacterial and viral diseases. Among these, bacterial leaf blight caused by *Xanthomonas oryzae* pv. *oryzae* is serious threats to rice production in India. It has high epidemic potential and is destructive to rice in both temperate and tropical regions. Biological control is a promising approach in protecting plants from diseases, but it needs some new innovative changes in the application strategies so as to increase the efficiency and minimise losses. In such technological innovations, microencapsulation is gathering noteworthy considerations due to its robust applications in modern agriculture. Antagonistic microbes such as *Bacillus* and *Trichoderma* have been widely used in agriculture for promoting plant growth and biocontrol. However, their non-effective formulations and short life limits the application of biological pesticides. *Trichoderma* as compared to *Bacillus* produces more metabolites; hence consortia of both the bio-inoculant spores can give appreciable results. Encapsulation of antagonistic microbes and their metabolites can enhance the shelf life, viability and their biocontrol activities by protecting them from adverse conditions.

IPM1 P31. Studies on pest succession, population dynamics of major insect pests and mites of rose under protected condition

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An experiment was carried out during 2017-2018 to study the insect pests and mites associated with rose crop in polyhouse and seasonal abundance of the major pests at village Shurmavai, Jabalpur (M.P.). Sixteen species of insects (11 pests and 5 natural enemies) and one mite species as pest belonging to 10 orders and 17 families were observed to be associated with various stages of the rose crop. Among them *Scirtothrips dorsalis; Edwardsiana rosae; Bemisia tabaci* and *Tetranychus neocaledonicus* were identified as the major pests, while *Phengaris arion*; *Spodoptera litura*; *Helicoverpa armigera*; *Pyhhria umbra*; *Eurema hecabe*; *Tettigonia viridissima*; *Lucilia sericata* and *Euploea core* as minor pests. Thrips and jassids were first

observed in the 35th SW and were available on the crop for 238 days and attained four and five peaks, respectively. Morning relative humidity showed significant negative influence on both the pest population. First appearance of whitefly and mites were observed in the 37th and 6th SW and were available for 224 and 77 days and attained four and one peak, respectively. Temperature and relative humidity exhibited significant positive and negative impact on both the pest population, respectively. The lower leaves were least preferred by jassid, whitefly and mites, followed by middle and upper leaves.

IPM1 P32 Repellent effect of certain biopesticides on *Stromatium barbatum* (Insecta: Coleoptera: Cerambycidae)

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Stromatium barbatum (Cerambycinae: Hesperophanini), a pest of mango (*Mangifera indica*) has been found to infest the stem of the tree from April to November in the valley region of Imphal. The gravid female lays eggs in cluster on tree trunk which on hatching excavate and gradually penetrate into the stem. Controlling the grub within the stem will be difficult unless it is applied with systemic chemicals. Therefore, an attempt has been made to find out the repellent effect of certain phytochemicals such as *Acorus calamus* Linnaeus, (Acoraceae), *Cymbopogon citrates* (DC.) Stapf, (Poaceae), neem oil at different concentrations along with the conventional pesticide cypermethrin as a standard check. The result revealed that the repellent effect of different biopesticides in terms of insect movement from the source of treatment was 40cm for lemon grass oil (10%), 55cm for *A. calamus* (10%), 60cm for neem oil (5%) and cypermethrin 10% EC (0.06%) within 5 minutes after release of insect inside the glass chamber. Extrapolating the obtained data, it can be inferred that the repellent effect was appreciably good for the neem oil and cypermethrin, followed by *A. calamus* and *C. citratus* to some extent. Nevertheless, the latter two phyto-products could also be used as a protective repellent.

IPM1 P33. Biology and predating potentiality of spotless ladybird beetle, *Cycloneda sanguinea* (Limbifer) against *Tetranychus urticae* (Koch)

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An experiment was conducted to study the life biology and predating potential of spotless ladybird, *Cycloneda sanguinea* on different stages of *Tetranychus urticae*. The experiment was done at Acarology Laboratory of Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The spotless ladybird beetle was reared in the laboratory for our study. Its period of incubation; along with various larval instars, pupal period, pre-oviposition, oviposition and post-oviposition period was studied at 35°C and 30°C respectively. The mean and standard deviation was calculated of all the life stages. During the observation for its predating abilities it was found that the first, second, third and fourth instar of *C. sanguinea* was predating with an average of 18.74 ± 2.39, 38.35 ± 5.43, 69.13 ± 8.10 and 108.63 ± 10.20 mites respectively. It was observed that the number of *T. urticae* consumed by *C. sanguinea* increases with the instar. After observing the predating abilities of *C. sanguinea* during this experiment, it can be concluded that it is a good bio control agent for all stages of *T. urticae* and can be exploited for various IPM programmes.

IPM1 P34. Characterization of female sex pheromone components of jute semilooper, *Anomis sabulifera* Guenee (Lepidoptera: Noctuidae)

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Jute semilooper, *Anomis sabulifera* Guenee, (Lepidoptera: Noctuidae) is a devastating monophagous pest of jute causing damage upto 30- 37 percent defoliation. Its occurrence in the dense canopy is a challenge and sex pheromone aided monitoring and management is the key implication for biorational and integrated management of this pest. Sex pheromone components of the virgin females have been isolated and identified. Electroantennogram studies of synthetic standards viz. (9Z, 12Z)-octadecadienal, octadecanal, (9Z,12Z,15Z)-octadecatrienal, (6Z, 9Z)-heneicosadiene, (3Z,6Z,9Z)-heneicosatriene and virgin female pheromone gland extract with male antenna showed significant electrophysiological responses varying between 1.5 mV - 5 mV. GC-EAD when injected with female pheromone gland extract against male antenna showed responses during the time intervals from 17th to 25th minute. GCMS revealed the presence of p-acetoxy phenyl 2-butanone, 11-hexadecen-1ol-acetate, 9Z-hexadecenal, (6Z, 9Z)-heneicosadiene, (3Z, 6Z, 9Z)-heneicosatriene respectively between 17th to 25th minute. Wind tunnel experiments with male adult moths against synthetic standards viz. (9Z, 12Z)-octadecadienal, octadecanal, (9Z,12Z,15Z)-octadecatrienal, (6Z,9Z)-heneicosadiene, (3Z,6Z,9Z)-heneicosatriene, 8-methyl heptadecane and female pheromone gland extract revealed significant difference in treatment with (6Z, 9Z)-heneicosadiene in causing enticing over the other treatments. Experimental studies with GC-MS by injecting synthetic standard (6Z, 9Z)-heneicosadiene and (3Z,6Z,9Z)-heneicosatriene when examined revealed the detection of (6Z, 9Z)-heneicosadiene at similar time interval detected in GC-EAD study. The present study based on GC-EAD, GC-MS and wind tunnel experiments preliminarily reveals that sex pheromone components in female jute semilooper, *A. sabulifera* are (6Z, 9Z)-heneicosadiene and (3Z,6Z,9Z)-heneicosatriene and their blending ratios are to be further studied.

IPM1 P35. Integrated disease management of downy mildew in bottle gourd (*Lagenaria siceraria* (Mol.) Stand)

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Downy mildew disease of bottle gourd (*Lagenaria siceraria* (Mol.) Standl) is one of the most important foliar diseases, causing significant loss in India. Downy mildew disease found to cause serious losses in bottle gourd crop throughout Rajasthan and other states. Characteristic symptoms are first appear as pale green area on the upper surface of leaves that changes to bright yellow angular or rectangular spots. Leaf spot are irregular or blocky in appearance and are delimited by leaf veins. The minimum disease incidence (4.09%) and maximum yield (338.5q/ha) were observed in treatment T5(T0+ Seed treatment with carbendazim 12%+ mancozeb 63% @ 3 g/kg and drenching of Captan 70 % +Hexaconazole 5% WP @ 0.1% 15 days after germination followed by spraying of Tebuconazole 50% + Trifloxystrobin 25% @1g/l + spray with (Imidacloprid 17.8 SL @ 7.5 ml/ 15 l + Neem oil 0.2%) followed by Fosetyl-Al @ 0.1% followed by spraying of Tebuconazole 50% + Trifloxystrobin 25% @1g/l + spray with (Imidacloprid 17.8 SL @ 7.5 ml/ 15 l + Neem oil 0.2%) followed by Fosetyl-Al @ 0.1% at 10 days interval) while maximum disease incidence (28.54%) and minimum yield (225.7 q/ha)were observed in treatment T7(Control). Natural products such as herbal extracts may provide alternatives to synthetic fungicides.

IPM1 P36. Effect of banana pseudostem sap and *Pseudomonas fluorescens* on mango diseases in field condition

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Mango (*Mangifera indica* L.) is an important fruit crop of India and other sub-tropical and tropical countries of the world. Mango fruit is one of the most popular, nutritionally rich fruits with unique flavor, fragrance, taste, and health promoting qualities, making it number one among new functional foods, often labelled as "super fruits". In pre-harvest condition, several diseases are found on the mango which reduces the yield, decreases marketability and shelf life after harvest of the fruits. Widely used fungicides have led to increased activity in the development of biological control against plant pathogens. Hence, the present investigation on the biological control of mango diseases was carried out in in vivo condition, the efficacy of banana pseudostem sap and bio-control agent (*P. fluorescens*) on the disease severity of anthracnose, powdery mildew and grey blight of mango and found that spraying and drenching of banana pseudostem sap @ 2.0 % and 15%, respectively reduce the per cent disease intensity of anthracnose and powdery mildew as compared with control and increase the average yield of mango (average 81.58 kg/plant). In biochemical parameter significantly highest phenol content was also observed in this treatment.

IPM1 P37. Streptomyces-mediated biological control of charcoal rot of sorghum

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Increasing cost and negative effects of pesticides and fertilizers necessitates the idea of biological options for crop protection and production. Biological options such as plant growth-promoting rhizobacteria (PGPR), botanicals, animal wastes and crop residues serves not only an alternative to chemical pesticides and fertilizers but also have a direct impact on soil health and crop productivity. Among the PGPR, *Streptomyces* has been demonstrated to play a major role in crop production and protection. *Streptomyces* are Gram-positive aerobic actinobacteria with high G + C DNA content of 69─78 mol%. More than 75% of all known naturally occurring antibiotics such as chloramphenicol, cypemycin, grisemycin, neomycin and bottromycins, and a wide range of structurally diverse compounds with various pharmaceutical applications have been isolated from Streptomyces. Our present work is focused on use of *Streptomyces* and their secondary metabolites for the management of charcoal rot of sorghum caused by *Macrophomina phaseolina*. *M. phaseolina* is one of the important pathogen of sorghum causing charcoal rot disease in post rainy season, particularly when there is a long spell of drought. In the present study, one strain of *Streptomyces* sp. CAI-21 was demonstrated for its antagonistic potential against charcoal rot of sorghum under both greenhouse and field studies. Further, the secondary metabolite responsible for the inhibition of *M. phaseolina* was also purified. The structural elucidation of the purified metabolite is under process

IPM1 P38. Entomotoxic actinobacteria for management of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in pulses

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The gram pod borer, *Helicoverpa armigera* (Hubner) is the major biotic stress that significantly reduces the yield of pulses. In search of safe and ecofriendly novel insecticides of natural origin, an exploration was conducted and isolated 45 actinobacteria from soils of agri and horticultural ecosystems. All 45 actinobacteria isolates were cultured in Starch Casein (SC) broth at 28°C by shaking (150 rev./m) for initial 7d, subsequently on still position for 21d. After 28d the fermented broth was centrifuged to extract the biocompounds from the supernatant using ethyl acetate (EtOAc) solvent. The EtOAc extract of 45 actinobacteria isolates was utilized to conduct the bioassay against 3rd instar (9d old) larvae of *H. armigera*. Four Actinobacteria Isolates (AI) - 12, 16, 23 and 31 have illustarted 70% larval mortality. Further cultural morphology (growth in different media), spore structure (Scanning Electron Microscopy), biochemical utilization (carbon utilization tests, hydrolysis of starch and casein) and molecular tools (amplification of 16S rRNA gene) were used to identify the potential isolates. The four isolates were identified as AI 12 - *Streptomyces* sp. IIPR:AK02:01 (MK142738), AI 16 - *Streptomyces* sp. IIPR:BP05:02 (MK158076), AI 23 - *Streptomyces* sp. IIPR:KA02:02 (MK248519) and AI 31 - *Streptomyces* sp. IIPR:KR03:01 (MK595689) strains. The mixture of biocompounds present in EtoAc extract of four potential strains was separated by performing Thin Layer Chromatography. Once the elucidation and validation of the insecticidal biocompounds from potential strains is done, they can be exploited for the ecofriendly management of *H. armigera*.

IPM1 P39. Efficiency of *Trichoderma* strains against stem rot (*Macrophomina phaseolina*) of jute

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Fifteen *Trichoderma* strains (*T. viridae* and *T. harziamum*) including 9 collected from IARI, New Delhi and NBAIM, Mau and 6 native isolates from CRIJAF, Barrackpore (TVC-1,TVC-2,TVC-3,TVC-4,TVC-5 and TVC-6) were tested for their bio-control efficacy against *Macrophomina phaseolina*. Different parameters like, growth dynamics, growth inhibition and rhizosphere colonization under laboratory condition were carried out. Consistently the radial growth was higher in TVC 1 (2.5cm at 24h and 8.5cm at 72h), NBAII TH-10 (2.4cm at 24h and 8.4cm at 72h). Maximum rhizosphere colonization was recorded in TVC1 (300 x 103 cfu/g dry soil) followed by NBAII TH-1 and NBAII TH-10 (183 x 103 cfu/g dry soil). The native isolate TVC 1 consistently perform better (56.8% growth inhibition) followed by TVC 4 in inhibiting growth of pathogen. Among exotic isolates, NBAII TH10, NBAII TH1 also perform better. Growth promotion activities of TVC 1 was found to be the best (VI= 600). Leaf area at 15 days after sowing in *Trichoderma* inoculated soil was also measured. Maximum leaf area was recorded in TVC 1 (36.9 sq cm) followed by TV-H (33 sq cm) and TVC 4(25 sq.cm), least leaf area (11sq cm) was recorded in MTCC 8799. Germination as well as emergence of seedlings (cv. JRO 204) was monitored regularly. All the native isolates were better in reducing pre-emergence rotting (26-38%) than exotic isolates (60-74%). Whereas least post emergence rotting was recorded in TVC 1 (0.33%) followed by NBAII TH-1 (1.0%).

IPM1 P40. Diversity of resistance to millet head miner, *Heliocheilus albipunctella* in pearl millet, *Pennisetum glaucum* (L.)

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Pearl millet (*Pennisetum glaucum* L.) is the staple food crop for people living in semi-arid regions of Sahel, is regularly damaged by millet head miner, *Heliocheilus albipunctella* which is one of the economically important pest for the past 20 years. Inorder to identify the plant based resistance sources for millet head miner, we have screened forty pearl millet genotypes, using artificial infestation method. Analysis of variance revealed significant differences in the genotypes tested for head miner resistance. The genotypes Gamoji, ICMP 177001, ICMP 177002, ICMV 177003, ICMV IS 90311, LCIC9702, Souna 3, and PE08043 exhibited antibiosis resistance mechanism to *H. albipunctella* with appreciable agronomy and grain yield. The genotypes Faringuero, ICMV 167005, ICMV IS 99001, Sadore local, SOSAT-C88, ICMV IS 94206, and ICMP 177004 exhibited tolerance to head miner damage with good per se performance. The genotypes Moro, ICMV IS 92326, and Ex bornou also expressed resistance to head miner when compared with the susceptible check ICMV IS 92222. Association between the head miner resistance and morphological traits showed positive and significant correlation of larval production index (%) with head miner damage (r = 0.59**) and days to 50% flowering (r = 0.32*). Path coefficient analysis depicted the direct and indirect effects of the agronomic and morphological traits on grain yield, identifying the factors associated with the grain yield improvement. The identified resistance sources can be effectively utilized in breeding head miner resistance pearl millet genotypes/hybrids, with high grain yield and micronutrient concentration.

IPM1 P41. Effect of chickpea and linseed intercropping system on *Helicoverpa armigera* (Hubner) incidence and yield in chickpea

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The gram pod borer *Helicoverpa armigera* (Húbner) is most important pest of chickpea. Lot of pesticides are uses for control this pest but they not only leaves harmful residues but also effect on non target organisms and environment, pest resurgence and development of resistance to insecticides. Use of intercropping has been found to be not only eco-friendly but provide higher economic return. By adoption of intercropping, problems of incidence of insects and pests are greatly reduced. Therefore, a field experiment was conducted at Research farm, RARI, Durgapura, during 2015-16 and 2016-17 in randomized Block Design with three replications and eight treatments viz.- T1- Sole chickpea , T2-Sole linseed, T3-Chickpea +Linseed (3:1), T4- Chickpea + Linseed (4:1), T5-Chickpea + Linseed (5:1), T6-Chickpea + Linseed (3:2), T7- Chickpea + Linseed (4:2), T8-Chickpea + Linseed (5:2) to assess the influence of intercropping on the incidence of *H. armigera* (Hubner) and yield of chickpea. The lowest percent pod damage was found in treatment No T-6 (6.12%) and followed by T-7 (6.89%), T-8 (8.22%), T-3(10.43%), T-4 (12.73%), T-5 (14.03%), and T-1 (22.75%).

IPM1 P42. Effect of weed management practices on weed dynamics, yield and economics of chickpea (*Cicer arietinum* L.)

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A field experiments was conducted during 2013-14 and 2014-15 to study the effect of weed management practices on yield and economics of chickpea and to find out the most effective and economic weed management practice for chickpea under semi arid conditions of Rajasthan. The ten treatments comprising different pre, post emergence herbicides and hand weeding were tried in RBD with three replications. Results revealed that Two hand weeding at 25-30 and 40-45 DAS recorded minimum mean weed dry weight(81.8 g/m2), highest WCE (59.98 %)and maximum chickpea seed and stover yield during both years of study while the maximum mean net monetary returns (Rs.20208/ha) and B:C ratio (2.00) was recorded under pre-emergence application of pendimethalin 30EC + Imazethapyr 2EC. Further, among the herbicides, pre-emergence application of treatment T3 i.e pendimethalin 30 EC + Imazethapyr 2EC (ready mix combination) proved superior as it recorded highest mean grain and stover (11.29 and 16.62 q/ha) which were higher by 29.62 and 21.49% respectively, over unweeded check.

IPM1 P43. Microbiocides for synchronous management of root rot (*Rhizoctonia bataticola*) and American boll worm (*Helicoverpa armigera*) in cotton

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Cotton is the king of fibres and also known as ‘white gold’ dominates India’s cash crops. Root rot caused by *Macrophomina phaseolina* is one of the most serious disease of cotton particularly in northern states of India viz., Punjab, Haryana, Rajasthan and Western Uttar Pradesh and affects both, the *G. hirsutum* and *G. arboreum* cotton species. *Helicoverpa armigera* (Hubner) is a predominant bollworm causing major yield loss to non Bt- cotton. The use of microbial consortia is the subject of current interest for the synchronous management of pest and disease. In this study, fifty five strains of *Bacillus* were isolated from rhizosphere soils of cotton. Twenty *B. bassiana* isolates were collected. Among the *Bacillus* strains, ten strains were found to be effective against *M. phaseolina in vitro* with suppression ranged from 12.22 to 50 per cent. *Bacillus* strains were confirmed by biochemical tests. Strains were further screened based on production of siderophore, biofilm, HCN, IAA and GA3. Molecular identification was done by 16s rRNA partial sequencing approach and strains were screened for genes related to biocontrol activity (iturin, surfactin and Fengycin). Ten isolates namely EBb9, EBb10, EBb11, SB Bb1, INB Bb, MBb, AP Bb, TBb, KBb2, SBb2 of *B. bassiana* showed pathogenicity towards *H. armigera* with varied mortality rates ranged from 85 to 100%. Molecular identification of rDNA, chitinase and glucanase genes for *Beauveria* isolates were examined. The findings indicate that effective microbial consortia are the viable alternative of chemical pesticides in managing *H. armigera* and root rot of cotton.

IPM1 P44. Management of brinjal shoot and fruit borer *Leucinodes orbonalis* with chemicals and crude plant extracts

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Among the major biotic factors which hamper the production of brinjal, the shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee is most serious pest which occurs throughout the year and inflicts damage by attacking tender shoots in nursery and growing fruits till harvest. The pest is known to cause up to 70-80 % loss in marketable yield and over 90 % of fruits can get damaged in the years of high pest infestation. The present studies were carried out to evaluate the efficacy of some CIB recommended chemical insecticides and plant extracts for the management of shoot and fruit borer of brinjal. The crop was grown with all the recommended agronomic practices. Six treatments each replicated three times were compared with the untreated control in RBD. Results showed that a 3-spray schedule of chemicals consisting of quinalphos (Krush 25%) @ 2ml/L followed by cypermethrin (Auzar 25% EC) @ 0.30 ml/L after 15 days of 1st spray followed by quinalphos (Krush 25%) @ 2ml/L after 15 days of 2nd spray was found to be the most effective for the control of brinjal shoot and fruit borer resulting in minimum shoot infestation of 4.60% per cent (77.85 % reduction from the control) and fruit damage of 9.28 per cent on number basis with 77.45 per cent reduction in borer infestation and 10.55 per cent on weight basis (74.24 per cent reduction). This spray schedule was the most economical with the B:C ratio of 5.60

IPM1 P45. Effect of volatile compounds produced by *Trichoderma* spp. on *Rhizoctonia solani*

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Dry bean (*Phaseolus vulgaris* L.) can be affected by the pathogenic fungus *Rhizoctonia solani*. On the other hand, *Trichoderma* spp. is a widespread genera of fungi used as BCAs in agriculture. One of the control mechanisms shown by *Trichoderma* is the release of active volatile compounds. The aim of this study was to assess the *in vitro* effect of volatile metabolites produced by three *Trichoderma* strains, *T. harzianum*; *T. citrinoviride* and *T. velutinum*, upon *R. solani*. All fungal strains were isolated from PGI "Alubia de La Bañeza–León" bean fields. *Trichoderma* strains were grown for 2 days in the centre of 90mm Petri dishes with 18ml of PDA medium, prior to the addition of the pathogen. A 6mm plug of *R. solani* was placed in the centre of same Petri dishes as described before. The lids of both pathogen and BCA dishes were removed and placed together along their edge, facing each other, downwards and upwards, respectively. This was considered as day 0, and diameters of the pathogen colonies were measured after 1, 3 and 7 days. The results showed a high volatile-mediated antifungal activity of all *Trichoderma* strains evaluated, with inhibition percentages ranging from 85.34% to 92.68%, leading to an abrupt halt in *R. solani* growth from day 0 onwards, while controls without *Trichoderma* showed a steady growth. The results demonstrate that *Trichoderma* volatile metabolites can play a significant role in its antagonistic activity against *R. solani*. More assays are needed to elucidate these volatile-mediated fungal interactions.

IPM1 P46. Toxicity of native *B. thuringiensis* isolates against Bihar hairy caterpillar (*Spilosoma obliqua* Walker) and its mass multiplication through agro-industrial waste

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Bacillus thuringiensis is an important microbial bio-control agent occupying 75% share of the biopesticide deployed globally in 2015. The 4 native *B. thuringiensis* (Bt) isolates (F8.IIPR, Ak2.IIPR, F5.IIPR and F6.IIPR) harbouring vip3A and cry genes were compared with standard check (Bt.kurstaki HD1) for screening its toxicity against 2nd instar Bihar hairy caterpillar (BHC) larva, *Spilosoma obliqua* Walker, a sporadic pest in India. The spore crystal mixture (SCM) of Bt isolates was extracted and screened by diet contamination method. Three Bt isolates (F8.IIPR, Ak2.IIPR & F5.IIPR) had recorded lowest Lethal concentration (LC50) than standard check (5.83 × 103 CFUs/ml). The Bt isolates were multiplied in agro wastes viz., de-fatted groundnut seed meal and sesame seed meal along with standard nutrient broth. The percent sporulation was highest in de-fatted groundnut seed meal (11.1-583.3) followed by de-fatted sesame seed meal (20-400) and nutrient broth (5.9-133). Further their SCM was extracted and tested against 4th instar BHC larva. The highest mortality was recorded from groundnut seed meal (50-100%) followed by nutrient agar (40-90%) and sesame seed meal (30-80%). The protein content was found to be highest in de-fatted groundnut seed meal (2.05 mg/ml) followed by de-fatted sesame seed meal (1.84 mg/ml) and nutrient broth (1.57 mg/ml). To mitigate the climate induced insect pest emergence of sporadic insect pest such as S. obliqua there is a need of potential native Bt isolates. The present investigation reports identification of 3 potential Bt isolates for management of BHC and its mass multiplication in groundnut seed meal

IPM1 P47. Isolation of *Pasteuria penetrans*, an obligate bacterial hyper-parasite of *Meloidogyne* spp. from the rhizosphere of pulses

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Pulses play an important role in achieving United Nations Sustainable Development Goal: Nutritional Security and Sustainable Agriculture. India, world's largest producer and consumer of pulses achieved an all time record production of 25.23 million tonnes of total pulses during 2017-18. It is estimated that India needs to produce 39 million tonnes of pulses by 2050 as a means to ensure self sufficiency which entails an annual growth rate of 2.14%. This requires multi-pronged strategy to mitigate major constrains in pulse production. Root knot nematode, *Meloidogyne* spp. is one of key limiting factor and causes 20-35% yield losses in pulses in India. *Pasteuria penetrans* is an endospore forming bacterium which specifically parasitizes on second stage juveniles (J2) of the genus *Meloidogyne* and has high potential for their sustainable management. Non availability of effective strain(s) of *P. penetrans* against all races of *Meloidogyne* is one of the most important bottlenecks in utilizing its full potential. Surveys were carried out in four different agro climatic zones viz., middle gangetic plains (Varanasi) upper gangetic plains (Sitapur) north eastern plain zone (Deoria and Kushinagar) of Uttar Pradesh and southern plateau and hills (Salem, Tamil Nadu) and collected 106 nematode infected soil and plant samples from pulses rhizosphere for isolation of *P. penetrans*. Of these, we observed *Pasteuria* spore attachment on juveniles from seven samples; three from Varanasi, two from Salem and one each from Deoria and Kushinagar. The pure cultures of these seven isolates from single infected female are being multiplied in soil-less CYG medium.

IPM1 P48. Persistence of chlorpyrifos, fluopicolide and propamocarb in onion

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An experiment was conducted on persistence of chlorpyrifos, fluopicolide and propamocarb in onion as well in onion cropped soil along with the effect of various culinary processes in reducing their level of residues in onion. Chlorpyrifos (Chlorguard® 20 EC) persisted up to 10 and 15 days in green onion with the initial deposits of 4.538 and 9.076 mg/kg at the application rate of 1000 and 2000 g a.i./ha, respectively. The initial deposits of fluopicolide component of combi product Infinito® 68.75 SC were found to be 0.264 and 0.421 mg/kg at the application rate of 78.1 and 156.25 g a.i./ha, respectively, which persisted for 3 and 5 days at respective doses. Propamocarb as second component of combi product Infinito® 68.75 SC persisted up to 7 and 10 days with initial deposits of 0.803 and 1.547 mg/kg at the application rate of 781.3 and 1562.5 g a.i./ha, respectively on green onion. These residues were reduced to half in less than 2.5 days as per Hoskins 1961 formulae. A safe waiting period of 21 days can be recommended for chlorpyrifos based on the MRL of 0.01 mg/kg and 1 day for Infinito (fluopicolide and propamocarb) at MRL of 2 mg/kg on onion. The harvest time residues of all the pesticides in mature bulbs and soil samples were below determination limit values of respective pesticides. Among various culinary processes, microwave cooking after tap water washing was found most effective in dislodging the residues to the tune of 95.98-100.00 per cent in green onion

IPM1 P49. Evaluation of entomopathogenic fungi against maize fall armyworm, *Spodoptera frugiperda* (J. E. Smith) using laboratory bioassays

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Fall armyworm *Spodoptera frugiperda*, an invasive pest which has been reported to cause serious damage to the maize crop in India during 2018 and warranted immediate control measures for this pest. To develop a biocontrol based strategy using entomofungal pathogens against this pest, three strains of *Beauveria bassiana* (ICAR-NBAIR Bb5a, Bb-11 Bb-45), five strains of *Metarhizium anisopliae* (ICAR-NBAIR Ma-4, Ma-35, Ma-11, Ma-14, Ma-15) and two strains of *Nomuraea rileyi* (Nr-1 and NrSf-1) were evaluated against 2nd instar larvae of *Spodoptera frugiperda* in the laboratory bioassay at the dose of $1x10^8$ spores/ml. Among the ten strains tested, *M. anisopliae* ICAR-NBAIR Ma-35 caused 67.8% mortality followed by *B. bassiana* ICAR-NBAIR Bb-45 with 64.3% and Bb-11 with 57.1% mortality. Rest of the isolates showed 10.7- 28.6% mortality. Further, ICAR-NBAIR Ma-35 and ICAR-NBAIR Bb-45 isolates were subjected to dose and time mortality studies. ICAR-NBAIR Ma-35 showed LC50 of 1.1 x107 spores ml-1 and LT50 of 86.04 hours and ICAR-NBAIR Bb-45 showed LC50 of 1.9 x107 spores ml-1 and LT50 of 88.30 hrs respectively. The present study indicated the potential of *M. anisopliae* ICAR-NBAIR Ma-35 and *B. bassiana* ICAR-NBAIR Bb-45 against the devastating invasive pest, *S. frugiperda* infesting maize. Further studies have to be carried out in the *S. frugiperda* infested maize fields for their effectiveness

IPM1 P50. Alleviation of biotic stresses in kodo millet (*Paspalum scrobiculatum* L.) by rational approaches

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Among biotic stresses, few diseases like head smut, banded leaf and sheath blight, phanerogamic partial root parasite, *Striga* spp. and one insect shoot fly limits the sustainable production of kodo millet. Use of resistant cultivars is the best, economical and feasible option in kodo millet against biotic stresses for resource poor farmers. In the present study, kodo millet cultivars namely DPS 18, JK 13, BK 15 and TNAU 141, RPS 745, RPS 630, RPS 594, KOPN 8, 10, 14, 24, BK 5 were identified resistant to head smut and banded leaf and sheath blight, respectively. Soil application of value added *Trichoderma viride* + P.f. + B.s,@ 1kg/acre was found effective to reduce incidence of the banded leaf and sheath blight in kodo millet. Low incidence of *Striga* spp. was found in TNAU 141, KOPN 21, RPS 513, RPS 594, RPS 630, 631, RBK 155 exhibiting lower values of *Striga* related parameters. Minimum *Striga* count plot-1 and *Striga* vigour ratings along with highest grain yield (kg/ha) was recorded in soil application of FYM (2.5 t ha-1) + VC (1.25t ha-1) enriched with *Trichoderma* + *Azospirillum* @ 2 kg/tones of manure and 100% RDF. Kodo millet cultivars namely JK 41, JK 155, GPUK 3, JK 136, KMV 20, JK 48, JK 106, JK 65, JK 98 & JK 13 were found resistant to shoot fly. Spraying of 1500 ppm azadiractin at 15 DAS or spray of NSKE (5%) at 15 DAS were found to reduce the population of shoot fly effectively.

IPM1 P51.Toxicity and IGR activity of a brown algal seaweeds' solvent extracts on a polyphagous pest in Agriculture *Spodoptera litura* (Fabricius) (Noctuidae: Lepidoptera)

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Spodoptera litura (Fab.) has been reported to infest more than 100 crops and caused enormous loss. The problems caused by insecticides paved way for seeking better alternatives of which algal seaweeds with greater bio-active metabolites could be effective. In this context, a potential brown algal seaweed *Turbinaria ornata* (Turner) J. Agardh collected from Rameswaram coastal ecosystem has been investigated for their toxicity and Insect growth regulator activity against *S. litura* in Department of Entomology, Faculty of Agriculture, Annamalai University during 2017-2019. *T. ornata*'s solvent extracts (acetone, hexane and methanol) were tested against *S. litura* under laboratory conditions with eight treatments (10, 30, 50, 70, 100, 200 µl/l, an absolute control and untreated control) under CRD. Among the solvent extracts, the methanol extract pronounced the highest larval mortality (66.66%) followed by acetone (53.33%) and hexane extract (40%) at maximum concentration after 96 hours of treatment. The lowest level of pupation was also exerted by methanol extract (33.33%) followed by acetone and hexane extract (46.67 and 60% respectively) at the highest concentration. Hexane and methanol extracts demonstrated highest pupal mortality and adult malformation wherein methanol and acetone extracts pronounced maximum pupal malformation. Minimum percent of healthy adult emergence was recorded in methanol extract (20.00%) followed by acetone and hexane extracts (33.33% and 46.67%, respectively). The methanol extract performed better than the acetone

and hexane extracts in larvicidal and IGR activities. The insecticidal and IGR activity might be due to the presence of 20 phytochemicals which has to be investigated elaborately in future.

IPM1 P52. Exploration of natural enemy fauna of cotton mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) from central Kerala

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The cotton mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) a native of USA that coevolved with various host plants, has become highly invasive and polyphagous in India. It reportedly damages more than 200 plant species of economically important families such as Malvaceae, Solanaceae, Cucurbitaceae and Fabaceae. The pest received worldwide attention as an invasive pest of quarantine importance. In India, it is a major pest of cotton, while in Kerala it is reported to cause serious damage to okra (*Abelmoschus esculentus*) and China rose (*Hibiscus rosa-sinensis* L.). A survey was conducted to explore the availability of natural enemies of *P. solenopsis* on its various host plants around central Kerala districts. The recorded natural enemies of *P. solenopsis* included insect parasitoids (*Aenasius arizonenesis, Anicetus* sp., *Myiocnema comperei* and *Prochiloneurus* spp.) and predator (*Spalgis epius*). Relative abundance of natural enemies was also recorded from March 2016 to March 2017 in selected localities of Thrissur district. The number of parasitoids and predators varied significantly in summer, pre-monsoon and post-monsoon seasons with the highest percent relative abundance of *A. arizonensis*.

IPM1 P53. Management of entomological fruit drop in citrus using bio-pesticides

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Field experiments were carried out on *Citrus reticulata* Blanco (Nagpur mandarin) during 2015-17 at ICAR-Central Citrus Research Institute, Nagpur for evaluating the effects of different botanicals and repellents for the management of fruit piercing moths, *Eudocima* spp. The adult moths puncture ripening fruits leading to premature fruit drop as a result of rotting due to secondary fungal and bacterial infections introduced through punctures causing considerable fruit loss of up to 40-80%. Plant oils such as neem oil, castor oil, mustard oil, citronella oil, horticulture mineral oil each @ 1%; soaps such as neem soap, pongamia soap and botanical extracts of soapnut, sweet flag each @ 2% were evaluated in a grownup Nagpur mandarin orchard of less than 10 years old in randomized block design with 4 replications and 2 trees per replication. The experiments were initiated coinciding with colour breaking stage of Nagpur mandarin fruits during Ambia season (Oct-Nov) for three consecutive years. Observations on number of fallen fruits due to fruit piercing moths were recorded at 10 days interval up to 35 DAT and two sprays were given at 15 days interval. Results from pooled mean data for three seasons revealed that fruit drop due to fruit sucking moths was significantly lowest in HMO 1% treated units (11.29%) followed by pongamia soap 2% i.e 12.35 % and Sweet flag 2% @ 15.03%, respectively. Hence, these biopesticides could be included in the integrated pest management module against fruit sucking moth in citrus.

IPM1 P54. Seasonal fluctuations of *Pseudomonas* species in the brown plant hopper (BPH) microbiome -- its impact on and implications for BPH survival

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Brown planthopper (*Nilaparvata lugens*; BPH), a monophagous sap-sucking insect that feeds exclusively on rice, has become a major pest that causes immense yield loss worldwide. Conventional strategies to control this pest are proving unsuccessful and more importantly, populations of BPH are building resistance to most pesticides and rendering them ineffective within a few generations. This study was undertaken to investigate the probable role of gut microbes in facilitating its survival under adverse conditions. We focused upon diversity of *Pseudomonas* present in BPH, as over 190 species of *Pseudomonas* having remarkably different biology, are known to exist. While some *Pseudomonas* species are capable of synthesising essential amino acids and metabolites others possess capacity to detoxify xenobiotics. *Pseudomonas*-specific 16s rRNA gut-microbiome profiling indicated the differential presence of *Pseudomonas* in BPH collected from different regions of India. Data from the current study indicated that the microbiome of BPH is highly dynamic and is likely influenced by several physical, physiological and environmental factors. The present study can form the basis for utilising symbiont-based approaches to monitor different populations of BPH. Moreover, *Pseudomonas*, being a primary symbiont, can be engineered to effectively manage this pest thus serving as a promising approach for restricting BPH population size as part of an effective strategy for the integrated pest management (IPM) of this destructive pest of rice.

IPM1 P55. Assessment of naturally occurring bio suppressing agent- Hymenopteran parasitoids of *Maruca vitrata* Geyer in a pigeonpea bowl of Karnataka

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Studies on Assessment of Hymenopteran parasitoids of *Maruca vitrata* Geyer in a pigeonpea ecosystem (Kalabuaragi, Bidar and Yadagir district) were made in kharif season of 2014 to 2016 (Three Years) from field collected grown up larvae (4th instar) and reared in laboratory up to end of pupal stage and observed for parasitoid emergence in cages. The results revealed that three different species of parasitoids viz., *Bassus relativus* (Bhat & Gupta), *Trathala flavoorbitalis* (Cameron) and *Phanerotoma hendecasisella* Cam. were recorded in all the three districts of pigeonpea growing area of Karnataka (Pigeonpea bowl of Karnataka). The abundance of parasitoid was varied from one location to another and also from interval of collections. At Gulbarga collection made on 1st week of September found more percentage of *B. relativus* (14.66±2.51) followed by *T. flavoorbitalis* (8.33±1.52) and *P. hendecasisella* (4.00±1.73 %) parasitization in larval stage in laboratory. However in other two districts also the trend of parasitoids activity is similar but extent of parasitization was varied. More per cent parasitization was observed from the larvae collected at Bidar district followed by Kalabuaragi and lowest was from yadagir district. During second field collection made on 3rd week of September followed the same trend in all the field collected locations. Among three different species of parasitoids, *B. relativus* was recorded highest (16.66±1.52) per cent parasitization followed by *T. flavoorbitalis* (7.00±2.00) per cent and *P. hendecasisella* recorded lowest (4.66±2.08) per cent parasitization at Kalaburagi. This Research information gives us a scope to explore such natural enemies.

IPM1 P56. Ecofriendly management of major sucking pests pod bug, *Clavigralla gibbosa* Spinola and leafhopper, *Empoasca kerri* Pruthi of pigeonpea

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The Investigations were carried out to evaluate some biopesticides and botanicals against major sucking pests (pod bug, *Clavigralla gibbosa* Spinola and leafhopper, *Empoasca kerri* Pruthi) of pigeonpea crop during kharif 2017-18 at Zonal Agricultural Research Station, Kalaburagi, Karnataka, India under field conditions with seven treatments and three replications. The results reviled that neem seed kernel extract 5% spray recorded the lowest pod bug compared to other biopesticides used. This treatment was followed by *Lecanicilium lecanii* @ 2 g/litre. Where as, Neemazol 1% @ 2 ml/litre and Sasyarakshak @ 10 ml/litre were moderately effective. The biopesticides *Beauveria bassiana* @ 2 g/litre and *Metarhizium anisopliae* @ 2 g/litre were least effective in managing the pod bug population. Maximum benefit: cost ratio was obtained in NSKE 5% followed by *Lecanicilium lecanii* @ 2 g/l and minimum in *M. anisopliae* @ 2 g/l. Hence NSKE 5% and *L. lecanii* @ 2 g/l have to be used at least once or twice which are effective, selective, eco-friendly and economic against sucking pests in pigeonpea more particularly in organic way of pigeonpea cultivation.

IPM1 P57.Effect of endophytic bacteria against tomato early blight caused by *Alternaria solani*

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A total of twenty four endophytic bacteria were isolated from root, leaves and stem portions of tomato. All the isolated endophytic bacteria were evaluated for their antagonistic effect against *Alternaria solani* under *in vitro* using dual culture technique. Among all the isolates, the isolate EBT22 recorded maximum inhibition of 62.66 per cent followed by the EBT8, EBT18, EBT14 and EBT3 while the minimum (32.04%) inhibition was recorded by the isolate EBT24.The five potential endophytic isolates were further evaluated for their influence on plant growth parameters of tomato cv. Arka Vikas. Out of five isolates tested, the isolate EBT18 recorded highest germination (88.88%), root length (18.67 cm), shoot length (15. 91 cm) and vigour index (3302), while minimum were recorded by EBT3. The isolate EBT18 recorded minimum PDI of 20.30 per cent when applied as seed treatment + soil drench with a per cent disease reduction of 57.94 when compared to control under glass house conditions.The isolate EBT18 was identified as *Bacillus stratosphericus* based on 16S rRNA sequencing. In the present study, the isolate EBT18 showed positive reaction for IAA (++++) production, siderophore (++) production and also promoted plant growth and reduced disease index with maximum per cent of disease control.

IPM1 P58. Efficacy of endophytic *Beauveria bassiana* inoculated cotton plants against insect pests of cotton

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Entomopathogenic fungi are recognized as biological control agent worldwide. Furthermore, recent studies have shown that entomopathogenic fungi play an additional role in plants as endophytes and protect against insect pests also. The purpose of this investigation was to assess the colonization of *Beauveria bassiana* in cotton plants and to evaluate its insecticidal potential in cotton plant. Eight endophytic *B. bassiana* introduced into cotton plants by four different methods viz., seed coating, seed immersion, soil drenching and foliar spray under pot culture condition. *B. bassiana* inoculated plants were artificially infested with *Aphis gossypii*, *Pectinophora gossypiella* and *Spodoptera litura*. Cotton leaves from the *B. bassiana* inoculated plants were infested with Aphids and *S. litura* and green bolls were fed with larvae of *P. gossypiella* to assess the pathogenicity. The percent mortality was observed. Cotton plant inoculated by isolate *B. bassiana* 4 recorded with mortality of 15% in aphid, followed by 14% in isolate *B. bassiana* 3 inoculated cotton plants. For *P. gossypiella*, mortality of 17% observed in *B. bassiana* 4 inoculated plant followed by 15% in *B. bassiana* 1 inoculated plant. The mortality of 8% and 7% recorded for *S. litura* in *B. bassiana* 6 and *B. bassiana* 8 inoculated plants, respectively. Our results showed that insects feeding preference affected in cotton plants colonized by *B. bassiana* compared to uninoculated plant. This study broadens our knowledge on the potential of entomopathogenic fungi as endophytes in cotton plants, could be used in IPM programs, which lead to reductions in the use of insecticides.

IPM1 P59. Crop protection technologies using new laboratory samples of bio preparations based on bacteria strains of *Bacillus subtilis*

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New laboratory samples of biofungicides have been developed according to the original method in the Laboratory for the development of microbiological crop protection products and the microorganisms collection of the Federal State Budgetary Scientific Institution "All-Russian Research Institute of Biological Plant Protection". Their basis is the native strains of bacteria *Bacillus subtilis* BZR 336g, *B. subtilis* BZR 517 from the "State collection of entomoacariphages and microorganisms" (UNU 585858). Laboratory samples of biopreparations were tested in the south of Russia on winter wheat and apple trees of various varieties.The biological efficacy of the laboratory samples of biofungicides against the root rot complex was up to 67.3%, yellow leaf spot - up to 65.0%, septoria - up to 60.0%, powdery mildew - up to 85.3 %. The stored yield of winter wheat in technologies using laboratory samples of biological products amounted to 16.2 c / ha in comparison with the control variants. The highest biological efficacy on the apple trees was demonstrated by laboratory sample of biological product based on the *B. subtilis* BZR 336g strain. The stored yield was 24% higher in the experimental sample than on sample with the traditional technology (only chemical fungicides). Summarizing the results of field tests, we can conclude that the new laboratory samples of biofungicides developed at the All-Russian Research Institute of Biological Plant Protection are advantageous for use in green technologies for protecting winter wheat and apple trees after the state registration protocol.

IPM1 P60.Exploitation of tritrophic interaction between *Beauveria bassiana* (Balsamo) Vuillemin and *Plutella xylostella* (Linnaeus) for successful biological control programmes: a SEM study

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Diamondback moth, *Plutella xylostella* is a major pest of cruciferous vegetables around the world. This moth has developed resistance to almost all groups of insecticides. Entomopathogenic fungi (EPF) are one of the many alternatives which made them amenable for biological control of insect pests due to their broad host range. The EPF, *B. bassiana* was proved to be effective against this key pest of crucifers. In the present investigation, a native isolate of *B. bassiana* was isolated from naturally infected cadaver from Dharmapuri, Tamil Nadu and molecularly characterized as *B. bassiana* TM MH590235. Attempts were also made to unveil the tritrophic interaction between the entomopathogenic fungi over the surface of host plant on which the targeted insect feeds upon via Scanning Electron Microscopy (SEM). Dose mortality responses of the isolate against *P. xylostella* showed increase in mortality with increase in spore concentration. The LC50 for the isolate TM was 2.4 x 107 spores mL^{-1}. Ultra microscopy of infected cadavers showed the typical sympodial growth of *B. bassiana* over the insect cuticle. SEM revealed the sustenance of conidia over the host plant, cauliflower leaves till seven days after the treatment of leaves with known concentration (1 x 107 spores mL-1) of conidial suspension. The findings of the present investigation throw light upon a potent indigenous *B. bassiana* isolate and its utilization in developing liquid formulations effective against the destructive pest, *P. xylostella*

IPM1 P61.The factors influencing the capture efficacy of sex pheromone traps for *Grapholitha molesta* (Busck) in orchards

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This research investigated the factors influencing the capture efficacy of sex pheromone traps for *Grapholitha molesta* (Busck) in peach and pear orchards in Hebei Province, including trap, height, and direction differences. The number of trapped moths was the greatest in the treatment with the ship form traps, followed by the triangular traps and the basin, and the self-made bucket traps were the least effective at trapping moths. In the peach and pear orchards, the number of moths caught in traps hanging in the upper area of the canopy was the greatest, followed by the traps in middle, and the lowest hung traps caught the fewest moths. Traps were also hung facing different directions, and the number of moths caught were also different in this treatment. The traps hung facing east caught the greatest number of moths, followed by the traps hanging south and north. The traps hanging in center and west trapped the fewest moths. This study demonstrated that the OFM lived in upper place of canopy, and the reason why the ship form traps and triangular traps trapped more moths needs more research. The traps hung facing east caught the greatest number of moths, this maybe related with the times and the winds.

IPM1 P62. Effects of parasitism by *Microplitis mediator* Haliday on food consumption and development of *Mythimna separata* (Walker) larvae

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To explicit the effects of parasitism by *Microplitis mediator* Haliday on food consumption and development of *Mythimna separata* Walker Larvae and evaluate the application value of *M. mediator*. The comparative method was used in the laboratory to measure the relative reduction in food consumption and the development by *M. separata* larva after parasitization by *M. mediator*. The results indicate that the 4th, 6th, 8th day age larvae of *M. separata* parasitized by *M. mediator* consumed significantly less artificial diet than unparasitized larva in the same day age. The difference between the parasitized larvae in different day age was not significantly. The body weight of the parasitized larvae increased slowly before the 5th day and declined after the 5th day. All the parasitezed larvae can not pupate. After the 4th, 6th, 8th day age larvae were parasitized, the development duration of *M. mediator* was different, and the difference between different day age was significiently. The development duration of *M. mediator* was significantly shorten with the age growth of larvae. The results indicate that *M. mediator* can not only control the damage of the current generation but also to a great degree can reduce the population numbers of *M. separata*.

IPM1 P63.Bio-management of rice root knot nematode

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Rice root knot nematode (*Meloidogyne graminicola*) is a major problem in rice. In present study efficacy of a native isolate of *Trichoderma* was tested for the management of RKN. In *in vitro* evaluation of culture filtrate of *Trichoderma* on egg hatching and larval mortality of *M. graminicola*, 80% larval mortality and 8.35% egg hatching was recorded at 100 % concentration. In control 0.809 % larval mortality and 1.27% egg hatching was recorded. In pot experiment minimum 3.33 and 2.00 galls/plant were recorded in soil application of *Trichoderma* @ 4gm + carbofuran @ 0.3 gm/kg soil in the year 2016 & 2017 respectively. Where as in control 17.22 and 20.00 galls/plant were recorded during both years respectively. In the field experiments application of *Trichoderma* @ 10gm/m2 with FYM gave better control. In nursery at 25 days after showing 0.89 and 0.67galls/plant and after 60 days of transplanting 9.22 and 3.22galls/plant were recorded during year 2017 and 2018 respectively. In case of control 4.44 & 4.56 galls /plant in nursery and 34.78 & 21.56 galls/plant in field after 60 days of transplanting were recorded during both the years respectively. Increase in plant growth parameters was also recorded as compare to control.

IPM1 P64.Evaluation of cowpea genoptypes and biorational insecticides for management of legume pod borer, *Maruca vitrata* Geyer (Pyralidae: Lepidoptera)

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Legume pod borer, *Maruca vitrata* Geyer (Pyralidae: Lepidoptera) is a major borer pest and causes damage up to 20-60% in cowpea (*Vigna unguiculata*). Control of this pest relies heavily on the use of conventional insecticides. Host plant resistance and biorational insecticides are environmental friendly and sustainable pest management options for minimizing the insect pests incidence and severity in cowpea. Thus, trials were conducted to screen 93 copwpea genotypes for resistance and evaluate efficacy of biorational insecticides under field conditions against legume pod borer in cowpea during Kharif season 2017-18 at ICAR-Indian Institute of Pulses Research, Regional Research Station, Dharwad. There were five insecticide treatments and untreated control in three replicates in a RBD design. The first spray was done at the time of flowering and second spray at 10-15 days interval. The data on insect count and damage percentages obtained were subjected to transformation before one way analysis of variance. The results indicate that out of 93 cowpea genotypes, four genotypes viz., EC-394838, EC-72271, IC-97767 and GP-37 recorded with less than 10% pod damage by *M. vitrata*. Among different biorational insecticides evaluated, two foliar application of emmamectin benzoate 5WG@0.5gm/L at flowering time at an interval of 10-15 days was found most effective and gave 45% reduction in pod damage over untreated control from pod borer with highest marketable fruit yield. Thus, the cowpea genotypes and biorational insecticide indentified in the present study can be used in insect resistance breeding and IPM programme for legume pod borer *M. vitrata* in cowpea

Poster session II: Mitigating climate change

MCC P1. Invasive rugose spiralling whitefly (*Aleurodicus rugioperculatus* martin) plaguing coconut plantations in southern states of India

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Rugose Spiralling Whitefly (RSW) (*Aleurodicus rugioperculatus* Martin) is an invasive pest on coconut reported first time in 2004 at Belize and from South Indian region such as Pollachi, Tamil Nadu and Palakkad, Kerala during July-August 2016, and later occurrence from Andhra Pradesh. RSW is polyphagous sucking pest belonging to Order Hemiptera infesting more than 200 host plants. Extensive feeding of the insect leads to the excretion of honey dew which deposited on the upper surface of the leaves on other under storey crops. In the recent survey, we could observed ten alternate host plants in coconut homesteads. The shift in weather pattern reflected as deficit monsoon could be one of the primary reasons and increase in temperature over 2oC during summer which helps immediate upsurge of whitefly. In the present investigation, we could observe that more than 50% of the whitefly was parasitized by hymenopteran parasitoid, *Encarsia* sp from different tracts of South Indian states. This is one of the classical biological control strategies and any disturbance in the buildup of *Encarsia* sp. would invariably affect the long-term approach in pest bio-suppression. Parasitism was relatively low in indiscriminate use of synthetic pyrethroids gardens up to 25-30% in Pollachi, Tamil Nadu. To halt the emerging outbreak of RSW, the integration of biocontrol agents with other tactics such as application of 1% starch solution and yellow sticky trap on leaflets and palm trunk, respectively. To encourage build-up of parasitoid population introduce parasitized pupae to venerable zones of RSW.

MCC P2. Characterization and alternative splicing profiles of the sHSP gene family in pigeon pea (*Cajanus cajan*) and CWRs

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As an adaptive response to stress, the synthesis of heat-shock proteins (HSPs) increases in all organisms. In plants, HSPs are grouped into five classes based on their approximate molecular weight: HSP100, HSP90, HSP70, HSP60 and small heat-shock proteins (sHSPs). Though sHSPs are well characterized in the various models and crop plants, the evolution of alternative splicing in sHSPs is yet to be understood. In the present study, 39 sHSP genes from pigeonpea were identified and their phylogeny, gene structure, and protein features were studied. 21 of these sHSP candidate genes were mapped on to 7 chromosomes of pigeonpea. We have observed that two sHSP genes (Cc_HSP35.4 and Cc_HSP32.0) on chromosome 3 and Three sHSP genes (Cc_HSP17.5a, Cc_HSP17.5b, and Cc_HSP17.5c) on chromosome 8 were tandemly duplicated while two sHSP genes (Cc_HSP22.3 and Cc_HSP_22.2) may have shown segmental duplication on chromosome 2 and chromosome 11. A Time-series transcriptome analysis of *C. cajan*, *C. scarabaeoides*, and *C. acutifolius* was also conducted to examine the expression and alternative splicing of sHSPs transcripts during heat stress. We found that 9 of these HSP genes were alternatively spliced during heat stress. A high degree of variation

in alternative splicing was observed within cultivated pigeonpea species and as well as in between Crop Wild Relatives (CWRs) during heat stress. Findings from this work will be useful to the research community to deepen their understanding and to plant breeders for the development of thermo tolerant pigeonpea cultivars

MCC P3.Spatial distribution and seasonal abundance of invasive leaf miner, *Tuta absoluta* under different farming systems

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Tuta absoluta has emerged as a serious invasive pest of tomato in Himachal Pradesh. Recently a new concept of farming, Zero Budget Natural Farming (ZBNF) resulting in better yields and low pest incidence with reduced input costs has been started in the state. In the present study the impact of this farming system on *T. absoluta* in comparison to conventional and organic farming systems was studied. Tomato crop was grown under organic, zero-budget natural and conventional farming systems during 2018 and 2019. Incidence of *T. absoluta* was recorded on tomato under all systems at weekly intervals. In 2018 cropping seasonal incidence of *T. absoluta* was significantly lower in ZBNF system as compared to the conventional farming (CF) and organic farming (OF). Occurrence of *T. absoluta* was delayed by five weeks in ZBNF (4th week of June) as compared to conventional farming system (3rd week of May). In 2019 cropping season trend changed infestation was recorded from the second week after transplanting of tomato. Peak infestation was recorded in fourth week of June in all farming system. The distribution of leaf miner was highest on middle and lower leaves during initial growth stage however, it was highest recorded on upper and middle leaves during senescence of crop.

MCC P4. Post-flood outbreak of *Spodoptera litura* (Fabricius) in the Periyar belt of Kerala, India

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In August, 2018, the state of Kerala, India, witnessed one of the worst floods after 1924. Periyar river basin was one of the worst affected because of the torrential rains of more than 400 mm in 12 days starting from 8th to 19th August. Almost all the villages adjacent to Periyar river was flooded submerging crops for a period of 7-8 days. After 23rd August, rains receded and dry spell prevailed till September end. In the first week of October, 2018 severe outbreak of *Spodoptera litura* was reported from Keezhmad, Vazhakulam, Parakkadavu and Sreemoolanagaram panchayaths of Ernakulam district, which are adjoining Periyar river. In all these panchayaths, *S. litura* outbreak completely defoliated crops almost all the crops raised by farmers after the floods. Though, *S. litura* is a polyphagous pest in this tract, the scale of damage was unprecedented. There was hundred per cent crop loss in an area of more than 20 hectares. The sudden and massive outbreak of *S. litura* after floods may be due to the swarming of adults for egg laying after the withdrawal of flood water from the farm lands. The dry humid conditions, which prevailed after the floods, may have favoured the hatching and survival of caterpillars along with the destruction of natural enemies during heavy rains and floods. Hence, recurrence of extreme climatic events like floods due to climate change can lead to the outbreak of *S. litura* resulting in heavy damage to crops raised after floods.

MCC P5. Incidence of armyworms and cutworms of economically important crops of Southern Karnataka, India

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A roving survey was carried out in seven districts of Southern Karnataka during 2018-19 revealed the incidence and damage of armyworm and cutworms on maize, chilli, soybean, sunflower, castor, potato and ginger in Chikballapur, Hassan, Mandy, Bengaluru Urban, Tumkur and Mysuru. Variation in the level of infestation as well as larval population across the locations was evident during the surveyed season months i.e., kharif and rabi in 2018-19. At all the locations surveyed, maize had higher incidence of fall armyworm. The average incidence of fall armyworm in maize in different areas of Southern Karnataka recorded 20.18, 40.24, 45.7, 38.33, 77.26, 12.6 and 5.6 per cent damage on different stage of maize in Bangalore rural, Bangalore Urban, Mandya, Chickballapur, Tumakur, Hassan and Mysore, respectively. Incidence of *Spodoptrea litura* in chilli, soybean, sunflower and castor in different areas of Southern Karnataka observed 56.9, 86.66. 21.45 and 45.2, respectively. The average incidence of cutwom, *A. segetum* on potato and ginger was 7.76 and 5.11 per cent respectively. The fall armyworm generally confused with cutworms that have granulated skin and large pinacula, such as cutworm, *Agrotis ipsilon*. However, cutworms have the adfrontal suture extending to the epicranial notch while in *S. frugiperda* the adfrontal area extends only half that distance. *S. frugiperda* distinguished by the dorsal raised spots on 8th abdominal segment typically arranged in a square and particularly 9th segment in a trapezoid. *S. litura* larvae are differentiated by the black spots running near 3/4th of the body length behind the head.

MCC P6. First report of *Bipolaris (Helminthosporium*) leaf blight in brown top millet from Karnataka, India

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A new leaf blight disease on brown top millet (*Brachiaria ramosa* (L.) Stapf) caused by *Bipolaris* sp. was found for the first time in ICAR-AICRP on Small millets experimental plots at University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India during Kharif 2018. The pathogen was isolated, pure culture was established by single spore isolation technique and pathogenicity was confirmed under controlled conditions. The pathogenic isolate was identified as *Bipolaris*. based on cultural characteristics, conidial morphology and rDNA ITS (Internal transcribed spacer) sequence comparison. The conidia are obclavate to fusoid, ellipsoid to fusoid, or linear fusoid, straight to slightly covered pale brown, measuring 422.48 x 128.89 µm with 5-9 septate. The hilar structure of conidia is slightly protruberant and on germ studies conidia germinated on both the sides. The species was compared with closely related species of *Bipolaris* sp. infecting graminae family by molecular phylogenetic analysis. The ITS gene sequences of the isolate was deposited (MK03287.1) in NCBI gene bank. To best of our knowledge this is the first report of leaf blight on Brown top millet in Karnataka, India

MCC P7. Pathotype and racial diversity of *Ascochyta rabiei* isolates in the India

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Ascochyta blight is the most destructive disease of chickpea (*Cicer arietinum* L.) caused by the fungus *Ascochyta rabiei*, in areas where low temperature (15-25ºC) and high humid (>150mm rainfall) conditions during crop growth. The aim of the study was to determine the pathotypes and physiological races of thirty *Ascochyta rabies* isolates of India. Pathotypes and physiological races were identified using *Ascochyta rabiei* specific standard international chickpea differentials. Spore's suspensions adjusted to 5×10^5 spores/ml using a haemocytometer and sprayed on 12 day old seedlings of differential lines. All the test isolates were classified into four pathotypes and five physiological races based on their aggressiveness and virulence, respectively. We found eight isolates (26.66%) from Pathotype I (Least aggressive), two isolates (6.66%) from Pathotype II (aggressive), fifteen isolates (50 %) from Pathotype III (more aggressive) and four isolates (13.33%) from pathotype IV (Highly aggressive, killed all the differentials). Predominant pathotype present in India was Pathotype III followed by pathotype I, Pathotype IV and Pathotype II. Five races such as Race 1, 4, 5, 6 and 7 were identified. The most predominant race was 5 followed by 1, 4, 7 and 6, respectively. Among the 30 Indian *A.rabiei* isolates tested for presence of mating types found in India through multiplex PCR, only MAT1-2 was found. The race 2 and 3 was not found in India and irrespective of locations multiple pathotypes and races have been identified. Authors are grateful to Science and Engineering Research Board, New Delhi for funding to carry out this research

MCC P8. A new report of root mealybug *Paraputo lingnani* Ferris (Pseudococcidae: Hemiptera) from Kerala

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A species of mealy bug, *Paraputo lingnani* Ferris (Hemiptera: Pseudococcidae) was observed on the roots of the nut grass (*Cyperus rotundus L.*) in June 2019 during a field survey to Pulpally (11°51'43.0"N 76°10'57.0"E), Wayanad district of Kerala. Colonies of mealy bug were observed on tender roots and rhizomes. Infested plants showed yellowing symptoms initially and later complete drying of severely infested plants was observed. The field was a mixed plantation of black pepper and areca nut intercropped with elephant foot yam. The most dominant weed species observed in the plot was *C. rotundus*. This pest has earlier been reported from Palaearrctic (China), Oriental (India) and South-eastern Asia (Indonesia, Malaysia and Thailand). It is known to infest plants belonging to *Arecaceae* (arecanut), *Poaceae* (rice and sugarcane) and *Cyperaceae* (nut grass). In India, it is known only from Karnataka infesting *C. rotundus*. Their subterranean habitat and cryptic nature make their detection extremely difficult, though presence of ant near collar region acts as a clue for their presence. We provide detailed field and validation characters for its authentic identification and a key to the species of *Paraputo laing* known from India, for its easy segregation from other species. The shift of this species from weed host to major crops could pose a serious threat to agriculture and hence, studies on the pest population dynamics and distribution pattern is of prime importance.

MCC P9. *Thysanoplusia orichalcea* - the emergence of a key pest of potato in North-Eastern Hill region of India

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The Northeastern Hilly region is a vibrant region considered a cradle of flowering plants. Despite incessant rainfall occurring in most parts of the year, it is not immune to emergence of new key pests. Slender burnished brass moth, *Thysanoplusia orichalcea* has shifted from a position of minor to major threat, affecting production of potato in recent times. The trend is primarily due to the change in climatic conditions resulting in epidemic spread of the pest. Among various weather factors, temperature fluctuation is the major cause in enhancing insect's innate capacity, further contributing to increased progeny in the season The mean population of the insect witnessed an unprecedented rise, much above the economic threshold level with 14.5 larvae per meter row length affecting significantly development of tubers. The frequency of occurrence and density of the pest was 10.32 And 9.36 per week respectively. The severity resulted in various degree of skeletonisation, followed by severe defoliation, ultimately leading to the death of the plant, during the pre-rainy and post rainy season (2018), in the East Khasi Hill region of Meghalaya, India. The current scenario is assumed to be an exhibition of increasing trend, posing a persistent threat in the non-traditional areas of the north eastern hills due to the changing climatic changes. The prevalent conditions of temperature varying from 26^0c to 28^0c is conducive for its reproduction. Currently, efforts are being made to install different kind of pheromone traps and evaluate its effectiveness in monitoring and mass trapping the pest effectively

MCC P10. *Smicronyx lutulentus*, the parthenium seed-feeding weevil: challenges faced during colony establishment under quarantine in India

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Biological control of parthenium weed (*Parthenium hysterophorus*) was first attempted in India during the 1980s with the introduction of the leaf-feeding beetle *Zygogramma bicolorata*. It has been a long-felt need that additional biocontrol agents like the seed-feeding weevil, root-feeding moth and/or the stem-galling weevil must be imported to complement *Z. bicolorata* for a better management solution. *Smicronyx lutulentus*, the highly host-specific seed-feeding weevil, has been prioritized as the adults feed on leaves with females laying eggs into newly opened flower heads, wherein the grubs can consume the reproductive structures, thus reducing the number of seeds produced. Based on the strong Australian and South African reports, shipments of this weevil were received from Biosecurity Queensland on different dates during 2018/19. The weevils underwent quarantine screening in the QC-2 facility at the ICAR–National Bureau of Agricultural Insect Resources, Bengaluru. The challenges faced in colony establishment, standardization and refinement of rearing techniques in addition to the protocols and procedures followed for importation of this biocontrol agent are discussed in detail considering the more important host-specificity studies to be undertaken in the near future.

MCC P11. Status of new emerging insect pests of jamun, *Syzygium cuminii* Skeels from Anand, Gujarat

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Jamun (*Syzygium cuminii* Skeels) is a very common, large, evergreen and economically important tree of Indian subcontinent. A field survey was carried out to check the new emerging insect pests damaging the jamun crop in Anand, Gujarat. Number of insect pests was found damaging to the different parts of the tree including like nolid caterpillar, *Carea angulata* and the leaf miner, *Heliozela anna* damages to the leaves and some caterpillar and grubs of weevil damages the seeds of jamun. The status of seed borer and leaf miner was observed as major as they vigorously damages the seeds and leaves respectively while, the status of nolid caterpillar was observed as minor. All the insect pests were first time observed to feed on jamun tree at AAU campus, Anand, Gujarat. Hence, it is the first report of occurrences of leaf miner, nolid caterpillar and seed borers from Anand, Gujarat.

MCC P12. Induction of systemic resistance in cotton against reniform nematode *Rotylenchulus reniformis* with bio-products

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Plant parasitic nematodes are increasingly being recognized as significant cotton pests under the changed climate regime due to changes in precipitation and temperature patterns and gradual increase in area under micro irrigation and mono cropping of commercial crops such as cotton. Eleven districts of Vidarbha region of Maharashtra were sampled and fifteen percent were found to have nematode population exceeding threshold damage population levels for *R. reniformis*. Heavy infestation of reniform nematode has been recorded from farmer fields of Buldhana and Yavatmal districts of Maharashtra. In India, crop loss due to *R. reniformis* on cotton has been put between 9.5 to 17.4%. However, no effective and environmentally sustainable nematode management strategy is available. This necessitated the need to explore induction of systemic resistance against nematodes using natural products as a viable and sustainable strategy. Out of forty bacterial species evaluated, *Bacillus subtilis*, *B.cereus*, *Lysinibacillus sphaericus*, *Brevibacterium epidermidis*, *Providencia vermicola* and *Ochrobactrum pseudogrignonense* were found to induce resistance against reniform nematodes. *L. sphaericus* used as seed treatment was found to reduce nematode population and induce resistance against nematodes as evidenced by split root experiment. Bio formulations (plant derived products and bacteria in different combinations) were evaluated for confirmation of induction of systemic acquired resistance under field conditions on cotton cv PKV081. The spray treatments were better than the corresponding treatments applied to soil and four sprays of bioformulation applied at interval of 15 days reduced nematode population in soil by more than 56% and increased yield by 29% over control.

MCC P13. Effect of climatic factors on population intensity of insect pests damaging niger crop

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Niger (*Guizotia abyssinica*) although considered a minor oilseed crop, is important in terms of its 34 to 36% of quality oil and 18 to 20% of protein. It is the lifeline of tribal agriculture and economy in India. The productivity of Niger in India is low and fluctuating, insect pests are one of the constraints for increasing the productivity. As insects are cold blooded creatures, weather plays an important role on the population fluctuation and distribution of them. Seasonal incidence data of insect pests revealed that Niger caterpillar, Bihar hairy caterpillar, mirid bug, leafhopper and white fly were associated with crop, they were at peak during 43rd, 46th, 45th, 44th, and 43rd standard week respectively. Incidence of Niger caterpillar and white fly showed significant positive correlation with minimum temperature (r= 0.80 and 0.70) and sunshine hours (r= 0.75 and r=0.72). Path analysis revealed that morning relative humidity and rainfall had high direct negative effect on the incidence of Niger caterpillar and white fly. The incidence of Bihar hairy caterpillar, mirid bug and white fly showed non-significant (±) correlations with different weather variables. Path analysis revealed that minimum temperature had high direct positive effect on the incidence of Bihar hairy caterpillar, mirid bug and leaf hopper.

MCC P14. Climate changes influence on the toxicity of insecticides to *Apolygus lucorum*

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Temperature has long been considered as a critical factor on insecticide toxicity. Under the background of global climate changes, daily or seasonal temperature fluctuations, the effect of temperature on insecticide toxicity cannot be ignored. The mirid bug, *Apolygus lucorum* (Meyer-Dür), has progressively increased in population size and has acquired pest status in north-China. We determined the influence of temperature on the toxicity of several insecticides and its' mixtures to *A. lucorum* from 15°C to 35°C by exposing third-instar larvae to dip-treated asparagus bean pods. The results showed that imidacloprid, acetamiprid, hexaflumuron, avermectin and fipronil showed strong positive temperature effects (TCs). The TCs of pyrethroids were relative complex. β-cypermethrin showed strong negative TC, fenvalerate was not affected by temperature and λ-cyhalothrin showed weak negative TC. Temperature showed weak effect on other tested pesticides. The effect of temperature on CTC value was used to evaluate mixture efficacy of different temperature coefficient chemicals. The results indicated the joint toxicity of same temperature coefficient insecticide (TCI) types were unaffected by temperature. However, the effect of temperature was variable when considering the joint toxicity of different TCI types. The effect of temperature on the joint toxicity of both strong positive and strong negative TCI types was clear, and the results indicated a greater influence of the strong TCI when comparing the influence of temperature between strong/slight positive/negative insecticides. These results will guide pest managers in choosing the most effective insecticides and its' mixtures for *A. lucorum* control under changed environmental conditions.

MCC P15. Incidence of root rot of *Cedrus deodara* in different parts of Solan district of Himachal Pradesh.

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We conducted survey in different forest nurseries of Solan district, Himachal Pradesh during June, July, and August 2017-2018 and 2018-2019. The nurseries surveyed were: Kandaghat Range (Kiari, Karol, Bisha nurseries), Chail Range (Chiunth and Gaura nurseries) and Solan Range (Shilli and Nauni nurseries). The diseased nursery plants were collected in paper bags, photographed and studied for symptom development. Incidence of Root rot was recorded during the cropping seasons in different *Cedrus deodara* growing nurseries of Solan range. Incidence of root rot was found in all the locations surveyed. Maximum incidence of the root rot was recorded in Kandaghat range (37.35%) followed by Solan (33.85 %) and Chail range (30.93 %), respectively. Amongst nurseries, Bisha nursery had maximum incidence (62.15 %) followed by Nauni (48.46 %) and Chiunth nurseries (44.65 %), respectively. The overall mean of different years suggested that disease was 5.56 % more in the year 2018 -19. Bisha, Nauni and Chiunth nurseries were worst affected with root rot disease.

MCC P16. Analysis of the virulence constitution of *Puccinia striiformis* west in north-west China

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Stripe rust, caused by *Puccinia striiformis* West, is an important disease, which became a production destroyed problem on wheat and barley. Northwest is the biggest over-summer area of *Puccinia striiformis* West.f.sp.*tritici* (PST) in China, which is the main production area of barely in China. In order to know the virulence constitution of *Puccinia striiformis* West. f. sp. *hordei* (PSD) and the communication between PST and PSD, we start to analyze the virulence constitution of PST and PSD from northwest China. 398 isolates of PST were collected from Gansu，67 isolates of PSD were collected from Gansu, Qinghai and Sichuan. These isolates were investigated by virulence test, analysis of pathotype and forma specialis and determination of pathogenic range of PST which infected barley cultivar. The results indicated that the difference of virulence constitutions between PSD and PST was significant, the virulent communication between PSD and PST was emerged, G22 group was the biggest virulence group in PST and PSD population; 10% isolates of PST infected barley cultivar.

MCC P17. ICRISAT pests monitoring and surveillance at a glance and weather based forewarning models for chickpea and pigeonpea *Helicoverpa armigera*

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The extreme climate events and narrowing crop diversity are encouraging epidemics of agricultural pest and diseases (P&D) incidences and accounts for 40 per cent crop losses globally each year. These changes in the ecosystem promotes the disruption in the geographical synchronization of pests and beneficial insects as well as increases damage potentials of new invasive pests. Therefore, constant surveillance and monitoring of pest distribution are essential to take control measures timely. However, the ICRISAT Farm services (FS) and Integrated Crop Management (ICM) of RP-Asia Program have been monitoring and collecting daily field pest surveillance and trap data of the Patancheru campus from 1980s onward. The trend pest incidence in ICRISAT mandate crops (chickpea, pigeonpea, groundnut, pearl millet and sorghum) was decreasing over the years (1980s to 2018). Among the seasons pest's severity was severe in Kharif followed by Rabi and summer seasons. We tried to develop the weather based forewarning models for *Helicoverpa armigera* of chickpea and pigeonpea. The bimodal series of *Helicoverpa* population distribution were recorded the models were developed for pigeonpea [(Y=-1853.60 - 0.19* Z120 + 38.34 Z11 + 0.55 Z131 + 0.052 Z251) with 0.75 r2 value] and pigeonpea/chickpea [(Y=-978.72 + 0.149 Z130 + 0.63 Z131 + 0.17 Z141+ 2.23 Z251) with 0.69 r2 value] at 25-33 and 45-3 standard meteorological weeks (SMW). The accuracy of *Helicoverpa* incidence and economic threshold levels (ETLs) were cross examined with dates of pest control measure have been initiated. However, validation of these models under progress in the current cropping seasons

MCC P18. Exploring combined stress incited disease dynamics of chickpea x dry root rot interation

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Dry root rot (DRR) of chickpea caused by *Rhizoctonia bataticola* (Rb) has become an emerging threat to chickpea production. Under field conditions, the disease becomes highly aggressive, coincides with higher temperatures and decrease in soil moisture content (SMC). Thus establishing a sound relation between various climatic factors and DRR is necessary to design a rational strategy for combating this disease. Hence, the present study aims to quantify the roles of temperature, soil moisture and Rb as combined stress for causing infection and subsequent disease progression in chickpea. The results proved that a significant relationship exists between the biotic and abiotic elements in predisposing chickpea to DRR. Out of two temperatures (25°C and 35°C) and two soil moisture content (60% and 80% SMC) tested, the combination of high temperature (35°C) and low SMC (60%) was successful in inciting early disease symptoms in the chickpea cultivars tested. The disease severity based on percent susceptibility index (derived from modified 0-9 rating scale) and percent loss in root biomass also provided similar insights, where plants grown under the above combination displayed higher degree of root rot than the combination of low temperature (25°C) and high SMC (80%). A high positive correlation was observed between disease severity, temperature at 35°C and SMC at 60%, whereas, a negative correlation was realized for temperature at 25°C and SMC at

80%. Results of the real-time qPCR based absolute quantification for fungal propagules present in the root tissues sampled at different time points also corroborated with the above findings

MCC P19. Exploring combined effect of elevated CO_2 and temperature on *Fusarium* wilt development of chickpea

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Fusarium wilt (FW) caused by *Fusarium oxysporum* f. sp. *ciceris* (Foc) is one of the major diseases in chickpea. Under changing climatic scenario, elevated CO2 (eCO2) (550 and 700 ppm) and temperature (25°C, 30°C and 35°C) have potential impact on plant resistance mechanisms and pathogen virulence. Hence, the present study was aim to assess the impact of eCO2 and temperature on FW incidence and disease progression in two chickpea cultivars, JG 62 (susceptible) and WR 315 (resistant). Irrespective of temperature, the incubation period was delayed in eCO2 when compared to ambient. In case of combined effect, the maximum disease incidence was found in 30°C combined with 700 ppm as well as ambient CO2 conditions. To quantify the pathogen load and expression of several defence responsive genes in chickpea and virulence-related genes in Foc, qPCR study was employed. As compared to the eCO2, the expression of defence and virulence response genes in chickpea inoculated seedlings was highly up-regulated in ambient CO2 conditions irrespective of temperatures. The results suggested that among different defence-related genes studied, peroxidise gene was highly expressed in WR 315 cultivar, there by restricting the Foc colonization, by providing an evidence of efficient defense mechanism in the resistant cultivar. Moreover, in JG 62 the pathogenicity-causing secreted in xylem (SIX 14) gene was highly expressed as it mainly helps in colonization of Foc by defeating its defense in susceptible cultivar, which helps in providing more insights in understanding the compatible and incompatible interactions between chickpea and Foc

MCC P20.Eucalypt oil based bio-herbicide for sustainable management of noxious weed *Parthenium hysterophorous* L.

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Weeds are expected to show greater resilience and better adaptation to changes in climate. It could also influence the efficacy of herbicides, making weed management a major challenge for sustainable crop production. *Parthenium*, the noxious weed has ability to invade a wide range of environments due to its vigorous growth habit, high seed production, effective dispersal mechanisms and better adaptation to changing climatic condition. Allelopathy provides an alternative for relatively cheaper and environmental friendly weed control. Eucalyptus is an allelopathic tree that exerts its toxicity through leachates and essential oil. An experiment was conducted to test the herbicidal potential of essential oils of *Eucalyptus citriodora* on *Parthenium hysterophorous*. In the laboratory experiment, essential oils of eucalyptus in various concentrations (0.25, 0.50, 1.0, 2.0 and 5.0 ppm) were used. In field experiment, the effects *E. citriodora* at 1.0, 2.0, 5.0, 7.5, and 10.0 % concentration were used to determine the allelophatic potentials on plant height,

visual injury and mortality percentage of *P. hysterophorous*. In both the experiments, among the three eucalyptus species, maximum inhibitory effect was caused by essential oil of *E. citriodora*. Results showed that essential oil of eucalyptus species significantly inhibited germination and seedlings growth and the effect was concentration specific; as the concentration of oil increased, the allelopathic effects were more pronounced. In green-house experiment, application of essential oil at 7.5 and 10.0% concentration had significant bio-herbicidal action against tested weed. The results demonstrated that *E. citriodora* can be used as post emergence bio-herbicides against *P. hysterophorous*

MCC P21. Characterization of elicitor – the fungal chitosan to inducing the defence and promoting the growth in *Oryza sativa*: A sustainable agronomical approach

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Global climatic changes and expansion of urban population have increasing concern of food insecurities. Different eco-friendly crop improvement strategies were focused to tackle the issues in plant development and yield. The present research involves in examining the growth improving properties and induction of natural defense system of plants by chitosan isolated from fungus. The chitosan was characterized by SEM and FT-IR. Rice seeds primed with fungal chitosan stimulated their germination potentials, reducing their germination time and increasing the germination energy. In addition, the primed seeds induced the seedling and plant height, producing higher number of lateral roots compared with control. The plants emerged out of primed seeds also induced the immune modulatory effect in terms of increased production of phenolic compounds, peroxidases and polyphenol oxidase enzymes. Hence the potential of chitosan as a biostimulant as well as a bioelicitor is proved. Consequently, the application of chitosan will reduce the application of chemical pesticides, which will minimise the health hazards and pollution posed by chemicals.

MCC P22. Effect of weather parameters on the seasonal dynamics of maize stem borer, *Chilo partellus* (Swinhoe) (Crambidae: Lepidoptera) in maize in Indo-Bangladesh border

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ICAR Research Complex for NEH Region, Mizoram Centre was conducted an experiment to study the seasonal dynamics of maize stem borer *Chilo partellus* (Swinhoe) in maize and its relationship with different weather parameters during rainy season in three consecutive year 2016-18 at Indo-Bangladesh border. 9 local maize local land races (MZM 4, MZM 6, MZM 3, MZM 7, MZM 8, MZM 11, MZM 17, MZM 19 and MZM 20) and 1 developed variety (RCM 76) were selected for this experiment with three randomized block design (RBD) and weather data was collected from the observatory of ICAR Research Complex for NEH Region, Mizoram Centre. The maize was shown last week of April. Maximum damaged was observed in MZM 11

(68.8%) followed by MZM 8 (54.6%) and MZM 3 (48.4%). Least infestation was observed in RCM 76 (22.1%) followed by MZM 6 (34.2%) and MZM 7 (36.4%). Damaged caused by maize stem borer *Chilo partellus* (Swinhoe) were observed throughout the crop season, where in maximum damaged plants were observed (25^{th} and 27^{th} Standard Meteorological Week (SMW) (i.e., 3^{rd} and 4^{th} week of June) with 64.40% and 69.80% maximum vegetative stage to tasseling stage of the crop. The correlation analysis indicated that population/ damaged of maize stem borer of *Chilo partellus* (Swinhoe) showed significant positive correlation with weather parameters viz., minimum temperature, morning and evening relative humidity while maximum temperature and rainfall showed negative significance with maize stem borer/ damaged plant. The stepwise regression analysis revealed that minimum temperature, morning and evening relative humidity could explain variations in maize stem borer *Chilo partellus* (Swinhoe) in three years. Among all the variables minimum temperature, morning and evening relative humidity was found to contribute significantly and showed 51.2 per cent effect on the population/damaged of maize stem borer *Chilo partellus* (Swinhoe) in first year, while 56.4 per cent variation and 43.5 percent variation found in second and third year of experiment. The model was validated partially satisfactorily and found significant variation between observed and predicted values ($p > 0.05$) from 2016-18. The overall results suggested that the models can be used for predicting the population and maximum plant damaged of maize stem borer *Chilo partellus* (Swinhoe) in maize for optimizing management strategies

Poster session III: Integrated pest management (IPM 2)

IPM2 P1. Trichoderma: an effective biocontrol agent and growth promoter for sugarcane ecosystem

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Trichoderma spp. are ubiquitous fungi with multifaceted potential including the ability to act as antagonists of plant pathogens and as plant growth promoters. Keeping this in view, investigations were carried out to identify *Trichoderma* strains with potential for disease management and growth promotion in sugarcane. A total of 186 *Trichoderma* isolates were established from rhizosphere soils (126) and from root (40), leaf (7) and stalk (13) tissue of sugarcane. Isolates were characterized for production of chitinase and cellulase enzymes, antagonistic activity against the red rot pathogen *Colletotrichum falcatum* and also for their plant growth promoting potential. Based on the studies, four most promising isolates, established from sugarcane rhizosphere, viz. STr-64 (*T. harzianum*), STr-83 (*T. longibrachiatum*), STr-108 (*T. longibrachiatum*) and STr-126 (*T. harzianum*) were identified. All the four isolates were effective producers of chitinase enzyme, while isolates STr-83, 108 and 126 showed high cellulase production with enzymatic index in range of 1.19 (STr-126) to 1.91 (STr-108). Against red rot of sugarcane, isolates STr-83 and STr-108 were found most promising exhibiting >70% inhibition in hyphal growth of *C. falcatum* in laboratory studies and 37-52% red rot reduction in field studies. In growth promotion studies, isolates STr-64, STr-83 and STr-126 showed effective nutrient solubilization. Considerably higher germination (46.6 to 51.7%) and higher yields (73.2 to 77.7 t ha^{-1}) were also recorded in these three treatments as compared to control (32.9% germination, 54.9 t ha^{-1} yield). Our studies showed *Trichoderma* as an effective antagonist, with potential for growth promotion, under the sugarcane ecosystem.

IPM2 P2. Bio-pesticide interventions for sustainable nematode management in India

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In India on an average, a national loss of Rs 21,068.73 million has been estimated due to plant parasitic nematodes. Rapid spread of nematode infestation through soil, crop residues and indiscriminate use of agro chemicals in horticultural ecosystems is a major concern for crop protection specialists. Management practices adopted by farmers include continual use of chemical nematicides, often at higher than recommended rates resulting in the build-up of resistance. In addition, bio-magnification and environment deterioration due to hazardous chemicals have rendered several cultivated ecosystems unstable and non-profitable. ICAR - Indian Institute of Horticultural Research (IIHR), Bengaluru, India has developed and successfully commercialized biopesticide formulations for managing nematodes. Biopesticides can be applied as seed treatment and substrate treatment which ensures production of disease free seedlings at the early stage. In main fields, soil application after enrichment of FYM/ vermicompost /neem cake with *Pseudomonas fluorescens, Paecilomyces lilacinus* and *Trichoderma viride/ harzianum* at the time of bed preparation and repeated application in standing crop through drip/ soil drenching has drastically reduced damage due to root knot nematodes and associated disease complexes. Following these interventions regularly, farmers are able to reduce the use of chemical pesticides to the tune to 40 – 50% with increased yields from 20 – 30% and cost

benefit ratio of 1: 2.5 to 1:3.4. ICAR-IIHR, Bengaluru has transferred these biopesticides technologies so far to 600 industry licensees all over India for commercial production of biopesticides.

IPM2 P3. Bio-efficacy of new pesticides against rots and sucking pests in groundnut (*Arachis hypogaea* L.)

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Groundnut (*Arachis hypogaea* L.) is an important oilseed crop grown in tropical and subtropical regions of the world, with India and China accounting for over 40 and 18 per cent of world production respectively. High incidence of pests and diseases is one of the major constraints affecting the productivity and quality of groundnut in India. Hence, the study was conducted to test the effect of different chemicals as seed treatment in managing sucking pests and stem rot and collar rot diseases of groundnut. The field experiment was conducted at Regional Agricultural Research Station, Palem, Nagarkurnool, Telangana State to evaluate the efficacy of five pesticides as seed treatment viz., Pyraclostrobin 3.5%+ Clothianidin 22.5% FS (P+C), Thiram 15%+Clothianidin 22.5% FS (T+C), Pyraclostrobin 3.5%+Thiram 15% FS (P+T), Pyraclostrobin 3.5% FS (P), Thiram 75% WS (T) and Clothianidin 50% WDG (C) as soil drench during Rabi of 2016 and 2017. IPesticide P+C was most effective in managing collar rot and stem rot recording disease incidence of 4.74 and 6.72 % respectively compared to 28.01 and 24.47 % in untreated control. This was followed by P+T (5.07 and 6.38 %) and T+C (5.99 and 7.23 %). Lowest incidence of aphids (6.72/5 cm shoot) and leaf hoppers (5.08/three leaves) were recorded with P+C followed by P+T (5.17 and 6.38 %) and T+C (5.32 and 7.23 %). It is concluded that seed treatment with Pyraclostrobin 3.5%+Clothianidin 22.5% FS can be considered as a chemical component in integrated pest and disease management in groundnut

IPM2 P4.Estimated generation number of *Maruca vitrata* in a temperate region, Korea

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Larvae of the legume pod borer, *Maruca vitrata* (Lepidoptera: Crambidae) cause a serious damage to the reproductive organs of *Vigna* species crops (red bean, mungbean, cowpea, etc.). Although the distribution area of this insect species covers mainly tropical and subtropical regions in the world, it has been found in a temperate region, Korea every year, too. However, its ecological information such as overwintering biology, host plant range and generation number have not been acquired for Korea, though those ones are important for designing an integrated pest management strategy. Based on results of non-production of overwintered insects in outdoor artificial rearing, weak cold-tolerance, and not much genetic correlation among neighboring local populations, it was postulated that this insect cannot overwinter in Korean temperate areas, but invades from other warm countries. Flying adults were caught from June to October, using virgin female adult traps and light traps. A temperature-dependent phenology model including developmental rate, physiological age distribution, survival rate and fecundity models was constructed, and the model was validated with the actual adult catch season data for estimating the generation number of insect. Conclusively, on the assumption that this insect invades during June, it was estimated that the first adult population can produce the next three or four generation within a year. In addition, it was estimated that the crop damage

during August and September in red bean fields of Korea is caused by larvae of the second, third or fourth generation.

IPM2 P5. Evaluation of fungicides for their efficacy against seed-borne fungi of groundnut (*Arachis hypogaea*)

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Salvaging of infected seed material by using fungicides facilitates the safe exchange of germplasm. Groundnut seed is known to be infected by a large number of seed-borne fungal pathogens that necessitates the identification of effective fungicides for the seed treatment. Therefore, an effort was made to evaluate the efficacy of different fungicides against seed-borne fungi of groundnut by employing the standard blotter technique. Seventeen fungicides, carbendazim 50% WP, mancozeb 75% WP, carbendazim 12% + mancozeb 63% WP (Saaf), thiram 75% WP, tebuconazole 50% + trifloxystrobin 25% WG (Nativo), carbendazim + thiram (1:1), captan 50% WP, captan 70% + hexaconazole 5% WP (Taqat), tricyclazole 75% WP, tebuconazole 2% DS, metalaxyl 35% WS, metalaxyl 4% + mancozeb 64% WP (Ridomil Gold), triadimefon 25% WP, myclobutanil 10% WP, dimethomorph 50% WP, chlorothalonil 75% WP and thiophanate methyl 70% WP were tested as seed treatment; untreated seeds served as a control. In general, the fungicide seed treatment improved the seed germination and reduced fungal infection. Seven fungi, *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus* sp. *Penicillium notatum*, *Rhizopus* sp., *Fusarium* sp., and *Rhizoctonia bataticola* were observed in the infected seeds. Maximum reduction (96%) in the infection by seed-borne fungi was recorded with Saaf @ 3 g/kg seed. Whereas, carbendazim + thiram (1:1) @ 3 g/kg seed, which is recommended and used for salvaging the infected groundnut seeds, recorded 94 per cent reduction over control. The results of this study clearly indicate that Saaf is quite effective for the treatment of infected groundnut seed.

IPM2 P6. Biology of anthocorid predator, *Blaptostethus pallescens* Poppius (Heteroptera: Anthocoridae)

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Biology of anthocorid predator *Blaptostethus pallescens Poppius* was studied on eggs of alternate host *Corcyra cephalonica* (Stainton). Eggs of *B. pallescens* inserted within the plant tissue hatched after a mean incubation period of 5.78 days. Newly hatched nymphs when fed on UV sterilized eggs of *C. cephalonica* developed normally with five nymphal instars. Duration of each nymphal instar from first to fifth were 2.63, 1.92, 2.01, 2.50 and 5.10 days respectively. After mating, females laid eggs after a pre-oviposition period of 4.2 days. Average fecundity of bugs was 146.46. Mean longevity of females was found to be higher (52.03 days) than that of males (40.18 days).

IPM2 P7. Life-cycle duration of South African *Meloidogyne* species: a key factor in IPM approaches to manage such pests

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Information is lacking about the life cycle of *Meloidogyne enterolobii*, an emerging threat species that overcomes genetic resistance that is effective against its counterpart thermophilic species *M. arenaria*, *M. incognita* and *M. javanica*. A glasshouse study (min. temp 21.6 °C, max temp 26.1 °C; 14L:10D photoperiod) was conducted and 1 200 second-stage juveniles (J2) of the three species inoculated on susceptible tomato seedling roots. The life-stage development 3, 5, 10, 15, 20 and 25 days after inoculation differed significantly among the species for most sampling intervals. At 3 DAI, motile J2 numbers did not differ significantly for the three species, with swollen J2 only recorded for *M. enterolobii*. Swollen J2, J3 and J4 numbers were significantly higher for *M. enterolobii* (compared to other two species) 5 DAI. Ten DAI, J3 and J4 were recorded for all species. Females of all species were present 15 DAI; significantly higher in numbers for *M. enterolobii* and *M. javanica* compared to *M. incognita*. Individual eggs were present for *M. enterolobii* and *M. javanica*, but egg-masses only at 25 DAI. Female numbers 15, 20 and 25 DAI differed significantly among the species; *M. enterolobii* having the highest. Twenty DAI a second generation was evident for *M. enterolobii*. Degree-days (DD) were 293 for *M. enterolobii* and *M. incognita* and 233 for *M. javanica*. The quicker life cycle of *M. enterolobii* is an important factor for developing IPM strategies.

IPM2 P8. Bioefficacy of native strains of *Trichoderma harzianum, T. asperellum* and *T. erinaceum* against post flowering stalk rot in maize caused by *Fusarium verticillioides*

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Post flowering stalk rot (PFSR) caused by complex of *Fusarium* spp. of which *Fusarium verticillioides* is the major species affecting productivity not only in India but also in other parts of the world. We isolated 59 isolates from PFSR affected winter maize growing areas of southern Rajasthan and eastern Gujarat states and through molecular sequencing using Tef1-α primer, it was found that major Fusarium species involved in causing PFSR was *F. verticillioides*. Of the 74 isolates collected from southern Rajasthan. To assess in vitro efficacy of *Trichoderma* isolates, Pakdaman's biological control indices (PBCIs) were studied and only three representative species *Trichoderma harzianum* referred to as BThr29, *T. asperellum* referred as BTas25 and *T. erinaceum* referred as BTer43 were used as seed treatment and soil application for the field trials based on their superior ability to produce inhibition zone against *F. verticillioides* in dual culture assay. In the field experiment, prior inoculation of *F. verticillioides* fungus was done and the effect of various treatments was observed. It was observed that soil application, seed treatment and furrow application with *T. harzianum* BThr29 @10g/lit water showed minimum % PDI of 13.3%, lodging 15.0% and disease reduction by 72.2% as compared to 10% PDI, 3.3% lodging and 79.1% reduction of disease on application of seed treatment and two sprays and furrow application with Carbendazim 12% + Mancozeb 63% @ 2g/lit water. As compared with *T. asperellum* and *T. erinaceum*, application with *T. harzianum* effectively reduced severity of PFSR at par with fungicidal application.

IPM2 P9. Bioremediation of hexachlorocyclohexanes (HCHs)-contaminated soil using charcoal enriched with a constructed bacterial consortium

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The technical hexachlorocyclohexane (t-HCH), a popular and broad-spectrum organochlorine insecticide prior to the 1990s, mainly consists of the α-, β-, γ- and δ- isomers. The use of t-HCH has now been banned in many countries because of its toxicity and long persistence in environment, but numerous contaminated sites are still present throughout the world. In this study, we demonstrated effectiveness of charcoal enriched with a constructed bacterial consortium in HCHs-contaminated soil. At first, we enriched HCHs-degrading bacteria, *Sphingomonas* sp. TSK-1, together with hexachlorobenzene (HCB)-degrading one, *Nocardioides* sp. PD653, in a special charcoal, CC150 (BET surface area 150 m²/g, pH 7.8) by immersing the charcoal in the mixed two cultures overnight. TSK-1 could completely dechlorinate α-, γ- and δ-HCH. For β-HCH, however, only two chloride ions per molecule were released. On the other hand, PD653 could completely dechlorinate only β-HCH among 4 isomers. To evaluate the enriched charcoal, 3g (MC:50%) of the material was mixed with 43g of wet soil (MC:30%), which was contaminated with 36.3 mg/kg of α-HCH, 13.6 mg/kg of β-HCH, 10.8 mg/kg of γ-HCH and 10.9 mg/kg of δ-HCH, and was incubated at 25°C under dark conditions with water supply (1-2 ml/week) for 2 weeks. The degradation rates were 67.1, 18.5, 76.1, 34.6 % for α-, β-, γ- and δ-isomers, respectively, and totally 55% of HCHs were degraded in comparison with the control plot (non-enriched charcoal). This is the first report to clean up HCHs-contaminated soil by the charcoal enriched with a constructed bacterial consortium

IPM2 P10. Control of stem rot of rice in different rice rotations

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The production of rice in Uruguay changed in the last years from lax rotations with pastures to more intensive systems with more rice or the incorporation of other crops in the rotation. Rice intensification can affect the dynamic of pathogens present causing changes in the development of diseases. Stem rot is an important disease of rice in intensified systems as this pathogen (*Nakataea oryzae*) produce sclerotia. These sclerotia survive for years in rice soils. Since 2012, a long-term experiment was installed to study different rice rotations in productive and environmental terms. Major interest is on the development and management of rice diseases. For two years, an experiment was carried out to study possible practices of chemical control in rotations with different percentage of rice in the cycle. Treatments consisted in a fungicide spray, fungicide combined with a copper phosphite and an unsprayed tester. The treatments were installed in an experiment with a history of rice-pasture rotation with the crop sequences: 1) continuous rice (7 years of rice), 2) short paddy-rice (second year of rice), and 3) short-paddy-soybean-rice-pasture (first year of rice after soybean and pasture). Incidence and severity of stem rot was evaluated before harvest. The results indicate that significant differences were found in incidence and severity according to year and rotation. Incidence and severity were higher in continuous rice, and then in second year rice. Chemical control reduced severity of stem rot in continuous rice independently of the year but was variable in the less intensified systems

IPM2 P11. Abundance and bio-diversity of spiders in sprayed and unsprayed *rabi* tomato

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Tomato, *Lycopersicon esculentum* is one of the widely grown vegetables in the world. Insect pests are the major biotic constraints in vegetable production in India and conservation of natural enemies plays an important role in pest management. A diverse group of spiders may be effective in biological control because they differ in hunting strategies, habitat preference and activity periods. Hence, the study focused on the abundance and biodiversity of spiders in Rabi tomato in the sprayed and unsprayed conditions. The experiment was laid out in a plot of 500 sq.m in Agricultural Research Institute (ARI), Rajendranagar during Rabi 2018-29. The plot was divided into two blocks viz., Block-B1 and Block-B2 where Block-B1 was considered as the sprayed block and Block-B2 was the unsprayed block. One spray of Dimethoate 30 EC at the rate of 2ml/L water was carried out in 49th standard meteorological week in Block-B1. A total of 815 spiders consisting of 16 genera and 18 species belonging to 10 families viz., *Araneidae, Lycosidae, Oxyopidae, Tetragnathidae, Salticidae, Thomisidae, Clubionidae, Linyphiidae, Pholcidae* and *Theridiidae* were recorded on the course of the study. various diversity indices viz., Margelef's Diversity index, Pielou's Evenness index, Shannon-Wiener Diversity index, Reciprocal Simpson index and Simpson index of Diversity for the sprayed and unsprayed blocks were found to be on par and were 1.6 and 1.4; 0.67 and 0.75; 1.5 and 1.7; 3.1 and 4.2; 0.32 and 0.24 respectively

IPM2 P12. Field efficacy of the new combination insecticide, spinetoram + methoxyfenozide 36% SC against pests of rice

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Rice is a staple crop of Asia and parts of the pacific region, and nearly 90% of rice produced and consumed is in the Asia-Pacific region. Insect pests alone can cause about 10-15% yield loss. A new combination insecticide, spinetoram + methoxyfenozide 36% SC which contains spinetoram a mixture of two synthetically modified spinosyns J and L)), and methoxyfenozide a moulting accelerating compound, was tested against the major insect pests of rice during the period 2016-2017 at Regional Agricultural Research Station, Pattambi. Two field experiments were conducted in two cropping seasons viz., Kharif 2016 and Rabi' 2016-17 using the rice variety Jyothi. The new insecticide molecule was tested at rates of 75ml/ha and 400ml/ha, in comparison with DPX-RAB55 SC @ 23.75g/ha, flubendiamide 480 SC @ 50ml/ha ,chlorantraniliprole 18.5 SC @150ml/ha acephate 95 %SG @ 526g/ha and dinotefuran 20%SG @ 200g/ha and an untreated control. The plots were laid out in completely randomized block design. The pooled results of both crop seasons trials revealed that the new combination insecticide, spinetoram + methoxyfenozide 36%SC @ 400ml/ha was found effective against gall midge, rice yellow stem borer damage (dead heart and white ear) and leaf folder and was on par with reference insecticides, flubendiamide 480 SC @ 50ml/ha and chlorantraniliprole 18.5 SC @150ml/ha. The grain yield per plot was also higher in the spinetoram + methoxyfenozide 36%SC @ 400ml/ha treatment (5979 kg/ha), followed by the chlorantraniliprole 18.5 SC @150ml/ha (4990 kg/ha) and flubendiamide 480SC @ 50ml/ha (4951 kg/ha) treated plots.

IPM2 P13. Soil properties influencing phytoparasitic nematode population on tomato in Limpopo Province, South Africa

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Tomato is one of the most important crops in Limpopo Province, South Africa. During a survey on plant-parasitic nematodes in tomato fields, 100 samples belonging to different fields belong to ZZ2 company were collected and analyzed for nematode distribution and soil factor affecting nematode diversity. To identify the factors that were associated with the nematode diversity, soil pH, organic matter content and a number of soil chemical elements and nematode community data were subjected to corresponding cannonical analysis (CCA). The numbers of each of the nematode species (*Criconema* sp., *Meloidogyne* sp., *Pratylenchus* sp., *Helicotylenchus* sp., *Xiphinema* sp. and *Tylenchorhnychus* sp.) were counted using an olympus stereomicroscope. The highest population density was detected for *Helicotylenchus* with 290 individual per 500 g of soil. An accumulated variability of 80.79% was detected in the soil factor by the F1 (54.05%) and F2 (26.75%). The result indicated that ammonium (NH4+) affect the *Tylenchorhynchus*, *Pratylenchus* and *Helicotylenchus*, whereas has no effect on *Meloidogyne*. In addition, pH showed no effect on *Meloidogyne* population. However, potassium (mg/kg) with the value of 0.171 showed a positive correlation with *Meloidogyne. Criconema, Pratylenchus, Helicotylenchus, Rotylenchus* and *Tylenchorhynchus* seems to be correlated with Fe (mg/kg), Mn (mg/kg) and Zn (mg/kg). The result indicated that *Xiphinema* is correlated with Boron (mg/kg) in the tomato soil samples. In conclusion, the tomato fields of ZZ2 suggested a normal range of plant-parasitic nematode, which a survey on the management of the harmful nematode such as *Meloidogyne* is needed

IPM2 P14. Shelf-life in cucurbitacin-containing phytonematicides: non-conformity to Arrhenius model

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Exhibition of shelf-life on products provides end-users with assurance that the product is still in compliance with label claims. Behavioural reaction orders of Arrhenius model had been consistently used to provide empirically-based shelf-life losses in food products. Due to non-conformity of cucurbitacin-containing phytonematicides to Arrhenius model reaction orders, we developed an alternative quadratic model that was consistent with behavioural reaction orders of cucurbitacins under fixed tropical and chilled conditions. Sampling for cucurbitacins was done at geometric series time-frame, with cucurbitacin analysis performed using high-performance liquid chromatography techniques. Under chilled conditions, the quadratic model could not predict shelf-life for Nemarioc-AL phytonematicide, whereas that for Nemafric-BL phytonematicide was 485 days. In contrast, under tropical conditions Nemarioc-AL and Nemafric-BL phytonematicides could be stored up to 543 and 2300 days, respectively. In conclusion, the two phytonematicides should, under tropical conditions, be stored at room temperature to enhance the shelf-life of the active ingredients.

IPM2 P15. Impact of spiders and predatory coccinellids on major pests in rice crop

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An experiment was conducted in a 1500 sq.m. plot in the College farm, Rajendranagar in the Kharif seasons of 2014-15 and 2015-16 to understand the impact of spiders and predatory Coccinellids on major pests in rice crop. Observations on number of pests, numbers and types of spiders and predatory Coccinellids were recorded every week from 30 days after transplantation to 120 DAT from five quadrats (four in the corners of the field and one in the center). Yellow Stem borer, leaf folder and Hispa were the major pests observed. 22 spider genera and 30 species belonging to 12 families and 6 genera of Coccinellids were recorded in the study. Pooled means on the abundance of the pests and predators were subjected to Correlation analysis to know the impact of the predators on the pests. Most of the spider genera were found to be significantly and positively correlated with the stem borer (r=0.52 to 0.68), though *Atypena* and *Pholcus* sp. had negligible positive impact. Most of the spider genera (except *Atypena*, *Pholcus* sp., *Telamonia* and *Tetragnatha*) had a negligible impact on the leaffolder and Hispa beetle. While *Atypena* had a significant negative impact on leaf folder and Hispa (r= -65 and -0.58 respectively) indicating its preference to feed on them, the other genera viz., *Pholcus* (r= 0.61 and 0.66 respectively); *Telamonia* (r=0.93 and 0.84 respectively) and *Tetragnatha* (r=0.77 and 0.83 respectively) had a positive impact.

IPM2 P16. Management of new invasive pest, *Spodoptera frugiperda* (J.E. Smith) using green chemistry insecticides based poison baits

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The fall armyworm (FAW), *Spodoptera frugiperda* is one of the very serious insect pests on variety of crops around the world. Recently, in August 2018 this dreaded pest was reported for the first time in India. Management of this pests predominantly involves spraying of insecticides several times, which works out very expensive. Here, efforts were made to standardize poison bait application using greener insecticides as an alternative to sprays to reduce the cost and to make it safe for consumption. Initially, efficacy of molecules was assessed through bait feeding studies in the laboratory. Subsequently, effective molecules were applied in the FAW infested maize field as both sprays and poison baits (applied in whorls of infested plants). Among the green chemistry molecules, spinetoram 11.7 SC, chlorantraniliprole 18.5 SC and novaluron 10 EC recorded highest larval mortality (93.53 to 96.76 % reduction over untreated control). Field studies suggested that bait application was as effective as foliar sprays involving same insecticide. Hitherto, only thiodicarb insecticide was recommended in baits for managing FAW and it is a highly toxic chemical. In this study we found that greener molecules with a waiting period of < 3-5 days were very effective as baits and cost of plant protection was substantially low when used as baits (upto 42 % cost reduction). This finding provides an opportunity for the growers to not only to cut down the cost of protection, but also to make the food safe for consumption, particularly as fodder maize fed to the animals.

IPM2 P17. Researches concerning seed treatment effectiveness for controlling of the maize leaf weevil (*Tanymecus dilaticollis* Gyll) at sunflower crops in south east of the Romania

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Romania has more than 1.0 million hectares as sunflower cultivation which represents the highest area within the Europe Union. Higher areas with this crop are located in south and south-east of the country. *Tanymecus dilaticollis* (Coleoptera: Curculionidae) is the main pest of both, maize and sunflower crops, mainly at south and south-east part of the country. The insect is harmful when plants are in the early vegetation stages (BBCH 10-14). Each year, around half million hectares cultivated with sunflower is attacked by this pest with different level of attack intensities. In case of high *T. dilaticollis* invasion, the sunflower seedlings could not survive and the farmers have to sowing again their fields. Drought and higher temperatures are favorable conditions for weevils attack. This paper presents some results about the effectiveness of the seed treatments with imidaclopird, clothianidin and thiametoxam active ingredients, both in field and laboratory conditions for T. *dilaticollis* control. The experiments was carried out in south-east of Romania, at NARDI Fundulea in 2018 and 2019. Attack intensity of *T. dilaticollis* weevils at sunflowers plants was rated on a scale from 1 (plants not attacked) to 9 (plants destroyed). In field conditions, in case of moderate pest pressure, attack intensity at untreated plants was 3.09 in 2018 and 5.09 in 2019. In laboratory conditions, in case of high pest pressure (4 weevils/plant) untreated plants were destroyed. Seed treatment provide effective protection of the sunflower plants, in first vegetation stages, against *T. dilaticollis* weevils, both in field and laboratory conditions.

IPM2 P18. Report of novel entomopathogenic fungi (*Alternaria alternata*) infecting greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) in North western Himalayan region

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Whiteflies (Hemiptera: Aleyrodidae) are important sap sucking insect pests of agricultural and horticultural crops that can cause heavy crop damages by direct feeding and/or by transmission of plant pathogenic viruses. Although, several management strategies are available to suppress whiteflies; efficacy, adoption and cost of operations are not satisfactory in comparison with chemical control. Moreover, whiteflies are known for their ability to develop resistance to insecticides and resurgence against many synthetic pyrethroids and neonicotinoids. This alarming situation embarks up on use of biocontrol agents for the management of whiteflies which are safe to environment and are not easily vulnerable for development of resistance by the pest. There are several entomopathogenic fungi like, *Paecilomyces fumosoroseus, Lecanicillium lecani* and *Beauveria bassiana* recommended for management of whiteflies. Recently *Alternaria alternata*, a novel entomopathogenic fungus was isolated from dead mummies of whiteflies (*T. vaporariorum*) infecting Salvia (*Salvia divinorum*) plants in open field conditions at ICAR-VPKAS, experimental farm, Hawalbagh (29.630N and 79.630E, 1250 amsl). The fungus has shown interesting bioefficacy against whiteflies with LC50 2.01X105 spores/ml for adults and 4.33X105 spores/ml for nymphs 48 h and 72 h after treatment respectively, under laboratory conditions. Further field studies are under progress to utilize *A. alternata* as an efficient biocontrol agent against whiteflies in green house and open field conditions.

IPM2 P19. The relevance of bio-intensive management of *Holotrichia serrata* through a multipronged approach

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Among the various species of white grub complex, *Holotrichia serrata* (*Fabricius*) is predominant in south India, more so, in Tamil Nadu. To arrive at effective bioagent based combinations of control agents, three entomopathogenic fungi (*Beauveria brongniartii*, *Beauveria bassiana* and *Metarhizium anisopliae*), two entomopathogenic nematodes (*Heterorhabditis indica* and *Steinernema glaseri*) and six insecticides (chlorantraniliprole, chlorpyriphos, fipronil, carbofuran, imidacloprid and phorate) with a control have been imposed at field recommended dose in pot culture. First instar grubs of *H. serrata* were inoculated 5/pot with three replications and recovered for observations on mortality after a month through upturning the pots. Effect of residual effect was observed by re-inoculation of grubs and recovered one month later. Mortality in treatments involving B. *bassiana* alone or with any of the insecticides resulted in 100% mortality of the whitegrub while the combinations with *B. brongniartii* (93.3%) or *M. anisopliae* (80%) or *H. indica* (93.3%) or *S. glaseri* (66.67%) resulted in varied levels of mortality. The residual mortality was observed at higher level of 77-100% barring some exceptions. *M. anisopliae* caused 80- 100% mortality in several combinations with the least being 80% in the combination with carbofuran. The EPN *H. indica* and *S. glaseri* performed best with 100% mortality when combined with chlorantraniliprole, fipronil and imidacloprid. In general combination treatments brought about better control with exemptions of EPF combinations with nematodes. Studies on persistence revealed better recovery of agent and residual efficacy against the pest. The findings aid in designing specific combinations for better management of white grub.

IPM2 P20.A Push-Pull system based on olfactory and visual cues to integrated control *Bactrocera minax* (Diptera, Tephritidae)

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The Chinese citrus fly, *Bactrocera minax* (Enderlein), is an important destructive pest of citrus fruit in China, Bhutan, and Northwest India for more than half a century. This insect pest is univoltine and its host range is restricted to the wild and cultivated citrus. Larvae feed citrus fruit pulp and grow inside the fruits. The infested citrus fruit turn yellow and drop before ripening. For controlling *B. minax* effectively, we established a Push-Pull system and conducted series experiments from 2012 to 2018. The infested fruits were deeply buried in every autumn. The food attractant was developed and lured (pull) the adults of *B. minax* in orchards. And then the repellent which mixed with mineral oil and extract from Xanthium (Compositae) (push) were study. Furthermore, the color sticky ball traps were used to increase the pulling effect. The results showed that the control effect of using food attractant alone is not ideal, the infected fruit rate of citrus fruit only from 98.12 % to 81.94 %. However, the bait food attractant outside the orchard combined with spraying the repellent inside the orchard can obviously reduce the damage of *B. minax*, and the infested fruit rate was down to 7.33 %. Further combination of the green sticky ball traps (lure), the infested fruit rate of the citrus was down below 1.2 % in the orchards. The results suggested that this push-pull system based on olfactory and visual cues is a highly effective strategy to control *B. minax*.

IPM2 P21. *Macrophomina phaseolina* (Tassi) Goid. the cause of seedling blight and charcoal rot of sorghum and its management in India

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Seedling blight in sorghum [*Sorghum bicolor* (L.) *Moench*] is a serious problem in post-rainy (Rabi) crop in semi-arid regions of India. Incidence up to 40% were recorded under higher temperatures (>32.0^{o}C) and soil moisture stress conditions, particularly, in shallow soils. *Macrophomina phaseolina* was observed to be the main cause of the disease based on symtomatology, microscopic observations and cultural studies. Besides, a few isolations also revealed association of *Fusarium* spp. Since this pathogen also causes charcoal rot, investigations were taken up during 2015 – 2018 to ascertain whether seedling blight isolate could cause charcoal rot. The pathogenicity tests conducted under both pot culture and field conditions revealed that *M. phaseolina* isolated from seedling blight sample was able to cause seedling blight (mortality) and charcoal rot in grown up plants particularly under soil moisture stress conditions. Investigation, explicitly prove that *M. phaseolina*, the cause of charcoal rot, is also the main cause of seedling blight in sorghum. The soil-borne pathogen initially infects the roots of the seedlings and then probably remains in latent form in root and green stems and becomes active when the host is under physiological moisture stress conditions facilitating development of charcoal rot. Seed treatment with *Trichoderma viride* based formulation (8g/Kg seed) and soil drenching with fungicide carbendazim 12% + mancozeb 63% (0.2%) prior to sowing resulted in 78.3% and 86.7% control of seedling blight respectively. The same treatments also exhibited 37.4% and 40.6% control of charcoal rot respectively at harvest

IPM2 P22. Effect of different pesticide seed dressing on diseases and pests of spring rape and its yield

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In order to clarify the effect of different seed dressing on seedling emergence rate and yield of spring rape and control efficacy against *Erysipe cruciferarum*, *Sclerotinia sclerotiorum*, *Ceutorrhynchus asper* and *Ceutorhynchus napi* of spring rape, the seed dressing experiments with fludioxonil 25 g/L FSC, imidacloprid 600 g/L SC, thiamethoxam 30% SC, imidacloprid 600 g/L SC+ fludioxonil 25 g/L FSC and thiamethoxam 30% SC+ fludioxonil 25 g/L FSC were carried out under three different planting densities. The results showed that different seed dressing treatments had certain effects on the emergence of spring rape, among which the effects of imidacloprid 600 g/L SC, thiamethoxam 30% SC, imidacloprid 600 g/L SC+ fludioxonil 25g/L FSC and thiamethoxam 30% SC+fludioxonil 25 g/L SC were greater than that of fludioxonil 25 g/L FSC. The control effects of imidacloprid 600 g/L SC+ fludioxonil 25g/L FSC and thiamethoxam 30% SC+fludioxonil 25 g/L FSC on *E. cruciferarum*, *S. sclerotiorum*, *C. asper* and *C. napi* were higher than that of single agent. Imidacloprid 600 g/L SC+ fludioxonil 25 g/L FSC had the highest control effect on *E. cruciferarum*, *S. sclerotiorum* and *C. asper*, respectively, reaching 59.25%, 72.98% and 66.80%. Thiamethoxam 30% SC+ fludioxonil 25g/L FSC had the best effect on C. asper with the efficacy of 69.23%. The disease index of *E. cruciferarum* and *S. sclerotiorum* was positively correlated with the planting density of spring rape. The control effect of seed dressing decreased with the increase of planting density. According to the comprehensive yield analysis the optimal planting density was 285000-345000 plants/hm^2.

IPM2 P23. Sensitivity analysis of *Colletotrichum* spp. from wolfberry to triazole fungicide in Gansu Province

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Wolfberry (*Lycium barbarum*, Solanaceae) is an important Chinese traditional medicine that is widely planted in northwestern China. After a recent, large increase in the planting area and density, anthracnose has become more damaging. The objective of this work is to evaluate the sensitivity of *Colletotrichum* spp. isolated from wolfberry in Gansu Province to triazole fungicids. The Petri plate was adopted to test the sensitivities of 102 isolates of *Colletotrichum* spp. from wolfberry to 4 triazole fungicids including difenoconazole, tebuconazole, propiconazole and flusilazole. The results indicated that the overall sensitivities of 46 *C. gloeosporioides* species complex to difenoconazole, tebuconazole, propiconazole and flusilazole were high. However, the sensitivities of 56 tested *C. acutatum* species complex isolates to four triazole fungicids were different and some strains were suspected to have decreased sensitivity. The sensitivities of *C. gloeosporioides* species complex and *C. acutatum* species complex collected in different years to those 4 triazole fungicid showed significant difference and the collected strains in 2017 showed relatively lower sensitivities. The sensitivities of *Colletotrichum* spp. isolates collected from different areas to those 4 fungicides were different. The strains of *C. gloeosporioides* species complex collected from Wuhe Jingyuan county had the lowest sensitivity. The strains with the highest sensitivity to difenoconazole and propiconazole were collected from Caowotan Jingtai county. The strains with the highest sensitivity to tebuconazole and flusilazole were collected from Sitan Jingtai county. There was no significant difference among the sensitivities of *C. acutatum* species complex from different areas to those 4 triazole fungicids.

IPM2 P24. Evaluating alfalfa cutting as a potential measure to enhance the abundance of predators to *Aphis gossypii* (Homoptera: Aphididae) in cotton-alfalfa intercropping system

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The effects of alfalfa-cutting and non alfalfa-cutting on the population dynamics of *Aphis gossypii Glover* (Homoptera: Aphididae) and several species of arthropod predators were examined in cotton-alfalfa intercropping pattern in north-western China. The objectives of this study were to evaluate the alfalfa-cutting as a potential management technique to enhance abundance of arthropod predators of *A. gossypii*. The entire study area consisted of 50-cm alfalfa strips intercropped with four-row cotton strips. Alfalfa cut twice on June and July, when the population density of *A. gossypii* was gradually increasing in cotton, forced some groups of predator to migrate into adjacent cotton fields from alfalfa. Individual number, species richness, and diversity of predators were higher in alfalfa cut cotton field than in uncut. The population density of *Adonia variegata* (Goeze) (Coleoptera: Coccinellidae), *Pardosa astrigera* L. Koch (Araneae: Lycosidae), *Chrysopa sinica Tjeder* (Neuroptera: Chrysopidae) and *Orius minutus* (L.) (Hemiptera: Anthocoridae) increased 120%, 101%, 61% and 7% in alfalfa-cutting than non alfalfa-cutting respectively. Meanwhile, the population density of *A. gossypii* in non alfalfa-cutting was 2.8 times larger than in alfalfa-cutting. This indicates that alfalfa-cutting induces predator immigration into adjacent cotton fields and helps control cotton aphids. This study provides cotton growers a potential cultural management technique for *A. gossypii* while conserving predators.

IPM2 P25.Importance of nanotechnology in insect pest management

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Nanotechnology is a promising field of interdisciplinary research. It opens up a wide array of opportunities in various fields like insecticides, pharmaceuticals, electronics and agriculture. The potential uses and benefits of nanotechnology are enormous. These include management of insect pests through the formulations of nanomaterials-based insecticides. Therefore, nanotechnology would provide green and efficient alternatives for the management of insect pests in agriculture without harming the nature. This art is focused on traditional strategies used for the management of insect pests and potential of nanomaterials in insect pest control as modern approaches of nanotechnology. The advances in science and technology in the last decades were made in several areas of insecticide usage. It includes either development of more effective and non-persistent pesticides and new ways of application, which includes controlled release formulation (CRF). One of the most promising is the use of micro and nanotechnology to promote a more efficient assembly of the active compound in a matrix in order to protect core materials from adverse reactions due to factors like air or light. There is a great concern regarding the nonmaterial which have potential to exert hazardous effects on human and the environment and when we have a Nano-pesticide. Nanomaterials need to be evaluated.

IPM2 P26. Frond injection: an innovative method of pesticide administration for the management of *Opisina arenosella* and safer to the natural enemies in coconut palm

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An investigation on frond injection method of pesticide administration for the management of coconut black headed caterpillar, *Opisina arenosella* (Walker) in coconut palm was carried out at farmer field in Mandya, Karnataka, India during the year 2017-2018. The field trials using different insecticides viz., imidacloprid 17.8 % SL, acetamiprid 20 % SP, clothianidin 50 % WDG, thiacloprid 21.7 % SC, emamectin benzoate 5 % SG, spinosad 45 % SC and cartap hydrochloride 50 % SP against *O. arenosella* injected to coconut fronds. The results showed that cartap hydrochloride was recorded 100 per cent larval mortality compared to other insecticides. All other different insecticides were found significant in controlling *O. arenosella* larvae. Furthermore, different dosages of cartap hydrochloride 50 % SP evaluated against *O. arenosella* significantly reduced the infestation of larvae on coconut fronds. All insecticides significantly reduced the pupation, pupal weight and adult emergence of *O. arenosella*. The different dosages of cartap hydrochloride injected to frond found effective in achieving larval mortality of *O. arenosella* and also safer to the natural enemies. The insecticides absorbed completely into coconut palm within 24 hours after injection using frond injection method and showed less time of absorption. An innovative frond injection method of pesticide administration was found an easy, quicker, efficient and accurate method for the management of *O. arenosella* without any secondary infection and damage to the tissue of the coconut palm and also found safer to the non-targeted fauna of coconut palm.

IPM2 P27. Nano-pesticides- a recent approach for insect pest control

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Pesticides are being used in agriculture to manage pests for better yield and production. However, due to evaporation, rains, photodegradation, hydrolysis and other factors, often pesticides are lost before achieving goal. Pesticides used in large quantities to manage pests often leads to serious environmental pollution and human toxicity. In addition, lack of selectivity, its unrestrained use can also lead to the elimination of the natural enemies. The recent formulation technology tries to overcome such problems however, with variable success; nanotechnology is one promising way to do so efficiently. Nanopesticides are considered to be all plant-protection products that (i) intentionally include entities in the nm size (range up to 1000 nm), (ii) are designated with a "nano" prefix (e.g., nanohybrid, nanocomposite), and/or (iii) are claimed to exhibit novel properties associated with the small size of their components. The principal objectives of nanopesticide formulations are (a) to increase the solubility of active ingredients (a.i.) and/or (b) to release the a.i. in a slow/targeted manner and/or to protect the a.i. against premature degradation. Acetamiprid loaded alginate-chitosan nanocapsules can be used in any type of soil due to its higher stability and controlled release at all the pH ranges. The nanoformulation is superior to commercial formulation in terms of controlled release. The delivery of pesticide in nanoform could be a contemporary way towards managing agricultural pests and to prevent excess discharge of toxic substances to the environment.

IPM2 P28. Impact of intercropping on *Helicoverpa armigera* and its associated larval parasitoid

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The investigation was conducted on Instructional Farm and Department of Entomology, Rajasthan College of Agriculture, Udaipur during Rabi 2018. Gram variety GNG-1581 was sown with different farm scaped treatments to study the seasonal incidence of gram pod borer and to compare the impact of bordered plants viz., mustard, marigold and sunflower along with bio-pesticide protectants on the abundance of associated larval parasitoid *Campoketis chlorideae* on gram pod borer. It can be observed that gram bordered with marigold 40 DAS recorded significantly the maximum parasitisation (75.00 %) as compared to that in gram without farms cape treatment (25.00 %). Similarly, 60 DAS the maximum parasitisation (66.66 %) was recorded in gram bordered with marigold and minimum (40.00 %) parasitisation in gram without farms cape treatment. The marketable yield of gram among different farmscaped treatment ranged from 1.26 to 1.89 kg/plot. The maximum marketable yield of 1.89 kg/ plot was recorded in gram bordered with marigold with bio pesticide application followed by gram bordered with marigold without bio pesticide application treatment.

IPM2 P29.Evaluation of different bio-pesticides against maize stem borer *Chilo partellus*

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The experiment to evaluate the efficacy of bio-pesticides against *C. Partellus* was conducted at Agronomy Farm, RCA, Udaipur during Kharif- 2016 & 2017. The results revealed that Spinosad @ 1ml/ 3 litre was found most effective bio-pesticide against stem borer with the minimum leaf injury rating (LIR) for both the years 2.40 and 2.06, respectively. However, the application of Delfin WG @ 5 gm also proved effective in controlling stem borer with mean LIR 2.86 and 2.47 for successive years. The data revealed that the stem borer infestation in terms of LIR ranged from 2.40 to 5.66 in different treatments during 2016; while, from 2.06 to 6.00 during 2017. The highest LIR 5.66 and 6.00 was recorded in application of Bb-45 isolate of *Beauveria*, which was found least effective in controlling stem borer under artificial infestation for both the years.

IPM2 P30. Evaluation of seed treatment against *Chilo Partellus*

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The experiment to evaluate the efficacy of insecticides viz., Thiamethoxam 30 FS @ 6.0 ml, 8.0 ml and 10.0 ml/kg seed, Imidacloprid 600 FS @ 4.0 ml, 6.0 ml and 8.0 ml/kg seed, Chlorpyriphos 20 EC @ 5.0 ml/kg seed, and Fipronil 5 SC @ 6.0 ml/kg seed against Chilo partellus infesting maize under artificial infestation conditions was conducted during Kharif, 2017 at Agronomy Farm, RCA, Udaipur. The observations were recorded at 30 days after artificial infestation in terms of leaf injury rating 1-9. The results revealed that the LIR ranged from 3.67-5.87 in different treatments. The lowest LIR 3.67 was recorded in treatment application of Thiamethoxam 30 FS @ 10.0 ml/kg seed followed by 4.06 and 4.13 in treatment Thiamethoxam 30 FS @ 8.0 ml/kg seed and Imidacloprid 600 FS @ 8.0 ml/kg seed, respectively. The maximum borer infestation was recorded in application of Chlorpyriphos 20 EC @ 5.0 ml/kg seed, with LIR 5.87. The application of Thiamethoxam 30 FS @ 6.0 ml/kg seed, Imidacloprid 600 FS @ 6.0 ml and 4.0 ml/kg seed and Fipronil 5 SC @ 6.0 ml/kg seed LIR rating was 4.20, 4.60, 4.67 and 5.20 respectively. Highest LIR rating 7.13 was recorded in untreated control.

IPM2 P31.A biological control method for the coconut rhinoceros beetle (*Oryctes rhinoceros*) in Solomon Islands

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A biological control method for coconut rhinoceros beetle (CRB) using an entomopathogenic fungus, *Metarrhizium majus*, also known as Green Muscardine Fungus (GMF), has been investigated in Solomon Islands. Laboratory experiments using commercial GMF spores to inoculate third instar CRB larvae

demonstrated an infection rate of 80% after 10-15 days. Artificial breeding sites (ABS; composting coconut stem and plant material) have previously been used elsewhere as a lure and infect method for field delivery of GMF against CRB. As establishing GMF within field populations of CRB has had mixed results, ABS field trials were established with the aim of improving their effectiveness for CRB management. By altering the media composition of the ABS materials, the attractiveness of ABS to CRB was improved. Due to the cost of commercial GMF for widespread use within the Solomon Islands, the use of CRB larvae was investigated as a simple cost-effective method to multiply the amount of GMF material available, while increasing the number of ABS that can be inoculated. Our results have demonstrated that, by using the infected CRB larvae as the source of GMF spores applied to improved ABS media, it is possible to achieve an 85% infection rate of developing CRB larvae within the ABS. We will present details of our work and discuss the opportunity these results present within the context of our efforts to manage the CRB pest in Solomon Islands.

IPM2 P32. Isolation and evaluation of bacteriophage against *Xanthomonas axonopodis* pv. *punicae* causing bacterial bligh of pomegranate

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The pomegranate (*Punica granatum* L.) known as the 'fruit of paradise' is one of the most ancient fruit crop of India. Among different pomegranate growing states Maharashtra is the leading producer occupied 2/3rd of total area followed by Karnataka, Andhra Pradesh, Gujarat and Rajasthan. Although in Himachal Pradesh it is being cultivated in lesser area but its cultivation by the farmers is increasing every year over the last few years. Among various pests and diseases affecting pomegranate cultivation, Bacterial blight (*Xanthomonas axonopodis* pv. *punicae*) is a major constraint. Over the years, many antibiotics and bactericides have been used by various researchers but could not combat this disease below economic threshold. The disease is still a major concern in all the pomegranate growing states of India. In order to find new alternative in managing the havoc and losses caused by this disease, candidate bacteriophage specific to Xap-95 isolate was isolated from sewage soil after enrichment of soil sample. The phage enumerated on double agar overlay method showed plaque of 5mm diameter after 24 hr of plating. The plaque size was found to increase to 9mm diameter after 48 hr of plating, which notify the potentiality of phage against Xap-95 isolate and open the perspective of bacteriophage against *X. axonopodis* pv. *punicae*, causing bacterial blight disease of pomegranate.

IPM2 P33.Comparative efficacy of selected synthetic and biopesticide against *Bemisia tabaci* (Hemiptera: Aleyrodidae) on *Luffa acutangula*

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Bemisia tabaci caused several damage to *Luffa acutangula* crop in western Uttar Pradesh, its nymph and adults cause severe damage to the crop which decline the productivity of crop consistently, So integrated pest management required for insect pest control. *L, acutangula* is an edible vegetable of western Uttar Pradesh, residual toxicity of the synthetic pesticide have brought about serious environmental problems such as the emergence and spread of synthetic pesticide resistance in many species of mammalian toxicity, and accumulation of pesticide residues in the fruit of *L. acutangula*. The Synthetic (Endosulfan) as well as Biopesticide (Leaf extract of *Callistemon citrinus*) at different concentrations used to compare efficacy against *B. tabaci* in laboratory conditions by dry flim technique (LC50). Mortality data were recorded after 24 hours of setting the experiments and analyzed statistically. Endosulfan found most effective for control of

insect pest as compare to leaf extract of *C. citrinus* but problems have highlighted the need for alternative biocontrol agent for chemical residue free consumable crop, although bio-pesticide (leaf extract of *C. citrinus*) was not at par with synthetic pesticide (Endosulfan) but its non-hazardous and biodegradable nature for eco-friendly pest management approach gave them more attention for integrated pest management.

IPM2 P34. Isolation, identification and characterization of *Trichoderma* spp. as a bio-control agent against black rot disease of *Allium cepa* (Onion)

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Aspergillus niger is a plant pathogen causing diseases in several plants including onion (*Allium cepa* L.). Onion black rot caused by *A. niger* is a very common disease in onion growing areas of Latur district, Maharashtra. The present investigation was carried out in an attempt to isolate various strains of *Trichoderma* spp. from collected soil samples of different locations of Latur district and to evaluate their potential asa bio control agent against *A. niger*. Accordingly, three *T. Harzianum* species viz., Th-1 (Murud), Th-2 (Renapur) and Th-3 (Savewadi) were isolated and identified through cultural and micro morphological studies from black rot infected soil habitats of onion crop. Seed treatment method is used in field study to evaluate potential ability of *T. Harzianum* isolates against black rot disease of onion. In field trial, Th-2 exhibited higher black rot disease control (60.68 %) followed by Th-1 (48.93 %) and Th-3 (42.74 %) over control. Moreover to this, seed treatment with a spore suspension of *T. Harzianum* significantly increased seed germination percentage, seedling growth and seedling vigor Index over control. Significant increase in per cent GP & SVI was obtained inTh-2 (GP= 25.46 % and SVI= 88.78%) followed by Th-1 (GP= 21.13% and SVI= 61.06%) and Th-3 (GP= 16.19 % and SVI= 49.39 %) over control. Thus, bio control agents such as *T. harzianum* can be easily isolated from soil habitats of onion crops and be used not only to control onion black rot disease but also to increase seed germination and seedling vigour.

IPM2 P35. *Bt* soybean does not affect feeding behavior of red-banded stink bug *Piezodorus guildinii* (Hemiptera: Pentatomidae)

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Bt soybean represents 13% of the global area sowing with this crop. Although the presence of Cry1A(c) expressed in Bt soybean efficiently controls different lepidoptera pests, the effect on non-target arthropods is of concern. Piezodorus guildinii is a major soybean pest throughout the Americas. It is known that Bt crops are not effective for its control, while sub lethal effects are unknown. This study aims to determine the effect of Bt soybean on P. guildinii feeding behavior. Assessment was performed by comparing DM59i (RR) and DM5958iPRO (RR/Bt INTACTATM) varieties, using an AC-DC electrical penetration graph (EPG) to record female adult feeding waveforms during 15h. Means of different waveform parameters for each

treatment (RR or RR/Bt) were analyzed by generalized linear models and Kruskal-Wallis (P-valor >0,05): number of waveform events per insect (NWEI), waveform duration per probe (WDPI) and per insect (WDI), WDPI standard deviation (WDPI SD), WDPI coefficient of variation (WDPI CV) and waveform duration within the total recorded period (PRT). Differential feeding behaviors were only detected between the pathway phase (stylet penetration deep into plant tissue) at WDPI, WDPI SD, WDI and PRT, which could be associated to morphological differences between the varieties and not to the presence of Cry1A(c) endoprotein. Food ingestion on leaves, stems and pod, salivation on pod and non-probing phases did not differ between treatments. These results suggest that RR/Bt soybean does not affect the feeding behavior of red-banded stink bug; therefore, its action thresholds would be the same as those used in non-Bt varieties.

IPM2 P36. Fungicidal activity of the herbicidal compound, glyphosate against blast disease on glyphosate-resistant transgenic rice

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Rice is the second most widely grown cereal used to feed more than 60% of the world's population. Biotic factors such as weeds and diseases are among the major production constraints in rice. Among the diseases, rice blast caused by a filamentous fungus, Magnaporthe oryzae is a threat in rice cultivation and alone is responsible for approximately 30% productivity losses globally which is sufficient to feed 60 million people. Similarly, weed infestation aggressively competes with rice for natural resources and applied agro-input. Among the weed management options, glyphosate (N-phosphonomethyl-glycine) is widely used non-selective, systemic herbicide to control annual and perennial weeds. It specifically inhibits the shikimate pathway enzyme, 5-enolpyruvyl shikimate-3-phosphate synthase (EPSPS), involved in the biosynthesis of aromatic amino acids and other essential secondary metabolites conserved among plants, fungi, oomycetes, and bacteria. Hence, this opens a new window to establish the role of glyphosate as a fungicidal compound against disease on glyphosate resistance transgenic crop. In this study, the role of glyphosate as a fungicide on the glyphosate-resistant transgenic rice plant (OsmEPSPS) was explored. The minimum inhibitory concentration of glyphosate on Magnaporthe oryzae in vitro was 80 mM. Glyphosate applied either as prophylactic or curative sprays on over-expressed OsmEPSPS glyphosate-resistant transgenic rice plants reduced blast severity that was comparable to tricyclazole - a well-known blasticide used in rice farming. The glyphosate-based simultaneous management of weed as well as blast disease in the rice cultivation will be a novel and integrated crop management approach to improve the rice yield and productivity.

IPM2 P37. Novel insecticide molecules to manage brown plant hopper in rice

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The brown planthopper (BPH), *Nilaparvata lugens* (Stal) (Hemiptera: Delphacidae) is an important pest causing considerable damage to rice crop in Kharif (wet) season in Telangana, India. Of-late, BPH population has shown increasing trend in the region because of injudicious and indiscriminate application of insecticides and cocktail mixtures of two or more insecticides with other agrochemicals like bio-products by farmers. Hence, there is need to identify new insecticides with due recognition to ensure ecological safety and

economic sustainability. In this context, efforts are being made to evaluate newer and novel chemicals for their bioefficacy against major rice pests. In the present study, field experiment was conducted to assess the efficacy of triflumezopyrim (DPX-RAB55) @ 251.75 g a.i./ha, flubendiamide + thiacloprid @ 120 g a.i./ha, flubendiamide @ 24 g a.i./ha, thiacloprid @ 60 g a.i./ha, rynaxypyr @ 30 g a.i./ha, dinotefuran @ 40 g a.i./ha against brown plant hopper in rice during Kharif, 2015 at Regional Agricultural Research Station (PJTSAU), Warangal. The results revealed that, triflumezopyrim followed by dinotefuran were effective against BPH recording 42 and 14.7 per cent reduction over control in plant hopper population, respectively, five days after spraying. After 10 days, triflumezopyrim, dinotefuran recorded 78 and 55 per cent reduction in plant hopper population, respectively, over control. Triflumezopyrim gave significantly higher yield of 4110 kg/ha followed by dinotefuran (4063 kg/ha) compared to 1780 kg/ha in untreated control. Triflumezopyrim and dinotefuran resulted in 130 and 128 per cent increase in yield as compared to untreated control, respectively.

IPM2 P38.Bacterial wilt of solanaceous crops in relation to physico-chemical properties of soil

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Bacterial wilt of solanaceous crops incited by *Ralstonia solanacearum* stands as a major limiting factor affecting the vegetable production in Kerala. Being a soil inhabitant, the survival of the pathogen is greatly influenced by physico-chemical properties of soil. Hence the present study involved a purposive sampling survey in four different agro ecological units of Kerala *viz.*, Northern central laterite, Marayur hills, Southern laterite and Palakkad central plains to analyse the effect of soil physico-chemical properties on bacterial wilt incidence in solanaceous crops. A significant positive correlation was observed for soil physical properties like bulk density and water holding capacity with bacterial wilt incidence and pathogen population in soil, whereas a negative correlation was observed in the case of soil chemical properties like soil pH and available Ca with bacterial wilt incidence as well as pathogen population. These properties which showed significant correlation was subjected to multiple regression analysis to deduce the most important determinants contributing to disease incidence. The results indicate that soil pH and Ca content in soil contributed significantly (96.8%) in the prediction of bacterial wilt incidence with negative correlation whereas Ca content and bulk density of rhizosphere soil contributed 92.2% in the build-up of pathogen population in soil.

IPM2 P39. Effect of seed biopriming on green gram (*Vigna radiata*) germination with different biofertilizers

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Green gram is an annual legume that produces seeds containing 22-25 percent protein and provides an important source of vegetable protein for humans. Biopriming is a very important seed invigoration technique

for rapid germination. In order to utilize the biopriming influence on seed germination and seedling growth with different biofertilizers like *Trichoderma viride*, *Pseudomonas fluorescens*, *Rhizobium*, Beejamrutha, Vermiwash, water and untreated control in eight different combinaion treatments used for the experiment with different methods like Petri plate method, blotter paper method and seedling tray methods.In case of Petri plate method all the treatments performed better over the control and Beejamrutha found significantly superior over other treatments followed by *Rhizobium* and *Trichoderma viride + Pseudomonas*. The blotter paper method showed that the seeds treated with *Rhizobium* found significantly superior germination over control followed by *Trichoderma viride + Pseudomonas* and Beejamrutha. Seedling tray method also showed significance difference over the control both incase of germination and seedling vigour. The seeds treated with *Trichoderma viride + Pseudomonas* observed highest germination with better seedling vigour followed by *Rhizobium* and Beejamrutha. The seed bio priming will improve the seed gemination as well as seedling vigour and its eco friendly cost effective method.

IPM2 P40. Implementation of integrated weed management in farmers field demonstrations of recent rice varieties

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Rice is grown under various agro-climatic conditions and the yield losses due to weeds alone is around 37%. More than 30 genera of weeds infest rice fields at different crop growth stages. With the objective of reducing cost of cultivation and increasing economic benefit, "Resource conservation and cost effective technology of drought tolerant short duration Variety DRRDhan42"technology was demonstrated in Kurnool district; "Drum Seeding Technology for drought tolerant short duration variety DRRDhan 46" was demonstrated in Chittoor District, AndhraPradesh, India.The tailor made packages including Integrated Weed Management (IWM) were implemented by providing critical inputs of mid-early High Yielding Variety DRRDhan42 and DRRDhan46 of ICAR-Indian Institute of Rice Research and optimum seed rate of 30 kg/ha for robust nursery; the pre-sowing herbicide application of Glyphosate 15 Days Before Transplanting; application of Oxadiargyl at 7 Days After Transplanting followed by chlorimuronethyl + metsulfuronmethyl at 25 Days After Planting ; application of bispyribacsodium at 30-40 DAT in fields depending on weed flora and intensity; top dressing of nitrogen based on leaf color chart (saving of 25-30 kg nitrogen); need based application of plant protection chemicals. By implementing the above mentioned management technologies, farmers reduced input cost and achieved higher monetary benefit of 3-30% resulting in higher benefit-cost ratios. In order to accelerate the rate of adoption, a farmer's day was conducted and more than hundred farmers of nearby villages witnessed the positive experiences of IWM interventions. The beneficiary farmers shared experiences and motivated other farmers. Media coverage in this outreach program is appreciable

IPM2 P41.Survey and identification of charcoal rot of maize caused by *Macrophomina phaseolina* in major districts of Telangana

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Maize is the third most important crop of India after rice and wheat. Fungal diseases are one of the major constraints in realizing the yield potential of maize crop. Among them Post flowering stalk rot (PFSR)

complex is the most serious and destructive disease in maize. Among PFSR complex, Charcoal rot caused by *Macrophomina phaseolina* (Tassi) Goid reported to be majorly responsible for increased yield losses in arid and semi arid regions of Telangana, Karnataka and Tamil Nadu, especially where moisture stress coincides with flowering stage of the crop. A roving survey was conducted in major maize growing areas of Telangana i.e. Karimnagar, Warangal, Khammam and Mahaboobnagar during *kharif* 2018 in the months of September and October. Highest disease incidence (14.80%) was observed in Karimnagar followed by Warangal (10.65%), Mahaboobnagar (10.15%) and the Lowest disease incidence was observed in Khammam (8.94%). Stalk samples were collected from 85 diseased fields during the survey and associated pathogen identified as *Macrophomina phaseolina*, which is a part of PFSR complex.

IPM2 P42. Phyto- sanitary irradiation of maize - an alternative to MBr chemical fumigation

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Maize is third most important food grain crop in India and traded between the countries and subjected to fumigation with Methyl bromide to control storage insects. In view of environmental concerns, MBr fumigation is phasing out which needs alternatives to disinfect the food grains. Dosi-metric studies were conducted with adult storage pests of maize i.e, *Sitophilus oryzae, Tribolium castaneum and Corcyra cephalonica* at 100, 200, 300, 400 and 500 Gy irradiation doses. 100 % mortality of all the test insects was obtained within 10 days and the insects have become sterile. No adult emergence was observed in maize even at 90 days after irradiation. More than 750 *Tribolium*, 60 *Sitophilus* and 50 *Corcyra* adults were emerged from one kg of untreated maize within 60 days. The germination % (66.6% - 0%)and seedling vigour index (3044 -668) of Maize was decreased with increased irradiation dose compared to untreated control with high germination (93%) and vigour (4278). Three months after storage, no weight loss in maize irradiated at 500 Gy compared to 40% weight loss with unirradiated maize infested . Three months after storage, there was no weight loss in maize irradiated at 500 Gy compared to 25- 40% weight loss with untreated maize infested with stored grain pests.

IPM2 P43. Effect of seed treatments in the management of dry root rot of soybean

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Soybean (*Glycine max* (L.) Merril.) is one of the most important oil seed crop known for its excellent protein (42 - 45%), oil (22%) and starch content (21%). It is an important oilseed and pulse crop and the most likely solution for overcoming the world's protein hunger. One of the major constraints in the endeavor of increasing productivity in soybean is its susceptibility to a large number of diseases caused by fungi, bacteria, viruses and nematodes and several of which are seed borne and seed transmitted. Soybean seeds are known to harbor several fungi which affect their health seriously, causing germination failures and also complete death of seedlings. The annual lossess due to seed borne diseases in soybean is estimated to the tune of 12%. Among different fungal diseases, Charcoal rot incited by *Macrophomina phaseolina* and anthracnose incited by *Colletotrichum dematium* are found major in all the soybean growing tracts of the world. Keeping this

inview, the present study was taken up to study the effect of biological and fungicidal seed treatments in reducing dry root rot of soybean under field conditions at RARS, Jagtial during the year 2015and 2016 adopting RBD design with plot size of 4 m x 4m replicated thrice using soybean cv. JS 335 and treated with *T. viride* @ 10 g/kg of seed, *T. harzianum* @ 10 g/kg, *Peudomonas flourescens* @ 10g/kg, Thiram + carbendazim (1:1) @ 3 g/kg, Pyraclostrabin + Thiophanate methyl @ 2 g/kg, Cymoxanil + Mancozeb @ 2 g/kg, Pyraclostrobin + Metiram @ 2g/kg and Untreated seeds. Irrespective of the fungicide and bioagent seed treatments, seeds treated with Pyraclostrabin + Thiophanate methyl (Xelora) @ 2 g/kg seed was significantly improved seed germination (95%) and reduced seedling mortality (6.5%) and dry root rot incidence (8.5%) over untreated seeds (80%, 8.8% and 9.2%) which was followed by seed treatment with Cymoxanil + Mancozeb @ 2 g/kg enhanced seed germination by 91% and recorded less seedling mortality of 8.8% and dry root rot of 9.2%. Among the three bioagents tested, seeds treated with *T. viride* @ 10 g/kg of seed recorded seed germination of 88.2%, seedling decay of 12.37% and dry root rot incidence of 11.1% and found significantly superior over untreated seeds (80%, 19.3% and 22.5%). The present study clearly indicated that seed treatments were found effective in reduction of seed and soil borne pathogens in soybean.

IPM2 P44. Assessing the abundance and diversity of nematode pests in maize-based rotation systems in South Africa to enable integrated pest management

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Maize, a staple food and an important livestock feed source in sub-Saharan countries, is parasitized by various plant-parasitic nematode species resulting in estimated yield losses ranging between 12-60 %. Results of three nematode surveys conducted in rain-fed and irrigation fields of local producers during the 2008, 2015 and 2018 growing seasons are discussed. Standard nematode extraction, counting and identification protocols were applied. Predominant nematode pest genera identified were *Meloidogyne* and *Pratylenchus*. Root-knot nematode species characterised contained single and mixed populations with *M. incognita* being predominant, followed by *M. javanica*, *M. arenaria* and *M. enterolobii*; the latter being a first report for South Africa. Crops locally used in rotation with maize are highly susceptible to the polyphagous *Meloidogyne* and *Pratylenchus* and will allow high build-ups of such genera, challenging effective management of such pests.

IPM2 P45. Management of pest and natural enemy in the field of pepper plant according to vegetation management

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Pepper is one of the most important vegetable crops in Korea. There are many pests such as aphids, thrips, tobacco moths, etc. In order to investigate the effect of insect pest control on vegetation management in

pepper cultivation, the density of pests and natural enemies on pepper field was investigated according to companion plant cultivation. This test was carried out in the organic cultivation field on the National Institute of Agricultural Science, Wanju city, Jeonbuk Province. The pests of pepper like aphid have several natural enemies and their density is effected by vegetation on farm field. Profit vegetation increase the density of natural enemies. Green manuals like hairy vetch function as cover crops on field while grass and weed are rare on farmland. Cover crops supply profit shelter of lots of natural enemies and increase their occurrence. On this study, we investigate the effect of vegetation management on natural enemies and insect pest in pepper cultivation with hairy vetch and investigate total productivity and damage of fruit.

IPM2 P46. Relative efficacy of new generation herbicides in transplanted rice

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An investigation was carried during *Kharif* to evaluate the relative efficacy of herbicides in transplanted rice (RNR-1446). Experiment was laid in randomised block design, replicated thrice, with sixteen treatments *viz;* Butachlor (Machete) @ 1.5 kg a.i ha^{-1} at 3-7 DAT, Cinmethylin + 2, 4 DEE (Argold) @ 0.375 kg a.i ha^{-1} at 7 DAT, Cinmethylin + 2, 4 DEE @ 0.500 kg a.i ha^{-1} , Flufenacet (Drado) @ 0.09 kg a.i ha^{-1} at 3-5 DAT, Flufenacet @ 0.12 kg a.i ha^{-1}, Anilophos + ethoxysulfuron (Rice guard) @ 0.312 + 0.12 kg a.i ha^{-1} at 10 DAT, Acetachlor @ 0.100 kg a.i ha^{-1} at 3-7 DAT, Acetachlor @ 0.150 kg a.i ha^{-1}, Pyrazosulfuron- ethyl @ 0.100 kg a.i ha^{-1} at 8 DAT, W10 Pyrazosulfuron- ethyl (Saathi) @ 0.150 kg a.i ha^{-1}, Alkombo @ 0.204 kg a.i ha^{-1} at 3 DAT, Chlorimuron ethyl + metsulfuron methyl (Almix) + Butachlor @ 0.04 + 1.0 kg a.i ha^{-1} at 3 DAT, Butachlor fb Almix @ 1.0 fb 0.04 kg a.i ha^{-1} at 3 fb 21-23 DAT, Two hand weedings (20 and 40DAT), Unweeded and Weed free check. Results revealed that next to weed free check, Anilophos + ethoxysulfuron @ 0.312 + 0.12 kg a.i ha^{-1} registered higher weed control efficiency (88.3%), lower weed index (7.1%), higher grain and straw yields (4.81 and 5.90 t ha^{-1}) and comparable with two hand weedings, which recorded weed control efficiency, weed index, grain and straw yields of 89.5, 5.9 % , 4.87 and 5.95 t ha^{-1} respectively.

Poster session IV: Host plant resistance

HPR P1. Improving pod borer complex tolerance in cultivated pigeonpea (*Cajanus cajan*) by using wild *Cajanus* species

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Among pod borers, the pod borer (*Helicoverpa armigera* Hübner) is the single largest yield-reducing factor in food legumes. In pigeonpea (*Cajanus cajan* (L.) Millsp.), an important food grain legume crop of the semi-arid tropics, pod borer causes maximum yield losses (25-70 %) followed by pod fly (*Melanagromyza obtusa*) (10-50%), spotted pod borer (*Maruca vitrata*) (5-25 %) and pod bug (*Clavigralla scutellaris*) (10-30 %). Worldwide, pod borer causes an estimated loss of over US $2 billion annually, despite over US $1 billion value of insecticides are used to control pod borer. High levels of resistance to pod borer is not available in the cultivated genepool. Crop wild relatives are the potential sources for introgressing resistance genes against pod borer into the cultigen. Several accessions of wild *Cajanus* species with high levels, and different mechanisms of resistance (oviposition non-preference and antibiosis) to pod borer have been identified, which can be utilized in breeding programs to improve pod borer tolerance of cultivated pigeonpea. Using pod borer tolerant wild *Cajanus* species (*C. scarabaeoides* and *C. acutifolius*) as donors and popular pigeonpea varieties as recipients, pre-breeding populations have been developed following simple- and complex-cross approach. Evaluation of four backcross populations under un-sprayed field conditions resulted in the identification of ~150 introgression lines (ILs) with low visual damaging rating score (5.0-6.0) at harvesting time and low total pod borer complex damage (<50%). These ILs are being re-screened under field and laboratory conditions for confirming resistance/tolerance. Utilization of these ILs in breeding programs will assist in developing new pigeonpea cultivars with improved pod borer tolerance and broad genetic base.

HPR P2. Screening and identification of novel compounds that induce Jasmonate-regulated defense gene expression

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To search for bioactive compounds that induce defense response in plants, we developed a high-throughput screening (HTS) system using firefly luciferase (Fluc) bioluminescence reporter assay using 96- or 384-multiwell plates. Transgenic seeds harboring promoter-Fluc fusion genes are germinated in the wells of multi-well plates and then treated with chemical libraries. Positive reactions are observed as the bioluminescence from the gene expression of the promoter-luciferase fusion gene in response to the chemical treatment. As a result of estimating the reporter activity of several defense related gene promoters in transgenic *Arabidopsis* seedlings, we found that the Vegetative Storage Protein 1 gene promoter from *Arabidopsis* shows a clear induction of Fluc activity in response to treatment with methyl jasmonate (JA) or its analog. The HTS of chemical libraries resulted in the discovery of several novel compounds that induce JA-mediated response of *Arabidopsis*. One of such compounds, designated YNU-001, is structurally

unrelated to JA or previously reported JA-agonists and acts as a strong inducer of JA-inducible genes at relatively low concentrations. Results of inoculation tests indicate that YNU-001 has plant-protecting activity against infection by necrotrophic pathogens or herbivores.

HPR P3. Induction of systemic resistance in brinjal plants by *Pseudomonas aeruginosa* against *Phomopsis vexans*

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Pseudomonas strain tested for their efficacy against brinjal leaf blight and fruit rot pathogen *Phomopsis vexans* under in vitro, glasshouse and field conditions. *Pseudomonas* was isolated from the rhizosphere soil of brinjal and identified as a *Pseudomonas aeruginosa* strain Pa15 on the basis of biochemical tests and by comparison of 16S rDNA sequences. The antifungal metabolite by Pa15 was extracted, purified and characterized. The antifungal metabolite produced by Pa15 has been identified as phenazine-1-carboxamide. Production of indole-3-acetic acid, siderophores, phosphatase and protease in Pa15 was determined. Vigour and a relative performance index were used to assay the growth promotion and antagonistic activity under in vitro conditions. Bioefficacy test, seed treatment and foliar application of talc-based formulation of Pa15 was superior in reducing the disease incidence and severity when compared to other treatments under glasshouse and field conditions. Further, induction of defense enzymes, such as peroxidase, polyphenol oxidase, phenylalanine ammonia-lyase, chitinase and β-1,3-glucanase and accumulation of phenolics were studied. The study revealed the probable influence of plant growth promotion and induced systemic resistance in enhancing the disease resistance in brinjal plants against leaf blight and fruit rot disease by Pa15.

HPR P4. Improvement of salt tolerance and resistance to *Phytophthora gummosis* in citrus rootstocks by controlled hybridization

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The sustainability of Mediterranean citriculture depends largely on the use of rootstocks that provide a better adaptation to biotic and abiotic constraints, as well as a good graft-compatibility with commercial cultivars. In the absence of rootstocks meeting all these criteria, the management of the available diversity and the selection of the desirable traits are necessary. In the present work, we conducted a controlled pollination program involving four different rootstock genotypes that belong to the germplasm collection of INRA Morocco. These genotypes included citrumelo cv. 'Winter Haven' (*Citrus paradise* Macf. x *Poncirus trifoliata* L. Raf.), Sunki mandarin (*Citrus sunki*), Cleopatra mandarin (*Citrus reshni*), and pomelo (*Citrus grandis*). The breeding program resulted in the development of a population of 199 seedlings, 31 of which expressed marked morphological traits of the male parent. Molecular characterization of these 31 genotypes using flow cytometry and microsatellite markers helped to determine their ploidy level and to confirm the parental origin of the zygotic seedlings. On the other hand, the phenotypic characterization of the potential

hybrids by early screening tests revealed heterogeneous responses to salinity and *Phytophthora* attacks. An interesting combination of salt tolerance traits (chloride exclusion, high relative growth, high stomatal conductance) with resistance to *Phytophthora* gummosis was observed in two citrumelo hybrids, H56 and H92, which seem therefore to be qualified for use in salt and *Phytophthora* affected regions as a replacement for the CTV-susceptible rootstock, sour orange

HPR P5. Artificial screening technique to identify the promising sources against rice false smut disease under field conditions

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Rice false smut caused by *Ustilaginoidea virens* has gained importance in India. Identification of suitable artificial screening technique to evaluate large number of genotypes is essential to identify the resistant source. During Kharif-2018, 162 different genotypes were screened through artificial inoculation under field conditions. The genotypes were inoculated with 2 ml of *U. virens* conidial suspension (2 x 10^5conidia/ml) at booting stage using a sterile hypodermic syringe during evening hours. For each genotype, 8-10 panicles were inoculated. Out of 162 genotypes, 70 were identified with no false smut symptom and 92 showed varied level of susceptibility. Percentage of infection among the genotypes ranged from 40-80% with no. of smut balls/panicle varied from 1-31. The disease free genotypes (70 Nos.) were again artificially screened, under the field condition during Rabi 2019. As there was a comparatively higher temperature, the inoculated plants were protected using green shade net and water spraying during morning and evening hours. Though the inoculated plants expressed the symptom, the infection intensity was less compared to Kharif season. Out of 70 genotypes screened, 40 were appeared to be free from *U. virens* infection and in the susceptible genotypes, maximum of 17 smut balls were recorded in a panicle. The genotypes free from false smut symptoms in both the seasons will be evaluated under artificial disease pressure in glass house and field conditions. Hence, the screening technique developed and standardized at ICAR-IIRR can be adopted under field conditions to identify the resistant sources against false smut disease of rice

HPR P6. Biochemical basis of resistance in brinjal genotypes against shoot and fruit borer (*Leucinodes orbonalis* G)

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An experiment was conducted to evaluate forty two brinjal genotypes for biochemical constituents such as, reducing and non-reducing sugar, total phenol, phenylalanine ammonia lyase (PAL) activity, solasodine content, polyphenol oxidase and peroxidase activity and its relation with infestation of shoot and fruit borer for two seasons during 2017 and 2018. Correlation between these biochemical characters with per cent infestation of brinjal shoot and fruit borer was studied. Per cent fruit infestation had significant and positive correlation with reducing (r= 0.90) and non-reducing sugar (r= 0.88), whereas significantly negative correlation was found with polyphenol oxidase (r= -0.85), phenylalanine ammonialyase (r= -0.87),

peroxidase (r= -0.87) and total phenol content(r= -0.91). Out of forty two genotypes IC090951, IC411485, Pant Samrat, BR-332-2 recorded with low sugar content, high polyphenol oxidase and high phenol, and lower infestation of shoot and fruit borer, these genotypes can be used in brinjal breeding programs. The role of important biochemical characters which may contribute more towards resistance to shoot and fruit borer has been discussed.

HPR P7. Morpho-physico-chemical components of resistance to pod borer, *Helicoverpa armigera* (Hübner) in pigeonpea [*Cajanus cajan* (L.) Millspaugh]

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Morpho physico-chemical components of resistance are essential for formulating strategies to evolve for Integrated Pest Management. Hence, an experiment was conducted at CCS HAU, Hisar (Haryana) to study the morpho physico-chemical components of resistance to pod borer, *Helicoverpa armigera* in pigeonpea with different sowing dates. Among four different sowing dates, the minimum pod infestation (1.70%) was recorded in (D4) 3rd week of July sown crop, whereas, it was observed maximum (4.54%) in (D2) 1st week of July. In different pigeonpea varieties, the minimum mean pod infestation (2.45%) was recorded in AL-201, whereas, the maximum mean pod infestation (3.72%) was recorded in Pusa-992. The glandular (type A) and non-glandular (type B) trichomes on pods of top and middle canopy of the plant and pod wall thickness were associated with resistance to *H. armigera*, whereas, the non-glandular lengthy (type C) trichomes and pod length were associated with susceptibility to *H. armigera*. The expression of resistance to *H. armigera* was also associated with the high amount of fat, phenol and tannin content. Crude protein and total soluble sugar content were responsible for higher pod infestation.

HPR P8. Screening of *Brassica juncea* – fruticulosa introgression lines for resistance against mustard aphid

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The study on the "Screening of *Brassica juncea* – *fruticulosa* introgression lines for resistance against mustard aphid" was conducted at Punjab Agricultural University, Ludhiana during the 2016 and 2017 crop seasons. One hundred and thirty three introgression lines were screened under field conditions for their resistance to mustard aphid along with *Brassica fruticulosa*, *Brassica juncea* var. PBR-210 and *Brassica rapa* var. BSH-1 on the basis of per cent plant infestation and aphid infestation index. The Aphid Infestation Index (AII) ranges from 0 to 5. AII for I8, I79, I82 and *B. fruticulosa* was 0.5, 0.9, 1.0 and 0.3 respectively for 2016 crop season. The corresponding values for 2017 crop seasons were 1.2, 1.1, 1.6 and 1.0. Out of the 136 genotypes, four namely I8, I79, I82 and *B. fruticulosa* exhibited consistent resistant reaction to mustard aphid and hence, fell in the resistant category while, I11, I77 and other 129 genotypes fell in the susceptible and highly susceptible category, respectively. Thus, two years of field screening resulted in identification of three introgression lines (I8, I79 and I82) along with *B. fruticulosa* to be resistant to mustard aphid. Further study on the mechanism of resistance concluded that mustard aphid showed least preference for feeding and colonization on these three introgression lines both under the field and laboratory condition.

HPR P9. Development of sick plot for jute stem rot caused by *Macrophomina phaseolina*

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Sick plot technique has been the most popular and efficient method of field evaluation of crop germplasm over the years and locations. Jute (*Corchorus olitorius* L.), also called golden fibre, is cultivated as pre-kharif crop in eastern India. Stem rot caused by *Macrophomina phaseolina* (Tassi) Goid. is economically the most damaging disease affecting both yield and quality of fibre and seed. Due to its seed, soil and air borne nature, its epiphytotics is linked with two other diseases, namely, Hooghly wilt and Root knot nematode killing crop. Attempts were taken to develop a sick plot with sandy loam and neutral (pH 7) soil for stem rot of jute at ICAR – CRIJAF, Barrackpore. Susceptible JRC 412 crop was incorporated into soil. *M. phaseolina* was multiplied on sterilized old jute seeds for incorporation into soil. The Percent disease index (PDI) and soil population of pathogen were monitored at regular intervals. PDI progressed slowly over the years from 2.8 in 2016, to 16.9 in 2017, 11.7n % in 2017 and finally reached peak of 63.5 during last year. The inoculum density of *M. phaseolina* was 3.54×10^3 colony forming units (CFU) initially at the surface up to 5-10 cm depth, gradually decreasing with the depth. The CFU slowly increased 4.47×10^3 in 2017, 6.46×10^3 in 2018 and finally reached maximum of 8.65×10^3 during 2019. Once inoculums level and disease pressure are stabilized for consecutively few years, sick plot is ready for mass screening of large number of entries for resistance against jute stem rot.

HPR P10. Exogenous application of different silicon sources and potassium reduces pink stem borer damage and improves photosynthesis, yield and related parameters in wheat

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Silicon (Si) and potassium are known to impart tolerance against biotic stresses in crop plants. A study was conducted to know the effect of diatomaceous earth (DE), a soil applied Si source and soluble silicic acid, a foliar applied Si source at two levels of potassium for their efficacy against pink stem borer (PSB) in wheat under field conditions. Effect of these Si sources and potassium on photosynthesis, yield and related parameters was also studied. Soil application of DE @ 300 kg ha^{-1} significantly decreased the PSB incidence and damage with lowest per cent white ear damage (12.47) and recorded highest grain yield (3.31 t ha^{-1}). Both soil and foliar applied Si sources along with potassium @ 36 kg ha^{-1} significantly enhanced the net photosynthesis rate, stomatal conductance, water use efficiency, intercellular CO2 concentration, spike length, spike weight, number of grains per spike, 1000 grains weight and significantly decreased the transpiration rate in contrast to untreated control (no Si application) and insecticidal check. Soil Si sources significantly enhanced plant available Si content in soil solution and thereby Si content in stem tissues of wheat plants in contrast to foliar Si sources. Highest B: C ratio (2.03) was recorded in soil application of DE @ 150 kg ha^{-1} which was more than insecticidal check (1.74). Both Si sources proved more effective than insecticidal check in managing PSB in wheat under field conditions and improved photosynthesis, yield and related parameters, which can be used for sustainable, eco-friendly management of PSB in wheat.

HPR P11. Relationship between *Mungbean yellow mosaic India virus* (MYMIV) and vector (*Bemisia tabaci* Gennadius) in soybean

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Whitefly (*Bemisia tabaci*) transmitted yellow mosaic disease of legume crops in Madhya Pradesh, Central India is considered as major constraint in the productivity of soybean. Based on the molecular studies, *Mungbean yellow mosaic India virus* (MYMIV) was found to be the most prevalent causal agent of YMD in soybean. Female whitefly is efficiently more active to transmit the virus than male. In this concern, an experiment was conducted to study the relationship between MYMIV and vector (*B. tabaci*) in soybean under insect proof net house consecutively during 2016-2018. The minimum acquisition access period (AAP) of 0.5 h was required by female adult whitefly to transmit the MYMIV in soybean seedlings. At 12 h of acquisition feeding period, 100% disease infection was attained and the disease symptoms appeared in 20.6 days which further reduced to 18.9 days at 24 h of AAP. At minimum inoculation period (IAP) of 1 h, the vector transmitted 10% MYMIV infection in the soybean plants and the first disease symptoms appeared in 24 days. At 18 h of IAP, 100% disease infection was recorded and the disease symptoms appeared in 17.5 days, which reduced to 15.8 days at 24 h IAP. A single viruliferous female adult whitefly was able to transmit 15% MYMIV infection in the soybean plants and the disease symptoms appeared in 27.3 days. However, 10 viruliferous adult whiteflies/ plant caused 100% infection and the disease symptoms appeared in 18.4 days. The maximum 15 days retention period of MYMIV was recorded in whitefly

HPR P12. Identification of defense proteins in pearl millet seeds effective against *Magnaporthe grisea*

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Pearl millet is an important source of energy and nutrition for millions of people in the drylands of sub-Saharan Africa and South Asia. Recently, blast, also known as leaf spot, caused by *Magnaporthe grisea* (Anamorph: *Pyricularia grisea*) has emerged as a serious threat to pearl millet cultivation causing substantial yield loss. Seeds tend to contain several storage proteins, some have an inhibitory action against plant pathogens. The present study aimed to identify the defense proteins in seed extrudes of ten pearl millet blast differential lines and investigate their protective effect against growth of *Pyricularia grisea* (Pg 45, Patancheru isolate). The biochemical observations of seed extrudes revealed the presence of plant defense linked hydrolytic enzymes chitinases (12-18 units/ml), β-1,3 glucanases (16-48 units/mg protein) as well as cysteine protease inhibitors (57-123 PI units/mg protein) among the tested lines. The pre-treatment of *P. grisea* media with respective line seed extrudes resulted in significant reduction (22-40%; $p<0.001$) of fungal radial growth and fungal dry weight (20-77%; $p<0.001$). The effective concentration for the 50% fungal growth inhibition (EC50) was identified as 400 and 600 µg/ml for resistant lines IP 21187 and ICMR 06444, respectively. Further, the seed extrudes were able to significantly retard the spore germination (by 18 h) and initial growth (by 48 h) of Pg 45 by 24-83%. These findings suggest that the identified proteins are playing synergistic role in pearl millet defense against blast pathogen, Pg 45 and provide the basis to explore the novel biological control strategies in plant defense.

HPR P13. RNA Interference (RNAi) technology: a novel tool against insect pests

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The current trends have triggered the development of new agricultural technologies to meet consumers' demand, while minimizing environmental impacts. RNAi is a biological process in which RNA molecules inhibit gene expression or translation process, by neutralizing targeted mRNA molecules. It is more efficient, user friendly, flexible, specific and stable technique for pest control. RNAi pathway involves formation of interfering molecules through activity of dicer enzyme. These interfering molecules can be small interfering RNAs (siRNAs) and microRNAs (miRNAs). The interfering molecules are then loaded onto RNA induced silencing complex (RISC) comprising of Argonaute protein (AGO). RISC directs the interfering molecules to their cognate target where homology based cleavage of target mRNA occurs. The main prerequisites to generate successful RNAi insect-resistant transgenic plants are: a) Identification of a specific gene with an essential function in the insect that can cause developmental deformities and/or larval lethality when knocked down or knocked out and b) dsRNA delivery by oral ingestion that must be uptaken by the insect cells and spread systemically. Synthetic dsRNA can be selectively introduced into cells and can robustly induce suppression of specific genes of interest. RNAi involves the basic conserved mechanism and this feature makes it a suitable approach for control of all types of insect pests. However, the use of RNAi approach for pest control at field level is still in its infancy and many road blocks need to be removed before establishing it as a viable insect pest control strategy.

HPR P14. Morphological and biochemical analysis of *Erysiph episi* causing powdery mildew of pea

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Powdery mildew caused by Erysiphe pisi is one of the important diseases responsible for heavy yield losses in pea crop worldwide. The resistance to powdery mildew in pea is recessive and governed by a single gene er1. Morphological studies on 16 pea genotypes revealed hyaline colour conidia with its shape varying from oblong (young) to cylindrical (matured) conidia. Conidia germination began within 2 hours after inoculation on the genotypes by producing germ-tube from the surface of the conidia. Direct penetration of host through the cuticular and epidermal layer appeared to be the method of infection by E. pisi. 12-24 hrs are required for mycelium to grow and penetrate leaf tissue after inoculation. A germ tube branched before penetration or grew from an appressorium to another penetration site. The percent appressoria causing penetration was significantly higher in susceptible parent PG-3 (89.57 %) compared to the resistant parent KPMR 516 (9.89 %) at 36 hai. A biochemical study revealed that the activity of SOD and catalase, enzymes involved in scavenging ROS, was increased after powdery mildew infection and was higher in resistant genotypes. The total phenol (TP) content was, also, observed high in resistant genotypes. The melondialdehyde (MDA) levels in the susceptible genotypes were higher than the resistant ones. Statistical analysis showed strong positive correlation between AUDPC and MDA; however, a negative correlation between AUDPC and SOD, CAT and TP, indicates that er1 induced powdery mildew resistance modulates antioxidant defence response in pea plants.

HPR P15. Expression of different biochemical mechanism of resistance to *Chilo partellus* in sorghum under field conditions

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Host plant resistance is an important component of pest management, and information on contribution of different mechanisms of resistance is important for developing cultivars with resistance to the target pests. Therefore, we studied the contribution of different components of resistance in five sorghum genotypes to sorghum stem borer, *Chilo partellus* occurring in India under field conditions. Plant damage by the larvae of *C. partellus* was evaluated visually on a 1-9 damage rating (DR) scale (1 being <10 % leaf damage, and 9 being >80 % leaf damage). Further, the activities of various plant defensive enzymes [peroxidase (POD), polyphenol oxidase (PPO), phenylalanine ammonia lyase (PAL) and catalase (CAT)], and the amounts of total phenols, condensed tannins, hydrogen peroxide (H2O2) and proteins were also recorded. The genotypes ICSV 700, IS 2205 and ICSV 93046 suffered lower leaf damage by *C. partellus* (DR 2.8-3.7) as compared to Swarna and ICSV 1 (DR 7.0 and 6.4, respectively). ICSV 700, IS 2205 and ICSV 93046 exhibited greater enzymatic activity and had more amounts of phenols, condensed tannins, hydrogen peroxide and proteins then the susceptible check, Swarna. There was a positive association between leaf damage and the activity of the defensive enzymes, and the amounts of phenols, condensed tannins and H2O2. These results suggested that the plant defensive enzymes (POD, PPO, PAL and CAT), accommodated phenols, condensed tannins and H2O2 were involved to impart resistance to *C. partellus*. This information will be useful for developing sorghum genotypes with resistance to *C. partellus* for sustainable crop production

HPR P16. Bak1–5 mutation uncouples tryptophan-dependent and independent postinvasive immune pathways triggered in *Arabidopsis thaliana* by multiple fungal pathogens

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A hemibiotrophic pathogen *Colletotrichum tropicale* (Ctro), formerly called *C. gloeosporioides*, is not adapted to *Arabidopsis thaliana* but is able to invade the *Arabidopsis* pen2 mutant. However, once Ctro invades pen2, its further expansion is blocked by post invasive defense. Here we investigated the contribution of tryptophan (Trp)-derived secondary metabolites to the post invasive resistance against fungal pathogens by using Arabidopsis mutant sets defective in Trp-metabolism pathways. We used fungal pathogens with different infection strategies, i.e. nonadapted hemibiotrophic pathogen Ctro, adapted hemibiotrophic pathogen *C. higginsianum* and necrotrophic pathogen *A. brassicicola* (Ab). As a result, we found that both CYP71A12-dependent biosynthesis of indole-3-carboxylic acid derivatives (ICAs) and PAD3-dependent biosynthesis of camalexin are involved in post invasive resistance against the tested three fungal pathogens. We also investigated the contribution of pattern recognition receptors for the recognition of pathogen invasion and

subsequent activation of Trp-derived metabolism pathways. We found that the bak1–5 mutation significantly reduced post invasive resistance against Ctro and Ab, indicating that a pattern recognition receptor complex commonly contributes to this second defense-layer against pathogens with distinct infection strategies. Unexpectedly, we found that the bak1–5 mutation had no detectable effects on Trp-derived metabolite accumulation triggered by pathogen invasion. Further comparative gene expression analyses suggested that pathogen invasion in *Arabidopsis* activates (i) bak1–5 insensitive Trp-metabolism that leads to antimicrobial small molecules, and (ii) a bak1–5 sensitive immune pathway that activates the expression of antimicrobial proteins.

HPR P17. Screening groundnut mini core germplasm for resistance to stem rot disease caused by *Sclerotium rolfsii*

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Stem rot, caused by *Sclerotium rolfsii* Sacc is an important soilborne disease of groundnut and posing major threat to its production worldwide causing yield losses in the range of 25-80%. Host plant resistance remains a cost-effective and sustainable strategy in managing soilborne diseases. In the present study, mini core collection of groundnut was evaluated under sick field conditions to identify potential sources of resistance to stem rot disease. Further to confirm the resistance identified under field conditions, a laboratory based oxalic acid response /resistance assay was also conducted as oxalic acid is the primary virulence factor in causing the stem rot disease. Results indicate that out of 184 mini core accessions evaluated in 2016 in the sick field, 38 accessions were found to be resistant with <20% mortality and 55 accessions were found to be moderately resistant with 20 to <30% mortality. In 2017, 13 accessions were rated as resistant and 40 accessions as moderately resistant to stem rot disease. Based on two-year field evaluations, 14 accessions rated with different disease reactions such as resistant, moderately resistant and susceptible were further subjected to oxalic acid response assay under *in vitro* conditions to confirm their disease reaction. The main stem and lateral branch portions of three accessions such as ICG's 2773, 4389, and 14482 were recorded lower wilting score (<3) when immersed even in higher (50 mM) oxalic acid concentrations for 36 hours. The disease reaction of these three accessions was rated as resistant/moderately resistant under field conditions too

HPR P18. Host suitability of kenaf varieties and germplasm lines for resistance against cotton mealybug, *Phenacoccus solenopsis* Tinsley

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During the last decade, infestation of cotton mealybug has been reported for the first time in mesta (*Hibiscus cannabinus*), an important bast fibre crop. Host suitability of mealybug was judged in terms of relative establishment rate, nymphal duration and survival on kenaf varieties and wild lines. Development of 20 uniform crawlers released on the 25-day-old kenaf seedlings in to females was significantly high (11 per plant) in WHIN 47 (*H. acetocella*) with establishment rate of 0.55 indicating higher susceptibility. Among the released varieties, JRM 3 harboured least female and crawler population (4.10 and 401.85 per plant respectively) while another wild line, WHIJ 50 also had adverse effect on mealybug establishment with 2.77 female and 190.54 crawlers per plant. The establishment rate of the insect was significantly low i.e., 0.14 and 0.21 in WHIJ 50 and JRM 3 respectively. The survival rate of the mealybug crawlers reared on the leaves of

the respective kenaf varieties/wild lines indicated significantly highest survival (71.60%) in JBM 81 being at par with the most susceptible germplasm line, WHIN 47 (71.24%). The wild germplasm line, WHIJ 50 recorded least survival (37.41%) and prolonged nymphal duration for both male (28.95 days) and female (23.30 days) mealybug. On the basis of establishment rate, crawler survival and nymphal duration of cotton mealybug, the variety JRM 3 and the wild line WHIJ 50 were identified to be significantly least susceptible which may be used for cultivation as well as source of resistance against cotton mealybug in varietal development programme.

HPR P19. Screening of some popular rice varieties against rice leaf folder *Cnaphalocrocis medinalis* Guenee in the Cauvery delta of Tamil Nadu

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Rice leaf folder *Cnaphalocrocis medinalis* Guenee is a major leaf folder species on rice which could cause around sixty percent damage in the cauvery delta of Tamil Nadu. Eight popular rice varieties of Tamil Nadu were screened against Rice leaf folder *C.medinalis* during Kharif 2018 at the experimental farm, Annamalai University, Annamalainagar. Highest percentage of leaf damage was recorded on BPT 5204 (13.8%) followed by ASD 16 (13.20%) and the lowest leaf damage was observed on TRY 3 (2.7%). The varieties were categorized as susceptible (BPT 5204 & ASD 16), moderately susceptible (CO 43, ADT 43 & ADT 38), moderately resistant (ADT 46 & Swarna sub 1) and resistant (TRY 3) to the rice leaf folder *C. medinalis*

HPR P20. Morphological and biochemical basis of resistance in okra to whitefly, *Bemisia tabaci* and *Okra yellow vein mosaic virus* (OYVMV)

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Field screening studies were conducted to determine morphological and biochemical basis of resistance in okra to whitefly, *Bemisia tabaci* and *Okra yellow vein mosaic virus* (OYVMV) with 25 okra germplasm accessions during summer season of 2015 and 2016 at National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Rajendranagar. The morphological and biochemical parameters analyzed in the selected okra germplasm lines indicated that among the morphological parameters, the germplasm lines possessing high trichome density, less leaf area, and dark green leaf colour along with biochemical parameters such as low nitrogen, protein, less total and reducing sugars, and high phenol content offered resistance mechanism against the whitefly as well as the OYVMV. The three immune okra accessions viz., RJR-124, PSRJ-12952 and IC344598 possessing the above characters were completely free from OYVMV, while the highly susceptible accessions PSRJ-13040 and RJR-193 possessing less trichome density, more leaf area, high sugars, high nitrogen content, and low phenol content were highly preferred by the vector and were highly susceptible to OYVMV. Total sugars, reducing sugars, nitrogen and protein content had positive correlation with the whitefly population and OYVMV incidence.

HPR P21. A rapid *in vitro* screening method for resistance to rice root-knot nematode *Meloidogyne graminicola*

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Rice root-knot nematode Meloidogyne graminicola is the most damaging nematode species infecting rice. Climate change resulting in reduced water availability and high temperatures is further aggravating this nematode problem in many rice growing areas. Currently available control measures are not giving desirable level of control of this nematode in the field due to several limitations. Breeding for resistance is considered as the practical approach for the management of this nematode. This can effectively be achieved by deploying rapid screening protocols for large scale screening of rice germplasm for identification of robust and reliable sources of nematode resistance. Here, we report a rapid in vitro screening protocol for screening of rice germplasm for resistance to rice root-knot nematode using Whatman No.1 filter paper sleeves wrapped in germination paper towel in which seedlings of rice entries were raised. The seedlings were inoculated with second stage juveniles (J2) of nematode and incubated at 25-30ºC. Twenty-five days after inoculation, observations on root galls and nematode multiplication were recorded. The entries were scored based on relative root gall index and nematode reproduction index. This method was found effective when validated with rice entries with known reaction to this nematode. Our results suggest that this method can used for rapid screening of rice germplasm in vitro for resistance to rice root-knot nematode.

HPR P22. Role of surface waxes in plant responses to biotic and abiotic stresses

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Aerial plant organs are covered with a hydrophobic cuticle, consisting of cutin and cuticular waxes, which forms a protective barrier against various abiotic and biotic stresses. Cuticular wax is a complex mixture of very long chain fatty acids and derivatives such as alkanes, alcohols, aldehydes, ketones and wax esters. Waxes are known to protect plant leaf surfaces from pathogen infection. Here, the role of *Arabidopsis* wax mutant (wsd, wax ester synthase/diacylglycerol acyltransferase) and barley eceriferum (wax) mutants were assessed in response to *Pseudomonas syringae* pv. tomato (Pst), a hemibiotrophic bacterial pathogen. The pathogen enters the leaf mesophyll through wounds or natural openings like stomata, and multiplies in the intercellular spaces (Katagiri et al., 2002, The Arabidopsis Book). Most of the wax mutants have an increased cuticle permeability probably due to the altered ultrastructure. A permeable cuticle might allow faster penetration of pathogens through the epidermal cell wall into the cells thereby triggering defense mechanisms which could serve as an important trait to study disease resistance. We already demonstrated that *Arabidopsis* wsd mutants show decreased tolerance to abiotic stress, and that the permeability of *Arabidopsis* wsd and barley eceriferum mutants is increased. In the future, additional analyses involving different plant-pathogen interactions are needed to conclude the contribution of wax genes and cuticular wax composition to plant defense mechanisms.

HPR P23. Field screening of brinjal genotypes against shoot and fruit borer, *Leucinodes orbonalis* Guenée

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Shoot and fruit borer (*Leucinodes orbonalis*) is a notorious pest of Brinjal. With concealed mode of feeding, the pest is able to evade powerful doses of insecticides. Apparently, adoption of integrated pest management practice is the key to check the pest population in field. In our study, an effort has been taken to assess morphological basis of resistance of brinjal germplasm against the pest. A total of 29 brinjal genotypes were screened in the field (Orchard, Tamil Nadu Agricultural University, Coimbatore) during 2017. Among them, the lowest shoot and fruit infestations were observed in IC 099706 (6.66 %) and HD 1 (14.50 %), respectively whereas the highest is in Arka Nidhi (27.30 %) and Omalur local (50.77 %). However, non-significant negative correlation was observed between shoot thickness (r=-0.192), trichome length (r=-0.162), trichome density (r=-0.071) and shoot damage. Similarly, fruit girth (r=-0.089), calyx length (0.071) had no relationship with fruit damage. Upon grouping the genotypes on scales of resistance, only HD 1genotype was emerged as tolerant one. Four genotypes viz., IC090926, Natham Keeri kathiri, Ujala Gold and VRM I Mullu kathiri were registered under moderately tolerant category. Highest number of genotypes tested in the field (17 genotypes) was under susceptible category as their level of infestation ranged between 26–40 per cent. Seven genotypes recorded more than 40 per cent fruit infestation and were hence classified under highly susceptible category. Hence, the study infer that the morphology of the screened genotypes does not significantly exert resistance pressure against the pest.

HPR P24. Lipophilic and amino acid profiles of different agro-ecological *Chilo partellus* populations fed on diverse maize genotypes

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The infestation and relative abundance of *Chilo partellus* (Swinhoe) are highly variable across different agro-ecological conditions. The expression of resistance in *C. partellus* is dependent on biochemical constituent of the host plant. The variation in biochemical constituents in the insect species from diverse agro-ecological regions vis-à-vis feeding on different host plants are important to understand the insect adaptation behavior and insect-plant biochemical interactions. Thus, present studies were conducted to know the effect of diverse food on lipophilic and amino acid profiles of *C. partellus* larvae from different agro-ecological regions. The profiling of *C. partellus* larvae of different populations reared on diverse maize genotypes revealed significant differences in amounts and proportions of 17 amino acids and 15 lipophilic compounds across stem borer populations and the test maize genotypes. The amounts of Glutamic acid, Glycine, Histidine, Arginine, Threonine, Alanine, Proline, Cystine, Methionine, Phenylalanine and Leucine were significantly higher in the larvae of Jhansi population reared on CPM 2, while lower in Raichur population reared on CPM 18. The lipophilic profiling of *C. partellus* larvae showed that the Hisar population of *C. partellus* reared on Basi Local had significantly higher Oleic acid content, and significantly and positively associated with larval growth. The lipophilic compounds, Eicosanoic acid, Squalene, Erucic acid, I-(+)-Ascorbic acid 2,6-dihexadecanoate, Myristic acid and Palmitic acid in the larvae of spotted stem borer were found associated

with development and survival indicating their role in nutritional physiology and plant resistance to *C. partellus* in maize.

HPR P25. Biochemical defense in maize seedlings against spotted stem borer, *Chilo partellus* (Swinhoe)

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Plant resistance to *Chilo partellus* in maize is a complex trait which depends on the interplay of several componential factors. Therefore, we studied the regulation system of certain biochemical constituents and plant defense in the form of activation of enzymatic and non-enzymatic antioxidants in response to damage by *C. partellus* in the seedlings of different maize genotypes viz., CPM 13, CPM 15, CPM 18 and CPM 8 along with resistant (CML 345) and susceptible (Basi Local) checks. The levels of total sugars, total soluble protein, starch, total phenol, and total antioxidant were significantly higher in resistant than susceptible maize genotypes both under damaged and healthy plant conditions, which further increased in response to damage by *C. partellus*. The catalase activity was highest in *C. partellus* resistant maize genotypes including resistant check, CML 345 both under healthy and damaged conditions. The non-enzymatic antioxidant scavenging activity of FRAP was also significantly higher in resistant maize genotypes, which in response to damage by *C. partellus* larvae further increased over the healthy plants. The activity of plant defense antioxidant enzymes viz., ascorbate oxidase, ascorbate peroxidase, phenyl ammonia lyase, tyrosine ammonia lyase was significantly higher in CPM 13, CPM 15, CPM 18, CPM 8, CML 345 than susceptible genotype, Basi Local, which further increased significantly in response to damage by *C. partellus*. Present studies clearly demonstrate regulation of biochemical based defense system against *C. partellus* in test maize genotypes, and these genotypes could be used in insect resistance breeding program.

HPR P26. Catalysing the host plant resistance: An insight into phyto-hormone mediated ISR against dry root rot of chickpea

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Dry root rot (DRR) of chickpea caused by *Rhizoctonia bataticola* has become a serious concern to chickpea production. Changing climatic elements like frequent low soil moisture stress and high temperature are among the probable factors increasing DRR incidence in chickpea. Management of the DRR is challenging, owing to its wide host range, lack of resistant sources and uneconomical chemical control measures. Therefore, an alternate resistance management approach against this disease may be achieved by exploitation of host plant resistance through phyto-hormone mediated induced systemic resistance (ISR). The present study aims to identify the role of phyto-hormones in inducing systemic resistance against chickpea DRR. Two Phyto-hormones Methyl Jasmonic Acid (MeJA) and Salicylic Acid (SA) were used in this study to induce systemic resistance (ISR) against DRR. Of them MeJA was proved to be a robust in playing vital role in inducing resistance against targeted pathogen. The disease severity based on per-cent disease susceptibility index (derived from modified 0-9 rating scale) showed that plants treated with MeJA 50ppm displayed lower degree of DRR severity than the other sub-treatments viz., MeJA at 25ppm and 75ppm. Also, the fungal propagule concentrations present in the root tissues sampled at different time points were analogous with the

above findings. A high positive correlation was observed in the results from real-time qPCR based absolute quantification.

HPR P27. Functional validation of P2c using RNAi mediated host induced gene silencing in groundnut

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Groundnut (*Arachis hypogea*.L) is the most popular legume cum oilseed crop cultivated majorly in all tropical and sub-tropical areas. Aflatoxin contamination in groundnut severely affects the quality of the yield and subsequently the economic trade. These are the potent Group-I carcinogenic mycotoxins produced by *Aspergillus flavus* and *Aspergillus parasiticus*. RNAi is one of the powerful tools that can be deployed to control aflatoxin contamination. *A. flavus* obtains its nutrients in a saprophytic mode and can produce several extracellular hydrolases (amylases, proteases, pectinases) to gain access into the host tissue nutrients. Studies have concluded pectinase P2c as a virulence factor that cannot undergo catabolite repression as other pectinases do and thus contributing to the aggressive growth and spread of *A. flavus* in the host. Silencing this P2c gene expression by small double-stranded RNA by host induced gene silencing (HIGS) mechanism leads to low or no production of P2c to invade host tissue. We transformed a groundnut variety ICGV 91114 with pectinase P2c RNAi cassette targeting the Pec-A gene, which encodes endo-polygalacturonase. This enzyme degrades the pectin, one of the plant cell-wall components. RNAi expressing groundnut plants show a reduction in mycelial growth and aflatoxin production at permissible limits. These results further strengthen our previous data demonstrating that small interfering RNA molecules may be used to silence virulence factors to reduce the crop invasion and spread of the infestation in groundnut, providing a first step resistance check at aflatoxin control and ensuring food safety.

HPR P28. Analysis of gene expressional changes triggered by *R. solani* AG1 IA infection in susceptible and resistant rice varieties revealed presence of host susceptibility genes favouring pathogen invasion

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Sheath Blight (ShB) is an important disease of rice caused by a necrotrophic fungus *R. solani*. Development of rice varieties tolerant to ShB pathogen has been so far unsuccessful primarily due to the unavailability of any resistant source in the rice germplasm. Moreover, being a necrotrophic fungus the molecular mechanism underlying the pathogen proliferation inside the host tissue is largely elusive. Therefore, using a combinatorial approach of RNA sequencing and genome editing we have tried to identify the interacting partners from the host side favouring the invasion and progression of the pathogen. We have used RNA-seq approach to analyse the gene expression changes induced upon inoculation of the AG1A strain of *R. solani*, at different time points, in a moderately resistance cultivar ‘ Tetep’ and susceptible cultivar ‘HP2216.' Our data suggest that the primary pathogen colonization occurs within 24 h and then it ceases with the plant cell death. However, we do speculate that the reinfection of pathogen in the close vicinity might enhance the degree of infection later on. In addition, from the comprehensive list of the differentially expressed genes we have identified few host susceptibility genes suggesting their role as a negative regulator of the plant immune

response. Our comprehensive transcriptome data and the identified susceptibility factors might serve as a valuable resource for understanding the molecular cross talk involved in plant-pathogen interaction.

HPR P29. *Alternaria* leaf spot of Varuna (*Brassica juncea*): investigating the dynamics of plant infection by the necrotrophic fungi *Alternaria brassicae*

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Alternaria brassicae has emerged as a devastating plant pathogen that causes Leaf spot or Blight in a wide range of oil yielding and vegetable Brassicaceae. Due to the lack of suitable resistance sources, this work was carried out to identify the mechanisms underlying the invasion of *A. brassicae* and the subsequent host responses. A comparative histopathological study was undertaken to explore the disease progression and host responses that underlie the defence responses of *B. juncea* and *Arabidopsis* to *A. brassicae*. A comparative histopathological analysis for disease progression and plant responses to *A. brassicae* in *Arabidopsis* and *Brassica juncea* revealed significant similarities between the two compatible pathosystems. Using a subset of resistant (Ei-2, Ull2-3, Lz-0, and Cvi-0) and susceptible (Gre-0, Est-1, and Zdr1) accessions, we show that the susceptibility to *A. brassicae* is associated with higher ROS accumulation and cell death. Susceptibility to *A. brassicae* was reduced in the rboh (D, E and F) mutants that are incapable of producing ROS, suggesting that RBOH D, E and F may act as negative regulators of defence against this pathogen. Additionally, our data also supports the hypothesis that the Jasmonic acid (JA), Ethylene (ET) and Abscisic acid (ABA) signalling pathways positively contribute to resistance against necrotrophic pathogens. These findings provide valuable insights into host pathogen interactions in the Brassica-*A. brassicae* pathosystem, which might be useful for the development of effective blight control strategies across oilseed *Brassica* species.

HPR P30. Regional characterization of pigeonpea sterility mosaic disease and exploring broad-based resistance

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Pigeonpea sterility mosaic disease (SMD) caused by *Pigeonpea sterility mosaic virus* (PPSMV) is a serious threat to pigeonpea production in the Indian-subcontinent. Recent reports on the possible existence of two different viruses associated with the SMD further complicate the etiology of this difficult to manage viral disease. In this regard, a comprehensive and systematic survey was taken up across several pigeonpea growing areas in southern India to know the disease prevalence and variability in virus isolates. Further, selected pigeonpea elite genotypes were screened in different locations for their broad-based resistance. Results indicate huge variation in SMD incidence among the surveyed states. The highest disease incidence (9.38 percent) was observed in Karnataka, followed by Tamil Nadu state with 8.44 per cent incidence. Andhra Pradesh and Telangana states recorded disease incidences of 4.51 and 2.08 per cent respectively. Samples collected from Patancheru location and tested using viral-specific RNA-3 segment primers were all positive for both the viruses. However, one of the samples collected from Bengaluru location and four samples from Coimbatore location had a positive reaction for PPSMV-2 only. In order to identify broad-

based resistance to SMD, 20 pigeonpea genotypes were screened in three different locations (Patancheru, Bengaluru and Coimbatore) in southern-India during rainy seasons of 2017 and 2018. Among them, ICPL-16078, ICPL-16086 and ICPL-16087 showed resistance reaction ((≤10 % incidence) in all the three locations, whereas, ICPL-16072, ICPL-16077 and ICPL-16083 showed resistance to Patancheru and Coimbatore isolates but highly susceptible (≥40 % incidence) to Bengaluru isolate.

HPR P31. Role of plant protease inhibitors in herbivory by *Pieris brassicae* L. (Lepidoptera: Pieridae) feeding on *Brassica oleracea* L. var. botrytis and/or *Tropaeo lummajus* L.

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Plant Protease Inhibitors (PPIs) are defence compounds produced in response to herbivory. Serine protease inhibitors are major PPIs which inhibit trypsins and chymotrypsins induced in guts of lepidopteran larvae feeding on multiple species of host plants. *P. brassicae* is a recurrent and global pest of crucifers. Recent reports suggest that it can feed prolifically on the edible garden nasturtium, *T. majus*. Mid gut trypsin activity of fourth instars was found to be adapted to PPIs isolated in our lab from these host plants. CFTI-L and TPTI-L (from mature leaves) were identified using ammonium sulphate precipitation, affinity chromatography and LC-ESI-MS from induced leaves of host plants. They strongly inhibited Bovine Trypsin (BT) and gut samples from larvae fed on alternate hosts as detected using synthetic substrates. CFTI-L and TPTI-S (from seeds) were found to resemble BoPI (Accession# T14442 reported from wild cabbage, Broadway, 1989). Results obtained were also confirmed by reverse zymography. Implications of this study can be employed to improve pest-management strategy using transgenic approaches.

HPR P32. Bio-chemical basis of nematode resistance in cotton in response to reniform nematode, *Rotylenchulus reniformis* infection

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The reniform nematode, *Rotylenchulus reniformis* is one of the major limiting factors affecting plant growth and yield of cotton in India. Apart from causing disease on its own, reniform nematode increases the incidence of diseases in cotton which in turn increases the yield loss many fold. Nematode management has been achieved by adopting various methods either singly or in combination. These methods are either directed toward the host and/or pathogen. Among different methods, identification of resistance to reniform nematode is the first step in developing resistant cotton cultivars. This study was conducted to study the biochemical basis for nematode resistance in cotton in response to Reniform nematode infection. Three *Gossypium hirsutum* cultivars with varying level of nematode resistance viz., Resistant (American Nectariless), moderately resistant (G Cot 10) and susceptible (Suraj) were selected for the study. Observations on different life stages of nematode (unswollen female, adult female, female with gelatinous matrix, female with egg sac, eggs/egg mass) and biochemical parameters (P peroxidase, G peroxidase, phenol and reducing sugar) were recorded at periodical intervals upto 21 days post infection. Elevated level of P peroxidase, G peroxidase, phenol and reducing sugar were recorded at 11 days post infection in all cultivars. Time taken to reach different developmental stage varies with the germplasm tested. There was significant difference in root and soil nematode population in different germplasm with American Nectariless recording

significantly low population followed by G cot 10. A positive correlation between nematode resistance and P peroxidase, G peroxidise and phenol was observed.

HPR P33. Differential gene expression profiling in response to pigeonpea sterility mosaic virus in pigeonpea (*Cajanus cajan* (l) Millsp.)

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Pigeonpea is an important grain legume of the semiarid tropic and become a significant component of the diet of vegetarians. Pigeonpea sterility mosaic virus (PPSMV) causes yield losses to the extent of 30-100%. Study is envisaged to recognize differentially expressed genes among pigeonpea cultivars during host-pathogen interaction. The resistant cv. IPA-16-F and susceptible cv. ICP-8863 was inoculated by PPSMV with three biological replications along with control samples. The RNA was extracted and further utilized to synthesize cDNA at seedling and flowering stage of pigeonpea. Gene expression analysis was executed by differential protein and Real-time PCR analysis. The comparative protein expression profile generated during seedling and flowering stage showed an elevated differential expression pattern indicated the expression of different defense protein or PR protein during the course of pigeonpea and PPSMV interaction. However, Real time gene expression analysis exhibited upregulation of flowering time control protein (FCA) gene, flowering time control protein (FPA) gene, pollen development SF3 gene, flowering promoting factor (FPF) gene, and flowering control protein (FCA) during the course of interaction of PPSMV.

HPR P34. Understanding the molecular basis for resistance of chow chow/chayote fruit to *Bactrocera cucurbitae* compared to cucumber

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Chayote or chow chow, an unassuming fruit shows high resistance to one of the most notorious agricultural pest, melon fly or *Bactrocera cucurbitae*. Primary biochemical characterization has suggested production of high levels of NO and H2O2 in the chow chow fruit compared to cucumber. The H2O2 is likely responsible for larval death in the fruit thus making the chow chow resistant to melon fly. In order to understand the molecular basis for production of H2O2 and to look at what pathways are triggered, fruit tissue transcriptome was obtained for cucumber and chow chow. Using Dseq statistics, DE genes were identified among the Infested and healthy cucumber and a total of 643 genes were found to be DE of which 481 were up-regulated and 162 were down-regulated in the infested cucumber. The KEGG pathways that had the most number of DE genes assigned in chow-chow were, folding, sorting and degradation, Carbohydrate metabolism, Protein families–genetic information processing, Signal transduction and Translation. Melon fly infested cucumber showed up-regulation of genes involved in ROs response pathways such are glutaredoxin, hydroperoxide lyase and patatin known to be misexpressed in response to pathogens. In chow chow, ROS response pathways and stress related pathways showed DE genes like heat shock proteins, cationic peroxidise and dehydration responsive protein. Further detailed analysis is being carried to identify and assign genes that are involved in these pathways which could then be used for functional characterisation.

HPR P35. Validation of putative candidate genes in planthopper resistance in rice

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Plant hoppers, such as brown plant hopper (BPH) and white backed plant hopper (WBPH) are most important destructive pests of rice. So far, 36 resistance genes for BPH and 14 for WBPH have been identified in rice. However, none of these provide resistance to both the plant hoppers. A breeding line RP2068-18-3-5, was identified with high level of resistance against both BPH and WBPH, though responsible loci appear to be different. Our ongoing research based on analysis of 180 F13 RILs derived from TN1 X RP2068 cross has identified a novel gene Bph33. Subsequent studies have identified three major QTLs against WBPH and three more QTLs for BPH. Here we report involvement of five likely candidate genes in conferring resistance to these plant hoppers. A set of 4 RILs with different reaction to these pests was chosen for validation of five candidate genes namely: HSP, LRR#1 on chromosome 1, LRK2, LRK3 and LRR#4 on chromosome 4. Stem samples were collected from control and infested plants at 6 & 12 hours after infestation. Results suggested that HSP gene was upregulated against both the plant hoppers. LRK2 and LRK3 were down regulated in all the samples. Performance of LRR#4 was inconsistent. More studies are in progress to confirm these results

HPR P36. Association of molecular heterozygosity with Sigatoka resistance in banana (*Musa* spp.) genotypes

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The investigation was carried out with a view to characterize and validate the DNA markers associated with Sigatoka resistance at molecular-level in a given elite banana genotypes. Efforts were made to study DNA polymorphism via markers linked to Sigatoka resistance in the given set of banana accessions. On the basis of percent disease index, 37 banana accessions were classified into three categories as resistant, moderately resistant and susceptible with 3, 27 and 7 genotypes, respectively. Thus, these three resistant cultivars namely, Namrai, Mutheli and Borkel Baista proved to be promising and can be utilized as donors to introgress Sigatoka-resistance in Musa breeding programme. A total of 720 (96.11%) polymorphic bands were detected across 53 loci from 15 polymorphic SSR markers with average PIC value of 0.759. In case of RAPD and ISSR, 194 (100%) polymorphic bands were detected by 3 RAPD markers with average PIC value of 0.842 and 261 (100%) polymorphic amplicons from 3 UBC-ISSR markers with PIC value of 0.614. Thus, high level of polymorphism could be detected across different marker-systems using present set of DNA markers. Genetic distance among 37 banana accessions was ranged from 0.077 to 0.717 with an average of 0.450. As revealed from the clustering in accordance with Sigatoka resistance, good number of hybrids can be obtained from the heterotic combinations of genetically diverse diploids and triploids. Thus, such 'Resistant x Resistant/Moderately Resistant' intra and interspecific crosses coupled with high productivity and fruit quality can be advocative in empirical banana breeding through MAS/MAB.

HPR P37. Deciphering the defence response against collar rot in chickpea (*Cicer arietinum* L.) during combined biotic (*Sclerotium rolfsii*Sacc.) and abiotic (soil moisture) stress

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As plants being sessile and grow in open field conditions, they always remain under constant threat of multiple-combined biotic and abiotic stress concurrently within its natural habitat. Some reports on combined stress revealed increasing susceptibility of the plants to pathogens. To overcome the effects of those combined stress, plants also have adopted a self-regulatory synchronized defence mechanisms. Collar rot (CR) (*Sclerotium rolfsii* Sacc.) in chickpea has become an emerging threat (biotic stress) under recent climatic change scenario as it is highly influenced by changes in soil moisture conditions (SMC) (abiotic stress). Hence, we studied the impact of different SMC viz. limiting (40%), optimum (60%) and upper optimum (100%) on CR development and pathogen colonization in two chickpea cultivars viz. ICCV 05530 (moderately resistant) and Annigeri (susceptible) over the course of infection. The results revealed that the CR incidence was directly proportional to SMC (R2 = 0.794). Minimum incidence was observed at limiting SMC, whereas maximum in optimum SMC. In combined stress (biotic and abiotic), the expression of defence-response genes were highly up-regulated in chickpea as compared to chickpea challenged with individual-stress. Beside response of host defence-related genes, pathogen's genes associated with host cell wall binding (lectin) and enzymatic degradation viz. cellobiohydrolase, endoglucosidase and endopolygalacturonase-2 were found to be highly up-regulated in limiting SMC as compared to other SMC during CR development. The results of this study indicated that low SMC was primarily responsible for delayed disease reaction due to tailored response of moisture and defence-related genes.

HPR P38. Exploitation of host plant resistance and characterization of *Macrophomina phaseolina*, dry root rot pathogen of mungbean

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The fungus *Macrophomina phaseolina* (Tassi) Goid belongs to class Botryosphaeriaceae of order Botryosphaeriales, has a widespread host range including mungbean (*Vigna radiata* (L.) R. Wilczek var radiata). The fungus causes dry root rot, which is an emerging disease of mung bean. The management of disease is difficult due to soil and seed borne nature of the pathogen. Host plant resistance could be a potential option for the control of the disease. In the present study *M. phaseolina* isolated from three legume crops such as mung bean, urd bean (*Vigna mungo* (L) Hepper) and vegetable soybean (*Glycine max* (L.) Merr.) were identified based on morphological characteristics and sequencing internal transcribed sequence (ITS) region of 18S rRNA. Screening (paper towel method) of 43 mung bean genotypes against *M. phaseolina* isolated from mung bean revealed that 9 genotypes were resistant in repeated experiments, with disease score ranging from 1.9 to 3.0. Among 9 genotypes, IPM99-125, EC693368, and EC693369 genotypes having lower disease score were further evaluated by sick pot method to verify their resistance. Genotypes IPM99-125 exhibited higher percentage of plant survival (81.9%) followed by EC693368 (77.4%) and EC693369 (77.7%) as compared to susceptible checks VC3960-88 (3.4%) and KPS1 (13.4%). In addition, cross pathogenicity experiment revealed that these three genotypes were resistant against two strains of *M. phaseolina* isolated from urd bean and vegetable soybean. IPM99-125 genotype recorded lowest disease score. Thus, IPM99-125 genotype could be useful in mung bean breeding programs to develop dry root rot-resistant varieties.

HPR P39. Identification of potential sources of resistance in mungbean against anthracnose disease caused by *Colletotrichum truncatum*

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Mungbean (*Vigna radiata* (L.) R. Wilczek var. radiata) is an important legume crop grown predominantly in South and Southeast Asia. Several biotic and abiotic factors hinder the production of mungbean. Among the biotic stress, anthracnose disease is an important fungal disease of mungbean, and losses are common particularly in humid regions. In our study, twenty mungbean lines (15 improved lines along with 2 resistant (VI000020 AY, VI004743 AG) and 3 susceptible (VI004423 AG, VI000212 A-BLM, VI004666 AG) checks from mini core collections) were screened in the field under natural incidence of the anthracnose. Cultural, morphological characteristics and molecular studies (based on 18S rRNA specifically ITS1 and ITS2 regions sequencing) of the pathogen revealed that the casual organism is *Colletotrichum truncatum* (Schwein.) Andrus & W.D. Moore. Among fifteen improved lines, AVMU 1639 was highly resistant, 5 lines were resistant, 7 were moderately resistant and 2 were moderately susceptible. Analysis on the relative progress of the disease showed positive correlation with rainfall, minimum temperature, maximum temperature and relative humidity. Preliminary results indicated that AVMU1639 could be used as a potential source in the anthracnose resistance breeding program.

HPR P40. RNA-Seq of Guar (*Cyamopsis tetragonoloba*, L. Taub.) roots: identification and characterization of SSR, SNP and InDel molecular markers

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Cluster bean [*Cyamopsis tetragonoloba*, L. Taub.] commonly known as guar, is an economically important legume crop because of the presence of galactomannan or guar gum in its seed endosperm. The high global demand of guar gum has led to the necessity of producing improved varieties of guar. The plant breeding programmes based on marker-assisted selection requires a rich resource of molecular markers. As the genome of guar is not sequenced yet there is limited molecular marker resource available for the genetic improvement in this crop. Hence, the purpose of this study is to enrich the molecular marker resource of guar by identification and characterization of high quality SSR, SNP and InDel markers from the root RNA-Seq data of RGC-1066 (gum producing) and M-83 (vegetable) varieties of guar. Approximately 30 million high quality pair-end reads of each variety were generated by an Illumina HiSeq 2500 platform and a total of 102,479 unigenes with an average length of 1016 bp were assembled by Trinity program. The functional annotation of assembled unigenes showed highest similarity of guar unigenes with Glycine max. The screening of 102,479 unigenes with MISA and SAMtools version 1.4 softwares resulted in the identification of 25,040 high-confidence molecular markers which consisted of 18,792 SSRs, 5999 SNPs and 249 InDels. Each of the 25,040 molecular markers was characterized, particularly with respect to its position in the unigene. For 71% of the molecular markers, the names, products and functions of the unigenes were determined and about 80% of the markers, from a random sample of molecular markers, showed PCR amplification. These markers are expected to be highly useful in molecular breeding programmes and in studying molecular mechanisms of root development, stress tolerance and gum synthesis in guar.

HPR P41. Evaluation of garlic (*Allium sativum* L) genotypes for resistance to onion thrips, *Thrips tabaci* Lindeman

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Onion thrips, *Thrips tabaci* Lindeman causes severe losses in garlic production in India and search for resistance cultivars and traits is gaining impetus to manage the thrips economically. Nine garlic cultivars were evaluated against onion thrips. Host plant traits, the parameters including leaf angle, plant height, number of leaves, number of cloves per bulb, total soluble solids and total phenol content were also estimated. On basis of damage rating, cultivar, UHF G12-2 was found as resistant; two as moderately resistant (G-282 and PGS-204), five as susceptible and one as highly susceptible. On the basis of thrips density, two cultivars (UHF G12-2 and Bhima purple) categorized as resistant, four genotype as moderately resistant; one as susceptible and two as highly susceptible. Regardless of scale of evaluation followed, cultivar, UHF G12-2 found to be resistant and G-282 and PGS-204 as moderately resistant. The relationship between leaf angle (r= -0.895**) as well as total phenol content (r= -0.836**) and thrips density revealed that a significant negative correlation; plant height, number of leaves had a non-significant negative correlation; while number of cloves and total soluble solid revealed a non-significant positive correlation. Regression analysis suggests that, wider central leaf angle is a key trait that reduces the thrips infestation. The principle component (PCs) analysis explained 81.2% cumulative variations in thrips infestation. Thus, garlic cultivar UHF G 12-2 could be promising genotype that is tolerant to onion thrips and high yielding. This can be utilized in further garlic improvement programme for developing pest resistant cultivars.

HPR P42. Sunflower broomrape (*Oroban checumana* Wallr.) and climate change effects

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Sunflower broomrape (*Orobanche cumana* Wallr.) is a holoparasitic plant that currently represents one of the most serious production constraints in many sunflower-producing countries around the world, especially in Central and Eastern Europe, Spain, Turkey, Israel, Iran, Kazakhstan, China. Broomrape attack is frequently severe and yield losses can reach up to 70-90%. Climate change could influence development of the pathogens/parasites, host-parasite interaction. Direct impact of climate change on sunflower pathogens/parasites are observed. Some dominant changes occur between pathogenic races of this parasite, according to its thermal preferences. In a classical study on the host-parasite system Sunflower- *Orobanche* it was showed the gene-for-gene model. Our studies demonstrated that races overcoming all the known resistance genes to races A to G were identified in the regions under high water stress in Romania.

HPR P43. Identification of pearl millet blast resistant source against different pathotypes

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Pearl millet leaf blast caused by *Pyricularia grisea* (teleomorph: *Magnaporthe grisea*), is one of the most important diseases of pearl millet in India. The disease can be best managed by breeding blast resistant hybrid cultivars. For identification of resistance in the elite hybrid parent lines, designated B-lines and R-lines (200 each) were screened under greenhouse conditions against six diverse pathotype-isolates of *M. grisea* (Pg 45, Pg 118, Pg 138, Pg 186, Pg 204 and Pg 232). Of the 200 designated B-lines, 34 lines were found to be resistant to at least one pathotype. Though none of the lines was resistant to all six pathotypes, ICMB 97222 was found resistant to five pathotypes. While three lines [ICMB 94333, ICMB 10999 and advanced B -line ((B x B) F2 S1-109-2-3-3-1-1-4)] were resistant to any four pathotypes. Eleven lines were resistant to three pathotypes and six were resistant to any two pathotypes. Maximum 20 lines were resistant to Pg 45 followed by 17 to Pg 186 and 15 to Pg 118 and 12 to Pg 232. Among designated R-lines, ICMR 08111 and ICMR 10888 exhibited resistance to all the six pathotypes. Whereas, ten lines were resistant to any five pathotypes and 11 lines were resistant to any four pathotypes. Maximum 44 lines were resistant to Pg 204 followed by 39 to Pg 45 and 33 each to Pg 118 and Pg 232. The designated A/B-lines and R-lines having resistance to multiple pathotypes can be used to develop pearl millet hybrids with durable blast resistance.

HPR P44. Validation of shoot fly resistance introgression lines using SNP markers in sorghum

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Shoot fly is a major pest in sorghum production, globally. Shoot fly management using insecticides is expensive and environmentally un-safe. Therefore, host plant resistance is exploited to develop shoot fly resistance (SFR) lines including transfer of shoot fly resistance QTLs using marker assisted backcrossing. QTLs controlling SFR component traits, glossiness, trichome density, ovipositional non-preference were used for introgression in this study. Three QTLs associated with shoot fly resistance were introgressed into elite cultivars Parbhani Moti and ICSB29004. Crosses were made between recurrent parents and the QTL donors viz., J2658, J2614, and J2714. The SFR QTLs were successfully introgressed using foreground and background selection. Phenotyping of these lines led to the identification of resistant lines for each QTL region present on chromosome SBI-01, SBI-07 and SBI-10 in ICSB 29004 and Parbhani Moti. Validated the introgression lines using single-nucleotide polymorphism (SNP) markers tightly linked to shoot fly resistant QTLs. Ten SNPs linked to shoot fly resistant component traits, glossiness and trichome density on SBI-10 and SBI-05 were used for validation. The results showed the introgression lines with QTL present on chromosome SBI-10 were segregating for four favorable alleles for leaf glossiness and two for trichome density in homozygous condition. Other introgression lines with QTLs on chromosome SBI-01 and SBI-07 for component traits - oviposition non-preference, seedling vigor are segregated for glossiness trait also. This study showed that SNPs can be used to validate introgression lines and can be used as genomic markers for early generation selection of shoot fly resistance lines.

Poster session V: Detection and diagnosis: DNA barcoding

DDB P1. *Fomitopsis cajanderi* and *Ipscally graphus*: impacts and implications on the genus *Pinus* (Pinaceae) in the Hispaniola

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The Hispaniola (Dominican Republic and Haiti) is the second largest island in the Caribbean region comprised of several terrains which differ in their origin and geologic history. The island has the highest peak of all the Antilles (Duarte Peak, reaching 3.175 m a.s.l.) and its lowest point, Lake Enriquillo, approximately 40 meters below sea level. The combinations of these factors have favored a large diversity of plants. The vascular flora plants of Hispaniola have already been well studied and possess about 6,000 species, of which 2,000 are endemic (33% endemism). *Pinus occidentalis* is an endemic species of the island and *Pinus caribaea* is an introduced and naturalized species. The species of pore fungi *Fomitopsis cajanderi* and the coleoptera *Ips callygraphus* are the main mortality agents of the genus *Pinus*. *P. occidentalis* is the main species on the island and its altitudinal distribution ranges from 100 to 3,050 meters above sea level. The damage caused by this fungus and insect is analyzed and described and information about its distribution is offered. Other pathogens that attack pine species are the ambrosia beetle *Xyleborus* sp. (Coleoptera). More studies on diversity and ecology, as well as extensive fieldwork regarding taxonomic and phylogenetic research are required and necessary in the island, in order to elucidate and understand the ecology of many forest and agricultural pathogens. It is urgently necessary to establish a binational strategy of forest health and a phytosanitary information system in order to mitigate and control the pathogenic organisms that cause forest diseases.

DDB P2. Molecular identification of insect pests in soybean of southern Rajasthan

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DNA barcoding is a rapid, reliable and cost-effective easy molecular identification tool of unknown and invasive insect pest species based on the reference sequences. This technique uses a short fragment of the mitochondrial cytochrome c oxidase subunit I (COI) gene which is sequenced and used as the 'DNA barcode' for distinguishing species. During kharif, 2017 & 2018, larvae, grubs, maggots and adults of pests from soybean fields were collected and preserved in 95% ethanol at -20ºC until further use. Total genomic DNA was extracted using DNASure Tissue mini kit and intact genomic DNA was visualized in 1.2% agarose gel. The PCR reaction was carried out for the amplification of Cytochrome oxidase subunit I (COI) gene which is of ~680 by using universal primers LCO1490 and HCO2198. The purified PCR products were sequenced and aligned. The homology was confirmed by using NCBI-BLAST and also from the Barcoding of Life Data system to confirm the identity of the sequence. The sequence was deposited in the Genbank of NCBI and accession numbers were obtained. A total of 15 sequences were analyzed and deposited in the NCBI gene bank to obtain the accession numbers. Some of the important insect pests of soybean are *Spodoptera litura* (MK000729); *Bemisia tabaci* (MK000727); *Amyna axis* (MK000726); *Spilosoma obliqua* (MK000725); *Chrysodeixis eriosoma* (MK000724); *Aloa lactinea* (MK000723); *Spodoptera exigua* (MK000731) etc. This

type of molecular analysis using COI genes are effective method for identifying insect-pests and also aid in better management practices in soybean.

DDB P3. Determining the seed health status of germplasm of ICRISAT mandate crops for long term conservation in the gene bank

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Genebanks are considered as reservoirs and sources of alleles for crop improvement. ICRISAT serves as a world repository of germplasm of its six mandate crops and five small millets. It conserves over 120000 accessions collected from different countries which are available as International Public Goods (IPG). Plant Quarantine Unit of the ICRISAT helps genebank in conserving healthy germplasm for the safe exchange of germplasm. The pathogens reduce the germplasm longevity during storage. To assess the seed health status, a total number of 38, 236 genebank accessions of sorghum (9705), pearl millet (6617), chickpea (8376), pigeonpea (5750), groundnut (3131), finger millet (3770) and five small millets (887) were tested during 2012 to 2018. Of the 38,236 accessions, 6688 accessions (sorghum: 880; pearl millet: 703; chickpea: 2710; pigeonpea: 41; groundnut: 383; finger millet: 1664; and five small millets: 307) were free from fungal infections. Saprophytic fungal contamination was found in 22,306 accessions [sorghum (5492), pearl millet (4819), chickpea (3195), pigeonpea (4677), groundnut (1747), finger millet (1935) and five small millets (441)]. A total of 9144 accessions comprising of sorghum (3332), pearl millet (1094), chickpea (2471), pigeonpea (1032), groundnut (1001), finger millet (75) and small millets (139) were found to be unfit for long term conservation and need to be regenerated as these accessions were infected with pathogenic fungi such as *Pyricularia grisea*, *Fusarium oxysporum*, *Phoma* spp, *Bipolaris* spp, *Exserohilum* spp. *Curvularia* spp., *Colletotrichum dematium*, *Alternaria alternata*, *Aspergillus flavus* and *Macrophomina phaseolina*

DDB P4. Survey of wilt complex of chickpea (*Cicer arietinum* l.) and molecular identification of complex pathogens

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Among the pulses, chickpea (*Cicer arietinum* L.) is the largest produced food legume of South Asia and third largest produced food legume globally. Chickpea wilt complex, which manifests itself by wilting or root rots, is one of the most important, devastating and challenging disease which can damage the crop at any stage. Survey of the wilt complex causing pathogens was conducted during rabi 2018-19 in major chickpea growing areas of Gujarat viz., Dahol, Panchmahal, Bhal and Ghed regions. It was revealed that the disease was prevalent at all the locations and the incidence varied from 2.25 to 58.50% thereby indicating seriousness of the problem. The pathogens were isolated from infected stem and root on Potato dextrose agar. The molecular identification was carried out by DNA extraction followed by PCR amplification of 18S rDNA gene target using universal primers ITS1 and ITS4. Based on sequence similarity, these isolates were identified as *Fusarium oxysporum*, *F. solani* and *Macophomina phaseolina*.

DDB P5. Gemini viral populations infecting cash crops in eastern India

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The family Geminiviridae is the second largest family of plant virus and contains four genera: Mastrevirus, Curtovirus, Topocuvirus and Begomovirus. More than 80 percent of geminiviruses, that cause devastating diseases of economically important crops in tropical and subtropical countries, belong to the genus Begomovirus. Different agro-ecological situations under which multiple begomoviral infections caused in plants might be a suitable candidate for emergence of newer viruses due to recombination and pseudo-recombination. Several weed host serve as alternate hosts for these viruses, especially when the main crops are absent in the field. With an aim to diagnose newer emerging begomoviruses and to understand their relationship, plants showing typical begomoviral symptom expressions, were searched from different families. Transmission electron microscopy, PCR amplification with specific primers, Southern blot hybridization, and CAPS analysis proved association of diverse Begomoviral populations with the diseases. Further some of the Begomoviral isolates were also cloned and the sequences were also analysed for determination of phylogenetic relationship among them. Sequence analysis of different begomoviruses and betasatellites associated with the diseases from different locations showed genomic diversity within them.

DDB P6. Ypt1 gene based recombinase polymerase amplification assay for *Phytophthora capsici* and *P. tropicalis* detection in black pepper

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Foot rot caused by *Phytophthora* is one of the major diseases of black pepper (*Piper nigrum* L.). Recent studies indicated that two species, *P. capsici* and *P. tropicalis* with different symptomatology infect black pepper. The pathogen infects all parts of black pepper vine and causes significant yield loss. Timely diagnosis of the disease is crucial for its successful management. Although PCR and qPCR assays are used for detection, the cost and time required to perform the assays is still high. Recombinase amplification assay (RPA) has the advantage of minimal assay time and it is performed under isothermal conditions. Hence, RPA assay was developed for the detection of *P. capsici* and *P. tropicalis*. Out of three sets of primers analyzed, primer set based on *Ypt1* gene could successfully amplify a 230bp product. Optimum amplification of RPA products were observed when the assay was performed at 37 °C with 14mM magnesium acetate for 40 minutes. Sensitivity analysis using serial dilutions indicated that RPA is 10 times more sensitive than PCR. During specificity analysis, non-specific bands were observed with other *Phytophthora* species and hence the assay was further fine-tuned with betaine. Addition of 1.0M betaine helped to avoid amplification of non-specific bands. The optimized RPA assay could detect *Phytophthora* from infected black pepper leaf, stem and root using both purified DNA and crude extracts. These results indicate the robustness of the developed RPA assay and its potential application in detection and differentiation of *P. capsici* and *P. tropicalis* infecting black pepper

DDB P7. Multiplex PCR assay for the simultaneous detection of chickpea chlorotic dwarf virus and Ca. *P. aurantifolia* in chickpea

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Severe stunting and phyllody symptoms were observed in different farmer fields of chickpea at Proddatur and Jammalamadugu mandals of Andhra Pradesh during Nov-Dec 2018 with an incidence of 20-30 per cent. Total DNA from symptomatic and non-symptomatic chickpea plants was extracted and PCR assay was performed using primer pairs P1/P7 and nested primers R16F2n/R16Rn for the amplification of phytoplasma and MCPF/R coat protein specific primers were used for the amplification of *Chickpea chlorotic dwarf virus* (CpCDV). But, generally it took lot of time and consumables in analyzing the samples by routine PCR assays. Hence an attempt was carried out to identify the phytoplasma and CpCDV association with chickpea stunt and phyllody by developing a multiplex PCR assay. PCR conditions were optimized by employing initial denaturation at 94ºC for 4 min followed by 30 cycles of denaturation at 94ºC for 1 min, annealing temperature at 56ºC for 2 min, extension at 72ºC for 3 min and final extension of 72ºC for 10 min. Three sets of specific primers used earlier for individual PCR assays for phytoplasma and virus were used together in the assay. Expected fragments of 1.8 kb, 1.2 kb and 590 bp were successfully amplified by this multiplex PCR assay ensuring sensitive and specific detection of the phytoplasma and CpCDV together in one PCR cycle. Further the amplification products were sequenced and confirmed mixed infection of CpCDV and Ca. *P. aurantifolia* (16SrII-D) subgroup associated with chickpea stunt disease based on DNA and coat protein sequence comparison analysis.

DDB P8. Mitogenome- and SSR-based markers differentiate brown plant hopper (BPH) populations from India

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Brown planthopper (BPH; *Nilaparvata lugens*) is the most destructive pest of paddy in India as it is capable of traversing long distances and therefore, widely distributed. To devise effective control mechanisms, it is necessary to understand the variability and identity of the insect populations prevalent in an area. In this study, the control region of BPH mitogenome, representing eight different populations from India was PCR amplified, using two different primer pairs, as two overlapping fragments (~0.8 kb and ~1.8 kb). Using bioinformatics tools, the complete contig of the control region of each BPH individual screened was re-constructed and its subsequent sequence analysis revealed presence of various tandemly repeated motifs of variable sequence, size and copy number. The complete sequence of the control region was subjected to restriction analysis in silico (digital Restriction Fragment Length Polymorphism; dRFLP). Based on the number of repeats present and the information obtained from dRFLP, it was possible to broadly differentiate the BPH populations. Subsequently, to enhance the effectiveness of the marker-based screening method, genomic Simple Sequence Repeat (gSSR) markers were also incorporated. Statistical evaluation of the combined dataset obtained using both types of markers helped assign Variable in Projection (VIP) score for

each marker. Successful identification of markers with high VIP scores and capable of effectively differentiating BPH population will help rapid identification of any variation in the population and thus would be invaluable for developing Integrated Pest Management (IPM) strategies for the effective management of this economically important pest of rice.

DDB P9. DNA barcoding of storage pests for effective pest management practice

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DNA barcoding is a technique of sequencing a short fragment of the mitochondrial cytochrome oxidase subunit I (COI) gene that has proven to be a useful tool for rapid and accurate species determination in many insect taxa. Also, DNA barcoding aids in the successful implementation of IPM that hinges on the accurate identification of pest and beneficial arthropods at the species level. In this present study, we developed barcodes for storage pests viz., *Triboilum castaneum*, *Sitophilus oryzae*, *Rhyzopertha dominica*, *Callosobruchus maculatus*, *Sitotroga cerealella*, *Lasioderma serricorne*, *Stegobium panecium*, *Caryedon serratus*, *Oryzaephylus surinamensis*, *Ephestia cautella*, *Cadra cautella*, *Pthorimaea operculella*, *Cryptolestes pusillus* and *Corcyra cephalonica* that were collected from different hosts. These barcodes serve as a base data for delineation of species, provides information on levels of genetic variation and movement between the populations which is essential for developing appropriate strategies for storage insect pest management. Also, these DNA barcodes have significant implications for quarantine detection, regulation, and management.

DDB P10. Chlorate phenotypes and molecular characterization of *Rhizoctonia bataticola*, the dry root rot pathogen of chickpea

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Rhizoctonia bataticola (Taub.) Butler. (Pycnidial stage: *Macrophmina phseolina*) causal agent of dry root rot is a major biotic constraint for chickpea production causing 10-20% yield losses annually in India. A thorough knowledge of variability of *R. bataticola* is essential to design disease management strategies for different agro-ecological zones of the country by breeding location specific resistant cultivars. In the present study thirty six pathogenic isolates of chickpea were subjected for variability analysis. Chlorate is analogue of nitrate, which acts as substrate for fungus growth and development. Chlorate utilization depends on nitrate reductase enzyme activity, the isolates sensitive to chlorate are deficient in enzyme and insensitive isolates have abundant enzyme activity. Based on phenotypic data isolates were classified in to three classes viz., sensitive (12 no.), moderately sensitive (7 no.) and insensitive (17 no.). Existence of three phenotypes indicated that, there is no host specificity observed regarding chlorate utilization. Genetic diversity of *Rhizoctonia bataticola* isolates was studied by SSR and SRAP markers and all the isolates were grouped in to four clusters. First cluster consisted of four isolates, second cluster contains two isolates, 29 isolates and one isolate was kept in separate cluster. In the present study, there is no correlation exists between chlorate variability with molecular diversity. The isolates had no apparent grouping according to geographical areas or host origin. This study indicated a wide host range of the pathogen and it might have spread in to many states through seed.

DDB P11. Conflicting status of genetic structuring in two fruit fly pest species (*Bactrocera dorsalis* and *B. correcta*) in Western Tamil Nadu

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Fruit flies of the family Tephritidae are one of the diverse and agriculturally important insects. It needs reliable taxonomic procedures to resolve species complexes, genetic and population structure analyses to effectively control this pest. Little attention has been given to the analysis of genetic diversity in South Indian populations. By using mitochondrial cytochrome oxidase, I and II (cox1 and cox2), the genetic structure analysis of *B. dorsalis* and *B. correcta* from different geographical locations of major fruit growing areas in Western parts of Tamil Nadu were investigated. Genetic diversity indices such as number of haplotypes (H), haplotype diversity (Hd), and nucleotide diversity (π) of the analysed populations revealed a high level of genetic diversity for both the species. However, distinct genetic structure was observed only in *B. dorsalis* not for *B. correcta* which might be due to incomplete species identification procedures in *B. dorsalis* and the probable infection from *Wolbachia*. Future studies should concentrate on extensive sampling from varied geographical locations of South India along with complete species delimitation and *Wolbachia* infectious status, as well as microsatellite marker analysis which would enable us to understand the complete genetic and population structure of this pest. This information will be useful to devise an area-wide management program for this destructive pest.

DDB P12. Molecular identification of common booklice by loop-mediated isothermal amplification

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Booklice in genus *Liposcelis* (Psocodea: Liposcelididae) often found in food industry and stored products worldwide, causing serious economic losses. The identification of booklice in morphological taxonomic methods is much more difficult because of their tiny size, at the same time, expertise and experience required. The traditional PCR identification technology needs expensive, specialized equipment. Loop-mediated isothermal amplification (LAMP) can be used as a rapid species diagnostic tool to deal with the situation. LAMP is worthy to be spread, with advantages of high efficiency, high sensitivity, high specificity and easy operation. In this study, a relatively quick and simple method was used to detect the DNA of common booklice species (such as *Liposcelis entomophila*, *L. bostrychophila*, *L. decolor* and *L. paeta*) rapidly and discriminate it from other common booklice species. Cytochrome coxidase subunit I (COI) was chosen as the molecular maker. Four special primers (F3/B3, FIP/BIP) were designed for each species. The LAMP reaction can be completed under 56℃ within one hour. The results could be visualized in typical trapezoidal bands by gel electrophoresis, qPCR and fluorescent display under UV light. This method can be applicable for rapid detection and identification in practice especially suitable for the basic units and on-site test.

DDB P13. The CGIAR 'Germplasm Health-Community of Practice' for strengthening germplasm phytosanitary safety and mitigation of transboundary spread of pests

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The CGIAR Germplasm Health Community of Practice (GH-CoP) comprise a formal network of 11 Germplasm-Health Units (GHUs), one per center. The GHUs have a common-mission to mitigate the spread of transboundary-pests (=pathogens and pests) during the germplasm distribution activities between CGIAR genebanks and partners programs located in several countries around the world. The GHU network under the auspices of the CGIAR Genebank Platform works in close collaboration with the national and regional plant protection organizations in enabling the production, maintenance and distribution of pest-free germplasm. The GH-CoP has formal and informal collaborations with an array of professionals engaged in pest detection, seed phytosanitation and policy making to enable safe movement of germplasm. The GH-CoP members frequently-interact and engage in collaborative activities; knowledge sharing through virtual and face-to-face meetings for learning and problem solving. This is achieved through organizing-training workshops, sometimes with the support of external experts, to develop new skills and technologies; develop harmonized quality management framework; establish technical sub-groups to develop innovations for improving operational efficiency; and develop common strategies, procedures and technologies for improved performance of the GHUs. The GH-CoP has undertaken new initiatives such 'annual phytosanitary awareness week' since 2017 with objectives to Inform, Update, Inspire and Engage partners and stakeholders to achieve the common mission of germplasm phytosanitary safety for "securing the path of food security". Experiences, augmentation plans and intensification of outreach efforts, including special events on 'germplasm phytosanitary safety' in conjunction with IYPH-2020, to widen the reach and benefits of GH-CoP will be presented.

DDB P14. Characterization of rice orange leaf (ROL) phytoplasma using multiple gene systems and in the vector zig zag leaf hopper in rice ecosystem

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Phytoplasmas are intracellular obligate-prokaryotes that lack cell-walls and have very small-genomes (680–1,600 kb). Many-fungal, bacterial and viral-diseases have been characterized and resistant breeding-programme is progressing very-well. Recently, on the basis of the symptoms and on 16SrDNA sequence-identity and phylogenetic-relationships the association of 'Ca. *P. asteris*' with Rice Orange Leaf-phytoplasma-disease in South-India was confirmed. Rice-orange leaf phytoplasma was characterized based-on multiple gene systems. The 16S-23S rRNA Spacer region of rice-phytoplasma was amplified by the

primer-pairs p1/p7 and p3/p7 at ~320 bp from all rice-samples. The phytoplasma infecting rice-samples were confirmed as-group I by the group specific-primer for 16SrI which amplified DNA-fragment at ~1.1 kb in all the samples. The *tuf* gene in phytoplasma (~1000 bp) and phytoplasma in rice-belonging to aster yellow (AY) group was confirmed by the primer-specific for aster yellow *tuf* gene with amplification at ~940 bp. The primer pair, AYsecYF1 and AYsecYR1 was used which amplified the *secY*-gene at ~1.4 kb in all the rice-samples which confirmed the phytoplasma-infecting rice-belonged to aster yellow-group. Among the different hoppers-collected from rice ecosystem namely, Green-leafhopper (GLH), Brown-planthopper (BPH), White backed planthopper (WBPH) and Zigzag-leafhopper (ZLH), ZLH alone showed positive result in the nested PCR assay with DNA fragment-amplified at ~1.2 kb of 16S rRNA gene of phytoplasma. Sequence-analysis revealed that the 1188 bp nucleotide sequences shared 98 % nucleotide-sequence identity with 16S rRNA gene sequences of 16SrI phytoplasmas namely rice orange leaf phytoplasma from Coimbatore and aster yellow-phytoplasma. Characterization of Rice-orange leaf (ROL) phytoplasma by multiple-gene systems will be discussed.

DDB P15. Studies on overwintering structure development of *Marssonina coronaria* in North Western Himalyan region

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Marssonina blotch is one of the major constraints in successful cultivation of apple and is widespread in the North Western Himalayas causing economic losses to apple growers. Infected leaf samples were collected from Rohru region of Shimla dist. (H.P.) at 15 days interval starting from December to May. Initially the acervuli were seen over the infected leaf, later significant variation were recorded from the sample collected at regular interval of time. Initiation of development of apothecia was recorded during the months of January to March. Fully developed apothecia with asci and ascospore were observed from last week of March to first fortnight of April. The apothecia were found to release the ascospore after mid of April. Ascospores served as primary source of inoculum. The study would further lead for better understanding of overwintering structure, disease initiation and adopting early and effective control measures to reduce the infection and yield losses.

DDB P16. Sanitation methods for the production of virus-free citrus plants in Morocco

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Citrus virus and virus-like diseases are widely distributed in Morocco and they cause very important economic losses to the country's citrus industry such as decline, loss of vigour, shortening of the commercial life of the infected trees, low yields and poor fruit quality. There is no effective chemical control against these diseases; therefore preventive measures must be based on the mass production of virus-free planting stocks. The Moroccan Ministry of Agriculture has established, since 1983, a national certification program for citrus nursery plants. The Certification scheme for pathogen-tested material of citrus has the aim of providing plants that are true-to-type, free from virus and virus-like diseases and substantially free from other pests. Shoot-tip-grafting and/or thermotherapy and somatic embryogenesis from stigma and style in vitro culture were proved to be most effective techniques in the complete elimination of the main citrus virus and virus-like diseases: Citrus tristeza virus, Citrus psorosis virus, Citrus exocortis viroid, Citrus cachexia viroid, Spirolamacitri,

Citrus variegation virus, concave gum and impietratura. Biological, serological and molecular assays are used for assessing the elimination of the virus, viroid and virus-like agents present in the mother plants. The obtained virus-free plants of many accessions are maintained under protected conditions in screen houses and used to release certified budwood for nurseries. Nowadays, more than five million certified virus-free citrus plants, of different varieties and rootstocks, are produced annually in the country.

DDB P17. Diseases on medicinal and aromatic plants in north coastal region of Andhra Pradesh state

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The surge in demand for plant based drugs lately led to systemic cultivation of many native species of medicinal plants. Due to large scale cultivation of these plants, the incidence of various pests and diseases has become a major problem. Among the diseases recorded on medicinal and aromatic plants, leaf spot, blight, rusts and powdery mildews are predominant and endemic at Horticultural Research Station, Dr.YSRHU, Venkataramannagudem. Leaf spots and blight caused by *Helminthosporium, Colletotrichum, Alternaria, Cercospora, Pseudocercospora* are major and also severe on many of the medicinal plants such as *Aloe vera, Corus calamus, Solanum nigrum, Cymbopogon citratus, Mucuna pruriens, Aristolochia indica, Rauwolfia serpentine, Piper longum, Hemidesmus indicus, Tinospora cordifolia, Decalepis hamiltom* and *Mumcru* spp from July to March with disease incidence ranging from 15 to 100%. Rusts were found to be the second major disease on medicinal plants including *Bauhinia* sp (*Uromyces* sp), *Indigofera tinctoria* (Udegeneracy. *M pruriens* (Mucuna), *Holarrhena anisenterica* (Hem leid holur hede), *Plumeria* sp (*Coleosporium plumeria*). Powdery mildew caused by *Oidium* spp was recorded in *Phyllanthus amarus* and *Anethum graveolens* in cool dry conditions prevailing from 1st week of November onwards. Among the viral diseases Yellow Mosaic Virus (YMV) on *Mucuna pruriens* is the major disease with yield losses ranging from 15-30% depending on the time of occurrence and stage of the crop. In addition to this viruses were also found infecting *Clitori ternatea* and *Hemidesmus indicus*. Little leaf disease by Phytoplasma was also noticed *Andrographis paniculata, Angelonia* grandiflora, Catharanthus *roeus, Datura fastusd* and *Ocimum gratissimum*.

DDB P18. Virulence profiling of *Magnaporthe grisea* adapted to pearl millet

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Blast disease caused by *Magnaporthe grisea* is a major biotic constraint in the production of pearl millet in India. The pathogen is highly variable in nature, but strains are mostly specific in their host range. Pathogenic variation among 88 *M. grisea* isolates collected from five major pearl millet growing states in India was studied on pearl millet host differentials under greenhouse conditions. Based on the host differential reaction (virulent = score ≥ 4 and avirulent = score ≤ 3 on a 1-to-9 scale) 88 isolates were clustered into 25 pathogenic groups. A maximum of 29 isolates were included in one group/pathotype (III), and the isolates of this group were virulent on all genotypes except IP21187-P1. The pathogenic group/pathotype I was the second largest group that contained 18 isolates and the isolates of this group were virulent on all the 10 host

genotypes/differentials. Grouping of isolates into different pathotypes and profiling of their virulence pattern will provide an essential foundation for the screening of pearl millet breeding lines for blast resistance. Five isolates representing pathogenically and geographically diverse groups have been selected for greenhouse screening of pearl millet lines.

DDB P19. Variation in the virulence of *Magnaporthe grisea* isolates adapted to finger millet

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Finger millet is a coarse cereal crop with a remarkable nutritional advantage and environmental sustainability. Blast disease is a major biotic constraint affecting yield and quality of finger millet. A total of 250 blast disease samples were collected from 15 locations comprising of disease samples from leaf, neck and finger region. A total of 110 single spore cultures were established, of which 16 isolates were from leaf, 46 from neck and 48 finger tissues. Pathogenicity of isolates was proved on 15 days old seedlings of a susceptible line VR 708 and the disease scores ranged from 4 – 8 (on 1-9 scale) across the isolates. Of the 110 isolates, 18 isolates were randomly selected and their pathogenic reaction was assessed on 10 host differential lines. Based on disease reaction, 18 isolates were distributed into seven clusters, cluster I was represented by eight isolates which were highly virulent on all the host differentials Fm.pg 180 from Bengaluru was the most aggressive isolate with a disease score of 7.1 followed by other isolates in cluster I. Isolates representing cluster III were avirulent on IE 2911 and IE 4497, whereas isolates from cluster IV were avirulent only on IE 2911. However, clusters II, V, VI and VII were independently represented by Fm.Pg 168 (avirulent on IE 4497), Fm.Pg 95 (avirulent on IE 2911 and IE 2957), Fm.Pg 32 (avirulent on IE 2957 and IE 4497) and Fm.Pg 237 (avirulent on IE 2957 and IE 6337), respectively. These pathogenically diverse isolates will be of potential use in screening germplasm and advanced breeding lines of finger millet for identifying resistant sources to blast disease

Poster session VI: Food and nutritional security

FNS P1. Fumigant and repellent activity of some essential oils against insect pests of stored grain belonging to order Coleoptera

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Post-harvest losses due to insect pests is an important delimiting factor in agriculture economics as many insect pests like *Sitophilus oryzae*, *Tribolium castaneum*, *Rhyzopertha dominica*, *Sitotroga cerealella*, *Callosobruchus chinensis*, *Corcyra cephalonica* etc cause heavy damage around 20-30% under stored grain conditions. In the present study, some essential oils viz. *Murraya koenigii*, *Callistemon citrinus*, *Citrus limetta*, *Curcuma longa* and *Pinus roxburghii* were tested for their fumigant and repellent activity against 4 coleopteran stored grain insects, *S. oryzae*, *R. dominica*, *T. castaneum* and *C. chinensis*. 38 different treatments were prepared singly and in combinations were used to check fumigant activity and the repellency test was conducted with different concentrations of essential oils used in experiments. It was found in the studies that all the 38 treatments including combination were effective against *R. dominica* but for *S. oryzae* only 4 oils were found effective at single concentration while none of the combinations were found to be effective. It was also observed that for *T. castaneum* 14 treatments were effective, while for *C. chinenesis* almost all the treatments were effective. Also, while testing repellent activity it was found that except *S. oryzae*, other test insects effectively responded to all the five essential oils.

FNS P2. Factors responsible for transit and handling losses of rice intended for public distribution - the way out!

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Andhra Pradesh State Civil Supplies Corporation Limited (APSCSCL) plays a significant role in ensuring food security of the vulnerable section of people by distribution of rice through various welfare schemes. It takes the responsibility of transportation, storage and delivery of the stocks under Public Distribution System during which about 2.2 Lakh MT of rice is being handled per month through 268 Mandal Level Stock (MLS) points meant for intermediate or transit storage of rice. The MLS points run by APSCSCL are mostly in the available warehouses which are semi-scientific or unscientific, hence certain losses are also inevitable. A detailed scientific study on the losses of rice at MLS points was conducted by Post Harvest Technology Centre, Bapatla. The major constraints identified were; lack of knowledge on proper post-harvest handling, inadequate and unscientific storage facilities etc. The various factors responsible for transit and handling losses include; different modes of weighment, gunny quality and use of hooks, non-usage of tarpaulins, rodent menace, insect and bird pests, pilferage or siphoning during interim storage, poor maintenance of warehouse, seized rice stocks, distant transportations and socio-economic aspects. Storage structure is the most important factor which can keep the losses caused by insects, rodents and fungi to a minimum level. Switching over to ‘silo’ systems can address several of the problems associated with the conventional storage and other structural lacunae.

FNS P3. Nutritional component analysis of edible insects from Nagaland

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Food and Agriculture Organization warns global famine within next 50 years, and scientists have started exploring alternate sources of protein from various resources including insects. In our studies, the preferred life stages of five most prominently used insect species by different tribes of Nagaland were procured for their nutritional analysis viz., crude protein, total sugar, total solids, total lipids, fatty acids and moisture content. The moisture content and total sugar content were significantly higher, and total solids and protein content lower in the processed as compared to unprocessed counterparts, indicating that the processing of insect samples degrade the protein. The grasshopper and dragonfly nymphs were found with significantly higher amount of total lipid content as compared to other test insects. Total lipid content was also found higher in roasted than the fresh insect samples. The lipophilic profiling of test insect samples revealed that the two PUFA (polyunsaturated fatty acids): oleic acid (18:1) and linoleic acid (18:3) were detected in all the analyzed insect samples. The percentage of total PUFA (Oleic acid) ranged from 23.10% in wood larvae (fresh) to 44.2% in Eri larvae (roasted) out of total fatty acids. The main PUFA in all insects was oleic acid (18:1), which is present in good amount in all test insects, while dragon fly nymph had the highest amount of linoleic acid (16.82%) among the test insect samples. The studies indicate that use of edible insects by indigenous Nagaland people ensures their nutritional requirement, and demonstrate additional way to human nutritional security.

FNS P4. Evaluation of different household practices to decontaminate synthetic pyrethroid insecticide residues from *Amarnathus tricolor* L.

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Amaranth (*Amaranthus tricolor* L) is a major leafy vegetable extensively cultivated and consumed in Kerala. Leaf eating caterpillars possess a serious threat to the economic part of the crop which prompts farmers to relay on pesticides on a larger scale. This resulted in severe problems of pesticide residues on amaranth. A preliminary survey was conducted to monitor these pesticide residues on amaranth. Among the various insecticides used on amaranth, organo phosphates (OP) and synthetic pyrethroids (SP) were predominant. Efficiency of different decontaminating methods for SP compounds were standardized here. Amaranth plants, sprayed with different SP insecticides viz., bifenthrin 10% EC, cypermethrin 25% EC, fenvalerate 20% EC and Lambda cyhalothrin 5% EC were subjected to decontamination methods viz., washing, 2% common salt, 2 % vinegar, 1% turmeric, 2% tamarind, 1% veggie wash (produced by Kerala Agricultural university, Vellayani) and cooking. The residues in control and processed plants were estimated by using Gas Chromatograph equipped with Electron Capture Detector. Dipping in 2% tamarind, 1% veggie wash for 10 minutes followed by three further washings + cooking and 2 % common salt were found to be effective in removal of SP insecticide residues at the average of 67 %, 64% and 63 %. This study facilitated standardization of simple and effective methods to remove residues of commonly used synthetic pyrethroid insecticides in amaranth.

FNS P5. Influence of pileus size on composition of biochemical parameters in milky mushrooms

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Calocybe indica, known as milky white mushroom is tropical in origin and is gaining commercial importance in Telangana state. The increased interest in consumption of milky mushrooms as food item depends mainly due to their nutritional, antioxidant and therapeutic values. In Telangana the market for the fresh mushrooms of *Calocybe* spp. is also based on the size of the pileus of mushroom. Keeping this in view the present study was conducted to see the effect of the pileus size on its biochemical composition in the milky mushroom variety *C. indica*. The fresh milky mushroom sporocarps of different sizes were selected for the studies which were oven dried at 40º C ground into fine powder and estimated for their biochemical composition. The results revealed that the protein content increased with increase in size of pileus up to 4.3cm diameter and then declined with increase in size of pileus. Lipid analysis in mushroom showed that the per cent lipid content decreased with increase in size of the pileus. While there is no specific correlation between the quantity of carbohydrates and size of the pileus, but there is a clear cut decrease in phenol quantity with increase in pileus size.

FNS P6. OchraVine Control - implementation of integrated and innovative management strategies to reduce the occurrence of ochratoxins along the vine value chain products: grapes, raisins/currants and wine

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Ochratoxin A (OTA) is a very toxic mycotoxin that constitutes a severe problem for viticulture and taking into account the extreme climatic events that are frequently faced in recent years, the OTA problem is arising in wine and raisins/currants. OchraVine Control project offers an inexistent innovative, sustainable and integrated smart ICT solution (OchraVine Control DSS) considering fungal, host and environmental indicators that affect OTA contamination along the vine grape-wine value chain. The OchraVine Control DSS will allow prediction and monitoring at pre- and post-harvest level to control *Aspergillus* infection and OTA contamination in vine cultivation by combining epidemiological data, biological and chemical management strategies, post-harvest technologies and precision agriculture tools. OchraVine Control DSS solution will pursue a field-to-fork approach and will link and translate the information derived from the OchraRisk and OchraDetect predictive map tools and real data obtained during the monitoring controls by the OchraSensor. OchraVine Control DSS tool in combination with data from the OchraRed Integrated Management Strategy will provide risk prediction information (i.e. geographic OTA vine alerts), practical recommended solutions for OTA management and will verify the compliance with legislation requirements in

a rapid and cost-effective way. This project has received funding from the European Union's Horizon 2020 Research and Innovation Program under grant agreement No 778219.

FNS P7. Effect of nanocides on rice weevil [*Sitophilus oryzae* (Linnaeus)] and seed quality enhancement in maize seeds

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An experiment was conducted to study the efficacy of different Nanocides viz, Nanosilica, Nanoalumina and Nanoclay, each at three different concentrations @500, 250, 125 ppm kg-1 seed, Diatomaceous earth @1000 ppm kg-1 seed and an untreated check against rice weevil and their impact on seed quality parameters at Seed Research & Technology Centre, Rajendranagar during 2016-17. All the eleven treatments were replicated thrice and statistically analyzed by using completely randomized design. The data on adult emergence, seed damage per cent, weight loss per cent, germination percentage, seedling vigour index were recorded at every three months interval. Nanosilica @ 500 and 250 ppm gave complete protection to maize seed from development and seed damage caused by *Sitophilus oryzae* (Linnaeus) and maintained the germination above IMSCS > 90% up to nine months of storage as compared to the control (25%). Nano silica @500 ppm and 250 ppm outperformed in enhancing the germination (90.67% and 90.00%) and seedling vigour index (2630 and 2010.67) compared to control (25% and 943), respectively. The three nano particles along with diatomaceous earth used for the management of *S. oryzae*, were also studied for their effect on the abrasion of cuticle and other parts of *S. oryzae* adults by using scanning electron microscope (SEM).

FNS P8. Phytosanitary cold treatment against *Drosophila suzukii* in ''RedGloble'' grape

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The spotted wing drosophila (SWD), *Drosophila suzukii* (Matsumura) distributes in the main Chinese soft fruits production areas, presents a problem because it is listed as a quarantine pest in some importing countries. The effects of phytosanitary cold treatment on postharvest control of SWD and the quality of “RedGloble” grape were examined. Firstly, immature life stages (eggs, first, second and third instars) of SWD in grape were observed at 25-26℃ and 65-70% RH. Secondly, according to the mortality of developmental stages in grape at 0°C for 12 h and 2°C for 24 h, eggs were identified as the most-cold tolerant developmental stage of SWD among the four life stages tested. Thirdly, cage-infested grape fruits with eggs, the most tolerant stage, were subjected to time and temperature tests in refrigerator warehouse. All results showed that there was no survival larvae developed from the treated grape after a 6-d cold treatment at 0°C and 7-d at 2°C. Probit or Logit analysis estimated the lethal time (LT) needed for the cold treatment to achieve 99.9968% ($LT_{99.9968}$) mortality (95% confidential limits) of eggs were 6.28 (5.34~7.80) d at 0°C and 8.96 (7.74~10.86) d at 2°C. The 7-d or 9-d cold treatment had no negative effect on the quality of the grape, on the contrary, the cold treatment could preserve “RedGloble” grape quality. All results suggested that cold treatment could be used as a methyl bromide alternative for postharvest control of spotted wing drosophila in grape.

Poster session VII: ICT in crop protection

ICT P1. Pest species sensitivity tests: necessity of pesticide content analysis of dipped leaves

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Today different laboratory tests are used for analyzing efficacy of pesticides against different arthropods. The IRAC susceptibility test methods propose among others the exposure of the pests to dry residues on leaf discs, depending on the pest species and the tested insecticide (www.irac-online.org). The preparation of dry residues is usually realized via spray application in a Laboratory Spray Tower or time- and cost-saving by dipping leaf discs in the desired test solution assuming to test the approved application rate. To check this latter assumption we analyzed the content of active ingredients (ai) on leaf discs from eleven agri- and horticultural plant species or varieties dipped into solutions of different pesticide formulations. Ai measurements were performed with liquid or gas chromatography-mass spectrometry. Depending on the plant species/variety, the dry residues on the leaf discs showed a high variability and ai-contents were for some plant species in mean up to 200% of the field spray rate. Apart from simple calculation errors the surface structure of the leaf disc and the properties of the formulation can influence the attachment of the pesticide, especially when the dipping method is applied. Therefore, the ai content adhering to the leaf discs cannot be generally predicted. Thus, statements about the susceptibility of organisms to pesticides are only acceptable if the intended residue content is appropriately controlled in the preparation of the bioassay (DOI 10.5073/20190326-153154).

ICT P2.Leafhopper diversity blueprint along the elevation gradient in the hill state, Himachal Pradesh, India

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Himachal Pradesh has congenial atmospheric conditions and is homeland for large number of insects. Despite being a hub of biological diversity, several insects remain poorly studied in the state including, cicadellidae, one of largest insect families of Hemiptera. Diversity, species richness and distribution pattern of leafhopper species in all the four agro-climatic zones of state with elevation ranging from 350 to 7000m amsl was explored covering 25 locations from 12 districts. 85 leafhopper species belonging to 61 genera of 12 subfamilies were recorded. Of these 4 species, *Gurawa monorcephala* Pruthi, *Leofa pulchellus* Distant, *Olidiana kirkaldyi* (Walker) and *Paralimnellus cingulatus* (Dlabola) appeared to be new records from Himachal Pradesh and 1 species, *Pseudosubhimalus* sp. nov was new from India. Species richness and diversity increased with rising altitude from low hills (350-650 m amsl) with a hump at mid hills (651-1800 m), following declining trend towards high hills wet temperate (1801-2200 m) and dry temperate zone (above 2200 m). This elevational disparity in species richness might be due to differences in physiological requirements and variation in habitat and resources availability. Mid hills and wet temperate zone had maximum plant diversity and a longer vegetation period compared to other two zones providing food and habitat for survival of maximum generations. Also global warming might be the one reason for shift of insect species including leafhoppers from tropical and subtropical regions to higher altitudes, while, some species confined to colder regions would have decreased or even extinct due to unavailability of their host plants.

ICT P3. Activity of the novel insecticide cyclaniliprole (Cyclapryn) against insect pests on paddy rice

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A novel insecticide Cyclaniliprole, Cyclapryn™ invented and developed by Ishihara Sangyo Kaisha, Ltd. (ISK) is categorized into group 28, the ryanodine receptor of the Insecticide Resistance Action Committee (IRAC) mode of classification. This compound has the insecticidal activity against wide spectrum of agricultural pests such as Lepidoptera, Thysanoptera, Hemiptera, Coleoptera and Diptera. ISK is supposed to get a pesticide registration on fruit tree and vegetables around the world. In addition, ISK focuses on study and develop this compound against pests on paddy rice. In this study, we report the efficacy of Cyclapryn against some pests such as *Cnaphalocrocis medinalis*, *Chilo suppressalis*, *Naranga aenescens*, *Lissorhoptrus oryzophilus*, *Oulema oryzae* and so on in rice cultivation.

ICT P4. Role of information and communication technology (ICT) in agriculture

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The rapid advancement in Information and Communication Technologies (ICT) has given rise to new applications that were impossible just few years ago. The agriculture sector faces major challenges of enhancing production in a situation of dwindling natural resources necessary for production. ICT plays an important role in uplifting the livelihoods by using an agro computer based information system. System that can provide relevant information about a crop, such as varieties, soil type, temperature, fertilizer, time of planting, pest and diseases control measures, rainfall etc. of the crop to get maximum benefit. ICT can play an important task in maintaining feasible information as it consists of major technologies like computer technology, communication, and information management technology. These technologies are useful for exchanging and organization data, information and data useful for the invention agricultural information systems. Thus the potential of ICT can be assessed as a means for direct involvement to agricultural production, indirect means for empowering farmers. ICT could be used to develop the agriculture, help farmers to get applicable information concerning agro- inputs, crop production technologies, processing, market and management of farm agro- business. Although there remains a wide gap in access between rural and urban areas, the spread of technology in rural areas has led to important changes in the agricultural sector and the agricultural libraries and information centres cannot be ignored and it have to play a very important role in the advancement and betterment of agriculture.

ICT P5. Status of pea diseases under agroclimatic condition of Jabalpur division and their management

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Pea (*Pisum sativum* L.) is an important Rabi season pulse crop and second most important food legume of the world. Pea is usually affected by several soil, seed and air borne pathogens. A survey was conducted in Madhya Pradesh to know the prevalence of various pea diseases during rabi season of 2018-19. The diseases were prevalent in all the areas surveyed and the highest mean incidence of seedling disease observed at

Jabalpur 48.00% and lowest at Mandla district 13.46%, Maximum Downy mildew disease incidence at Jabalpur 18.30% and lowest disease incidence at Katni district 2.26%, Maximum wilt disease incidence at Jabalpur 37.60% and lowest disease incidence at Mandla district 21.53%, Maximum Powdery mildew disease incidence at Jabalpur 56.90% and lowest disease incidence at Mandla district 33.59%. The seed treatment and foliar application of Carbendazim + Mancozeb are very effective and resulting in maximum germination, Plant Height, Shoots per plant, Pod length, No. of pods/plant, Seed per pod and highest yield than other fungicides. Seed treatment by Metiram + Pyraclostrobin are very effective for seed and seedling diseases with minimum (4.44%) incidence observed. Further Carbendazim + Mancozeb are very effective for wilt with minimum disease incidence (3.40%) observed in treated plots. Similarly, Dinocap is very effective for powdery mildew disease and Metiram + Pyraclostrobin is very effective for downy mildew disease. The Carbendazim + Mancozeb treatment contributed to maximum yield 17.55 q/ha, highest gross returns with a benefit cost ratio of 2.97 compared to other treatments. Further in our study disease intensities were correlated with weather parameters.

ICT P6. Studies on biochemical parameters of Pigeonpea *Cajanus cajan* (L.) Millsp genotypes against *Callosobruchus chinensis* L. (Coleoptera: Bruchidae)

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The present investigation aims to analyze bio-chemical (nutrient & anti nutritional) parameters of 15 different accessions of pigeonpea (*Cajanus cajan* (L.) Millsp) seeds in relation to total protein, total sugars, total tannins, total phenols, total flavonoids and trypsin inhibitors per cent for bruchids *Callosobruchus chinensis* were carried out in Entomology Unit, ICRISAT, Hyderabad. These results indicated that the biochemical compounds such as proteins and sugars make the accessions/cultivars to susceptible while the phenolic compounds such as phenolic acids, flavonoids, tannins seemed to impart a degree of host plant resistance to the *C. chinensis* infestation in pigeonpea. Based on contents of various parameters of the cultivars were found a higher levels of total sugars and protein in ICPL 332WR and ICPL 161 respectively. Whereas ICPW 68 was found to be higher content of tannins and phenols substances, while in case of ICPL 8863 showed highest amount of flavonoids and highest per cent trypsin inhibition were found in the accession, ICPL 87091 among the various cultivars studied. Therefore the aforesaid biochemical parameters would be useful for IPM system to protect pigeonpea grains during storage against pulse beetle attack.

ICT P7. Estimation of diafenthiuron residue in cabbage using high performance liquid chromatography (HPLC) and confirmation by liquid chromatograph –mass spectrometry (LC-MS)

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Dissipation of diafenthiuron in cabbage was studied following the application of diafenthiuron, 50 WP at 300 and 600 g ai ha-1 at Entomological Research Farm, Punjab Agricultural University, Ludhiana. The samples were extracted with acetonitrile, quantified using high performance liquid chromatography (HPLC) and confirmed by liquid chromatograph- mass spectrometry. The average initial deposits of diafenthiuron were

observed to be 0.60 and 1.27 mg kg-1 on the cabbage heads following third application of diafenthiuron at recommended and double the recommended dosages, respectively. Half-life periods for diafenthiuron were found to be 1.88 and 2.15 days at single and double the application rates, respectively. Residues of diafenthiuron declined below its limit of quantification of 0.05 mgkg-1 after 7 and 10 days, respectively, at recommended and double the recommended application rates. The results show that use of diafenthiuron does not seem to pose any risk hazard and a waiting period of 1 day is suggested for safe consumption of cabbage.

ICT P8. Post application of formulated mixture of triasulfuron + dicamba for weed control in winter wheat

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Herbicides rate cutting is an example of poor application of chemicals that can have potential adverse implications due to rapid herbicide resistance evolution. Three years studies during 2014 – 2016 have examined the combined effect of reducing new generation herbicide (triasulfuron + dicamba) doses 0.18, 0.15 and 0.12 kg/ha-1 and biological components to control weeds in winter wheat (*Triticum aestivum* L.). Weeds were mainly diminished when herbicide (triasulfuron + dicamba) 0.18 kg/ha-1 plus biological agents was applied compared with other treatments. Furthermore, satisfactory reducing of dominant weeds such as *Viola arvensis*, species of *Poaceae* and also in some cases, *Stelaria media* were achieved with below-labeled herbicide dose as 0.15 kg/ha-1 plus biological agents. Hence, the higher efficacy weed control was desirably obtained with the maximum (triasulfuron + dicamba) rate combined to biological agents but the difference was not high compared with dose 0.15 kg/ha-1. The lowest herbicide dose 0.12 kg/ha-1 plus biological agents had considerably lower weeds control efficacy on reducing of *Viola arvensis*, *Poaceae* and *Stelaria media*. It was determined that variation of herbicide doses combined with biological agents influenced yield and yield components, the highest yield (7.8 t/ha-1) was obtained with herbicide rate 0.15 kg/ha-1 Plus biological agents.

ICT P9. Effects of wheat cultivar mixtures on stripe rust disease and yield

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Wheat stripe rust, caused by *Puccinia striiformis* f. sp. *tritici* (Pst), is an important wheat disease worldwide. Cultivar mixtures can delay the resistance loss of wheat cultivars, and thus have got more and more attention. In this study, thirteen mixture treatments with different component cultivars and five monocultures included in them were planted in field experiments in Kaifeng, Henan province in China in three seasons from 2015 to 2018. Artificial inoculations of Pst mixed races were conducted in springs of three years respectively. In the 2015-2016 experiment, the AUDPCs and apparent infection rates of wheat stripe rust in all mixture treatments except a mixture coded K7 which composed of three immune cultivars were significantly lower than the most susceptible component cultivars included in them ($P<0.05$). And the relative control efficacies of all mixture treatments varied from 38.76% to 67.18% except mixture K7. There was no significant correlation between the relative control efficacies and the number of component cultivars of mixtures. But negative correlation was observed between the relative control efficacies of mixtures and their AUDPCs. Based on the results of 2015-2018 experiments, the proportions of mixture treatments that showed relative yield increase were 54%, 46% and 38%, respectively. The mixture effects of mixture treatments on disease

decrease could be affected by the selection of component cultivars and disease intensity. And the efficacies of mixtures on yield increase could be affected by disease stress and component cultivars.

ICT P10. Quantification of latent infection of corn leaves infected by *Puccinia polysora* Underw. using Real-time PCR

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Southern corn rust, caused by *Puccinia polysora* Underw is a destructive air-borne disease worldwide. It is of great significance to rapidly and timely diagnose and quantify *Puccinia polysora* in leaves under the condition of latent infections for prediction and reasonable control measures of southern corn rust. Specific primers and TaqMan probes were designed respectively based on the ITS sequence of *Puccinia polysora* and the Actin 2 gene sequence of maize. A real-time PCR detection system for the incubation period of southern corn rust was established to detect the DNA content of *Puccinia polysora* in corn leaves and the DNA content of corn. Then, this method was applied to detect the disease during the incubation period, and the disease prediction equation was established. Artificial inoculation experiments were conducted to determine the dynamics of molecular disease index (MDI) (quantity of *P. polysora* DNA （pg）/ quantity of corn DNA （ng）) by using this real-time PCR assay. Then investigating the dynamics of disease index (DI) after the symptoms appeared. A linear equation was developed based on MDI-AUDPC and DI-AUDPC: $y = 0.7472x + 212.4$($R^2 = 0.8175$, $P=0.0351$). This provides a scientific and reasonable technical mean for early detection and prediction of southern corn rust, and can provide reference for early prevention and control of the disease.

ICT P11. Evaluation of Reklemel TM active against the root-knot nematode *Meloidogyne incognita* in brinjal

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The root-knot nematode, *Meloidogyne incognita* is one of the major threats to brinjal productivity. At the same time there are only a few chemical nematicides available in India. Among them phorate has been banned and carbofuran will be withdrawn in the near future. Reklemel active (chemical name: fluazaindolizine) is a new molecule formulated by Du Pont India specifically for the management of plant-parasitic nematodes. A field trial was conducted in brinjal to test the efficacy of Reklemel (formulated as 500 SC) against the *M. incognita*. The initial *M. incognita* population count before treatment and transplanting, as well as the population densities at 30, 60 and 90 days after transplanting were recorded. The results showed that Reklemel caused a significant reduction in the population densities of *M. incognita* over the initial population density. Among the tested rates, the 0.0375% solution concentration (equivalent to 75 mg ai/plant) showed the highest reduction (49.6%) followed by the 0.025% concentration (equivalent to 50 mg ai/plant) with 48.1% reduction, and the lowest concentration of 0.0125% (equivalent to 25 mg ai/plant) showed 29.5% reduction. The root galling index (0-10 scale) was lowest at concentrations of 0.0375% and 0.025 %. The chemical check (carbofuran at 2kg ai/ ha) showed a 13.1% reduction in the nematode population, whereas the untreated control plots showed a population increase of 32.5% over the initial population. The middle and

highest doses of Reklemel showed similar efficacy. The results indicate that Reklemel can be a new effective tool for plant-parasitic nematode management in India.

ICT P12. Evaluation on the efficacy of isoclast tm 240SC against the brown planthopper (*Nilaparvata lugens* s.) in rice

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The efficacy of the new chemical compound Isoclast 240SC (Chemical name: Sulfoxaflor) against the rice brown plant hopper (*Nilaparvata lugens* Stal), was evaluated under laboratory conditions. Laboratory assays were conducted on the efficacy of Isoclast 240 SC at different doses viz., 5.33ppm, 10.67ppm, 16.00 ppm, 21.33 ppm, 26.67 ppm, 32.00 ppm against nymphs and adult of the brown plant hopper. The mean percent mortality and corrected percent mortality was calculated. The results revealed that within 24 hrs, 86.5% nymphal mortality was observed in Isoclast 240 SC @ 32ppm followed by 26.67ppm dose (76.6%). Even, the lowest concentration treatment 5.33ppm recorded 40 per cent nymphal mortality. Observations at 72 hrs revealed complete mortality in both the 26.67 and 32.00 ppm concentration. In the lowest dose, 5.33 ppm, more than 50 per cent mortality (53.4%) was recorded. Results on BPH adults revealed that higher dose of 32ppm caused 73.4% mortality at 24 hrs followed by 21.33 ppm with 66.7% mortality. The observations at 48 hrs after treatment showed 86.7% mortality on 32 ppm treated plants followed by 66.67% mortality in the 21.33 and 26.67 ppm treatments respectively. Complete adult mortality was recorded after 72 hrs in 32 ppm treated plants followed by 84.7% mortality in 26.67 and 21.33 ppm applied plants. Probit analysis was conducted to determine the LC50 value and the results revealed values of 8.407 ppm for nymphs and 10.546 ppm for adult insects. The results of present study confirmed that Isoclast 240SC was found to be effective against the brown plant hopper.

ICT P13. Evaluation of the efficacy of Spinetoram + Methoxyfenozide 360 SC against the leaffolder (*Cnaphalocrocis medinalis* G.) and yellow stem borer (*Scirpophaga incertulus* W) in rice

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The efficacy of the new combination product Spinetoram + Methoxyfenozide 360 SC was evaluated against rice leaf folder and yellow stem borer under laboratory conditions. Bioassays were conducted on larvae of leaf folder and yellow stem borer separately in pot culture experiments with doses of 16ppm, 21.33ppm, 26.67ppm, 32ppm, 37.33ppm, 42.67ppm, 48ppm along with untreated checks. The results revealed that 46.4% larval mortality was observed in the 48ppm dose followed by 42.67ppm (43.3%) in the 24 hrs observations. The 48 hrs observation showed double the rate of mortality. Around 96% mortality was recorded in the highest dose of 48 ppm followed by 86.6 & 86.4% mortality in 42.67 and 37.33ppm doses respectively. At 96 hrs, the lowest dose treatment 16ppm recorded 96.7%t death of the released larva. Probit analysis for leaf folder larva indicated that LC50 value 23.1ppm against leaf folder larva. In yellow stem borer bioassay the results indicated that at 48 ppm more mean number of dead larva (11.2no.) recorded followed by 42.67ppm (9.5nos). Since, yellow stem borer is an internal feeder one-time observation at 72 hrs

after treatment was made. The mean larval mortality was more in 48 ppm (74.5%) followed by 42.67ppm (63.3%). The low dose 16ppm and 21.33ppm treated plants recorded 24.5 and 31.3 per cent larval mortality respectively. Probit mortality for yellow stem borer larva were worked out and observed that LC50 for larva was 32.231ppm. The results confirmed that the new combination product of Spinetoram+ Methoxyfenozide 360 SC was effective against leaf folder and yellow stem borer.

ICT P14. Did the fall armyworm invade South Africa with resistance to insecticides?

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The Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), was first reported in South Africa in 2017, after it invaded West African countries during 2016. The overuse of insecticides elsewhere for control of this pest has led to resistance against various insecticide groups. The status of insecticide susceptibility of *S. frugiperda* populations that arrived in South Africa through migration, is currently unknown. This pest is known for its fast development of resistance to insecticides and base line data are therefore needed for future resistance monitoring. The aim of this study was to determine the base line susceptibility of two *S. frugiperda* populations collected in South Africa to selected insecticides. The toxicity of these insecticides was estimated using the IRAC susceptibility test method no. 007. Mortality was assessed after 72 hours of exposure. Percentage mortality values for each bioassay were corrected using Abbott's formula. Corrected mortality data from the dose-response bioassays were subjected to probit analysis using POLO SUITE®. For both populations, the estimated LC50 values for emamectin benzoate, spinetoram, methoxyfenozide, chlorantraniliprole and methomyl were below the recommended dosage rates, but the estimated LC50 values for chlorpyrifos and lambda cyhalothrin were well above the recommended dosage rates. The Fall armyworm populations that invaded South Africa therefore have alleles with resistance to chlorpyrifos and lambda cyhalothrin. It can, however, be effectively controlled using other registered insecticides with different modes of action. Effective applications and well-planned insect resistance management programs should be followed to prevent resistance development to insecticides.

ICT P15. Potential of silicates in deactivating the mycelia of *Macrophomina phaseolina* (Tassi) Goid, the dry rot pathogen of ginger (*Zingiber officinale* Rosc.)

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Dry rot of ginger caused by *Macrophomina phaseolina* was observed as post-harvest infections during storage. But detailed investigations showed that the pathogen is not only post-harvest in nature, but also infect the crop during growing stage. The usual management strategy includes treatment of ginger seed rhizomes with fungicides before storage. Since the pathogen is infecting the crop during growing stage, soil application of chemical/bioagent is also required to manage the disease. Silica is reported to have the ability to enhance resistance against root rot pathogens. The present study analyzes the in vitro effect of three silicon sources (solid and liquid forms of sodium and potassium silicate and sodium metasilicate) on the growth of *M. phaseolina*. Sodium meta-silicate limit the fungal growth at 70 mM whereas sodium and potassium silicate restricted the mycelial growth at 3 % concentration. Silicate effect on mycelial growth showed alteration in hyphal morphology with constrained growth of mycelia as observed by bright field and SEM analysis. The biochemical analysis of mycelia exposed to different silicates revealed increase in glycerol and

EPS content which in turn resulted in alteration in the cell wall structure. The lipid peroxidation and the cell permeability was higher for silicate treated mycelium. Silicon treatment enhanced the activities of defense related enzymes in ginger rhizome inoculated with *M. phaseolina*. These findings suggest a possibility of using silicates as an alternative for fungicides against dry rot disease. This is the first attempt to study the effect of silicate molecules in ginger against dry rot pathogen *M. phaseolina*.

ICT P16. Bio-efficacy and phytotoxicity study of ametoctradin 300 G/L + dimethomorph 225 G/L SC against downy mildew disease of grapes

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Grapes are one of the most widely produced fruit in the world. Grape crop is affected by different diseases. Among them downy mildew of grapes is one of the most important diseases of grapes. The disease is widely prevalent and appears every year and reduces the quality and quantity of the crop apart from making vines weak. The ruling variety in Karnataka, Thompson Seedless suffers huge losses due to this disease resulting in drastic reduction in productivity if left unchecked or if proper control measures are not adopted. The present investigation was therefore initiated to elucidate efficacy of Ametoctradin 300 g/l + Dimethomorph 225 g/l sc fungicides for management of diseases. Among all the treatments Ametoctradin 300 g/l + Dimethomorph 225 g/l SC and Ametoctradin 300 g/l + Dimethomorph 225 g/l SC (market sample) @ 1000 ml/ha recorded the significantly least downy mildew incidence (13.84% and 14.01%) over all other treatments and is better than the Ametoctradin 300 g/l + Dimethomorph 225 g/l SC Ametoctradin 300 g/l + Dimethomorph 225 g/l SC (market sample) @ 800 ml/ha. Next best treatment was Cymoxanil 8% + Mancozeb 64% WP @ 1500 g/ha with percent diseases index of 19.58% while control showed with 48.21% percent diseases incidence. With respect to yield highest fruit yield was recorded by spraying Ametoctradin 300 g/l + Dimethomorph 225 g/l SC whereas unsprayed control recorded lowest yield (11.96 t/ha).

ICT P17. Survey for diseases and pests affecting chickpea and lentil crops in central highlands of Ethiopia

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A field survey was conducted during October 2018 to monitor occurrence of insect pests and diseases affecting chickpea and lentil in central highlands of Ethiopia. Surveyed fields were randomly selected following major highways and feeder roads. Types of insect pests, fungal and viral diseases present, and their incidence were determined on the basis of symptoms observed. The following insect pests were recorded: green aphids (75% of visited fields), thrips (60%) and black aphids (5%) in lentil, and pod borer (89%), cut worms (4%) and bruchids (4%) in chickpea. Wilt/root rots was recorded in 90% lentil and 93% chickpea visited fields, in addition, Ascochyta blight (4%) and rust (15%) were recorded in chickpea visited fields only. A total of 292 chickpea and 250 lentil samples with symptoms suggestive of virus infection (chlorosis, stunting, yellowing, reddening, mosaic/mottling) were collected from 27 chickpea and 20 lentil fields. Serological results showed that Chickpea chlorotic stunt virus was the most common (72% of chickpea and 54% lentil samples), whereas, Pea seed-borne mosaic virus was detected in lentil (42.8%) and Beet western yellows virus was detected in chickpea (8.2%) only. In virus-infected fields, over 50% yield reduction was estimated in August planted lentil and up to 100% in late planted lentil on residual moisture from August and October planted lentil did occur. It was concluded that new management strategies should be developed and

introduced to manage viruses and their vectors as well as wilt/root rot and pod borer in both crops to minimize yield losses.

ICT P18. Plant growth promotion by a nematophagous fungus, *Pochonia chlamydosporia*, on black pepper (*Piper nigrum* L.)

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The nematophagous fungus, *Pochonia chlamydosporia*, is one of the most promising biological control agents of plant-parasitic nematodes. The fungal isolate was tested for its direct plant growth promoting activities such as production of indole-3-acetic acid (IAA), ammonia and its capacity to solubilize inorganic phosphate and zinc. The isolate was found to be positive for ammonia and IAA production as well as phosphate and zinc solubilisation. The IAA production was quantitatively estimated and found to be 9.8 µg/ml while the phosphate and zinc solubilization indices were in the range of 1.3 ± 0.07 and 1.1 ± 0.01 response units. It also showed indirect plant growth promoting traits such as production of siderophores (2 ± 0.04 response units) and cell wall-degrading enzymes like α-amylases, cellulases and pectinases. The isolate also showed antagonism at varying levels to other plant pathogens like *Pythium*, *Phytophthora*, *Colletotrichum*, *Helminthosporium* and *Fusarium* species. In pot culture experiments, application of the fungus at the root zone of black pepper cuttings significantly increased shoot and root length, shoot and root biomass, number of secondary roots and leaves and leaf chlorophyll content compared to untreated plants. The contents of nitrogen, phosphorus, potassium, calcium, magnesium, copper, manganese, iron and zinc in both soil and plant were also enhanced significantly on inoculating with this fungal isolate. The nematophagous and multifarious growth promoting traits of *P. chlamydosporia* strain IISR- MTCC5412 suggest that, besides its biocontrol potential, the fungus has great potential as a plant growth promoting agent in sustainable agriculture.

ICT P19. Incidence of major insect-pests and management of soil-inhabiting insects in groundnut (*Arachis hypogaea* L.)

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The study revealed that the incidence of aphid (*A. craccivora*), jassid (*E. kerri*) and thrips (*S. dorsalis*) was commenced in second week of August. Jassid and thrips touched the peak during the second week of September (7.00 jassid/3 leaves and 3.80 thrips/3 leaves). Aphids touched its peak in the third week of September (7.60 aphid/3 leaves). The incidence of tobacco caterpillar, *S. litura* was commenced in the second week of September and touched its peak in the second week of October (1.40/ plant). The aphid exhibited a negative correlation with temperature and rainfall, whereas positive correlation with relative humidity. Jassid exhibited a negative correlation with temperature and positive correlation with relative humidity and total rainfall. The correlation between thrips and temperature was negative but with total rainfall, the correlation was positive and non-significant and correlation with relative humidity was positively significant. The tobacco caterpillar exhibited a negative and significant correlation with relative humidity and total rainfall. Among different treatments, soil application of phorate 10 % G at 25 kg ha^{-1} at the time of sowing was found most effective which caused highest reduction of white grub and termite. Next effective treatments were drenching of Chlorpyriphos 20 EC at 600 ml ha^{-1}, Imidacloprid 200 SL at 2400 ml ha^{-1} and Fipronil 5 % SC

at 2500 ml ha^{-1}. The drenching of *Metarhizium anisopliae* at 4 x 1012 conidia ha^{-1}, *Steinernema carpocapsae* at 5 b Ijs ha^{-1} and *Beauveria bassiana* at 4 x 1012 conidia ha^{-1} were least effective.

ICT P20. Population dynamics of major insect pests infesting black gram (*Vigna mungo* L.)

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A field experiment on the population dynamics of major insect pests infesting black gram (*Vigna mungo* L.) was carried out at Agronomy farm, Rajasthan College of Agriculture, MPUAT, Udaipur during Kharif, 2018. The major sucking insect pests observed on blackgram were aphid, *Aphis craccivora* (Koch); jassid, *Empoasca kerri* (Pruthi); whitefly, *Bemisia tabaci* (Gennadius) and thrips, *Caliothrips indicus* (Bagnall). The population of aphid (36.67/ 5plant), jassid (30.67/5 plant) and whitefly (35.67/5plant) were attained peak during first week (31 SMW) of August; thrips (17.33/5plant) population in second week (32 SMW) of August. The population of aphid, jassid, whitefly and thrips exhibited a non-significant positive correlation with temperature and while thrips exhibited positive significant correlation. Aphid and jassid exhibited significant correlation with relative humidity and rainfall.

ICT P21. Bio-efficacy Virtako 1.5 GR (Chlorantraniliprole 0.5%+ Thiamethoxam 1%) against pests complex in onion

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Onion (*Allium cepa* L.) is an herbaceous bulbous plant that is cultivated for bulb production either as biannual or perennial and is one of the important condiments widely used in all households round the year as raw vegetables. Recent research has suggested that onions in the diet may play a part in preventing heart disease and other ailments. Onion bulb is rich in phosphorus, calcium and carbohydrates. One of the important constraints in yield is attack of pests and diseases. Among the insect pests *Thrips tabaci, Agrotis ipsilon, Helicoverpa armigera* are important pests reduce the yield drastically. During the year 2017-18 and 2018-19 field experiments were conducted at Ranebennu (tq) Haveri (Dist), to know the bio efficacy of Virtako 1.5 GR (Chlorantraniliprole 0.5% + Thiamethoxaml 1%) against pests complex in Onion with Virtako1.5 GR at different dosages (@75a.i.g/ha, 90a.i.g/ha, and 105 a.i.g/ha,) and commonly insecticides Chlorantraniliprole 0.4%GR.35 a.i.g/ha, Thiamethoxam 75% SG 70 a.i.g/ha, Fipronil 80% WG60% a.i.g/ha, and Dimethoate 30% EC a.i.g/ha, Among the treatments Virtako 1.5 GR (Chlorantraniliprole 0.5% + Thiamethoxam 1%)@ 105 a.i.g/ha was found to be superior in reducing the *T. tabaci, A. ipsilon,* and *H. armigera* pest population and recorded higher yield 22.00 kg/ha in both seasons. Hence Virtako 1.5 GR 105 (Chlorantraniliprole 0.5% + Thiamethoxam 1%) a.i.g/ha can be recommended for the management of Onion pest complex safer to natural enemies, did not show any phytotoxic effects on onion crop at higher dosages (105 a.i.g/ha and 210 a.i.g/ha).

ICT P22. Sex pheromone and early warning system of *Bactrocera minax*

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Bactrocera minax (Enderlein) (Diptera: Tephritidae) is an important pest causing serious mandarin fruit drop in China. In this study, the Spatial-temporal distribution and activity trends of *B. minax* were evaluated by using probability kriging. The results showed that the edge concentration was discovered during the most weeks in adult occurrence, and the population of the adults aggregated with high probability within a less-than-100-m-wide band on both of the sides of the orchard and the woods. constructing fruit flies early warning system using the B/S structure in the geographic information network platform by geographic information system (GIS), This system contains the information reporting system, display system and expert consultation system, citrus fruit flies early warning system, and is able to analysis and display alarm map of real-time pest dynamic. In this paper, we found sex pheromone of *B. minax*, which can attract perfectly its male adults in last two successive years in citrus orchards.

ICT P23. Differential colonization of *Solanum sisymbriifolium* by *Ralstonia solanacearum* strains

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Grafting desired scions of tomato and eggplant onto disease-resistant rootstocks is a tactic used to manage bacterial wilt caused by *Ralstonia solanacearum* in South Asia. *Solanum sisymbriifolium* is frequently used as a rootstock, but plants grafted onto this species have failed recently in some locations in Bangladesh and Nepal. To determine the susceptibility of *S. sisymbriifolium* plants to colonization by *R. solanacearum*, eight strains from wilted tomato or eggplant grafted onto *S. sisymbriifolium* rootstocks, or wilted non-grafted plants in Bangladesh and Nepal were used to challenge *S. sisymbriifolium* seedlings. Plants were inoculated by root drenching and stems were cut 0.5 cm above the soil line 5, 12 and 20 days post-inoculation (dpi), then placed in 500 µl sterilized distilled water for 24 hrs. Populations of *R. solanacearum* in the bacterial ooze determined by quantitative real-time PCR (qPCR) were strongly positively correlated with populations determined by dilution plating. All eight strains were recovered from inoculated plants. *R. solanacearum* populations remained relatively low until 20 dpi. There were significant differences in numbers of bacteria detected in ooze among the eight strains. None of the *S. sisymbriifolium* plants wilted up to 36 dpi, although tomato 'OH7814' seedlings inoculated with the same *R. solanacearum* strains began wilting at 7 dpi.