Herbicide Resistance Action Committee of CropLife Philippines
Monthly Seminar Series 29 July 2022 via Zoom

Herbicide resistance management in lowland vegetables

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Trivia question #1

Which anthocyanin pigment makes the eggplant purple?

a. Delphinidin

b. Nasunin

c. Cyanidin

d. Pelargonidin

Trivia question #2

Which weed species has reports of multiple resistance to as many as 14 sites of action?

a. *Echinochloa colona*

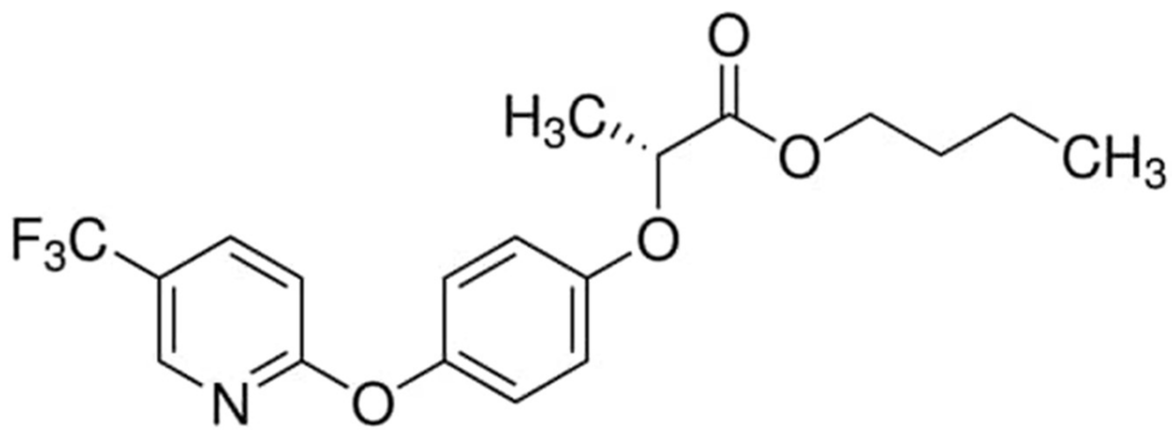
b. *Eleusine indica*

c. *Lolium rigidum*

d. *Cyperus rotundus*

Trivia question #3

Which herbicide has this chemical structure?



a. Fenoxaprop-P-ethyl
b. Fluazifop-P-butyl
c. Fluorodifen
d. Florpyrauxifen

Presentation Topics

- **Common weeds** in lowland vegetables
- Weed **management options** in lowland vegetables
- Herbicide **selection** and **mode of action**
- Development of **herbicide resistance** in weeds of lowland vegetables
- Possible solutions for mitigating **herbicide resistance** in lowland vegetables

Economic Importance of Lowland Vegetables

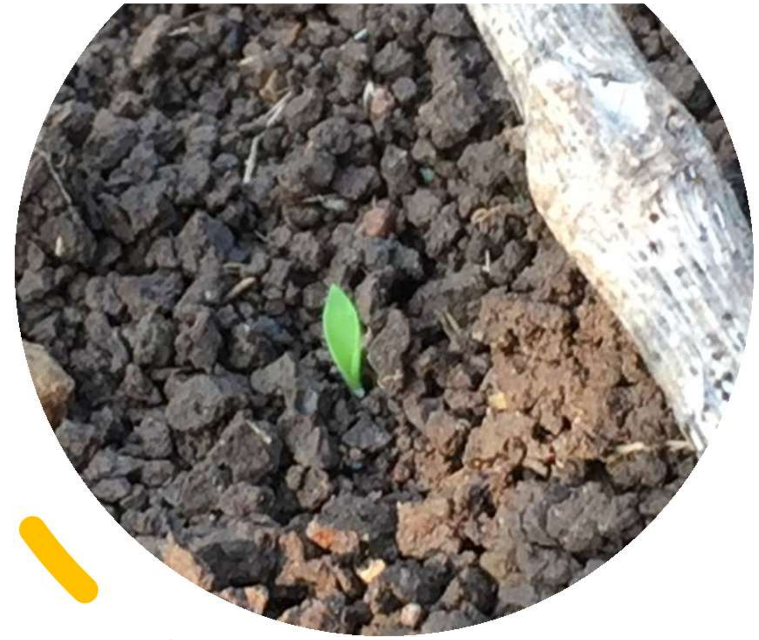
Vegetable	Production (metric tons)	Area (thousand hectares)	Top Producers	% of Total Production
Eggplant	241.90	21.45	Ilocos Region CALABARZON Central Luzon	37 % 13.7 % 10.9 %
Garlic	7.75	2.57	Ilocos Region MIMAROPA Region	65.8 % 22.2 %
Mungbean	35.34	3.8	Ilocos Region Central Luzon	35.7 % 15.5 %
Onion	184.43	18.26	Central Luzon Ilocos Region MIMAROPA Region	62.7 % 21.8 % 10.5 %
Sweet Potato/ Camote	537.30	No data	Eastern Visayas Bicol Region Central Luzon	19.7 % 16.3 % 9.5 %

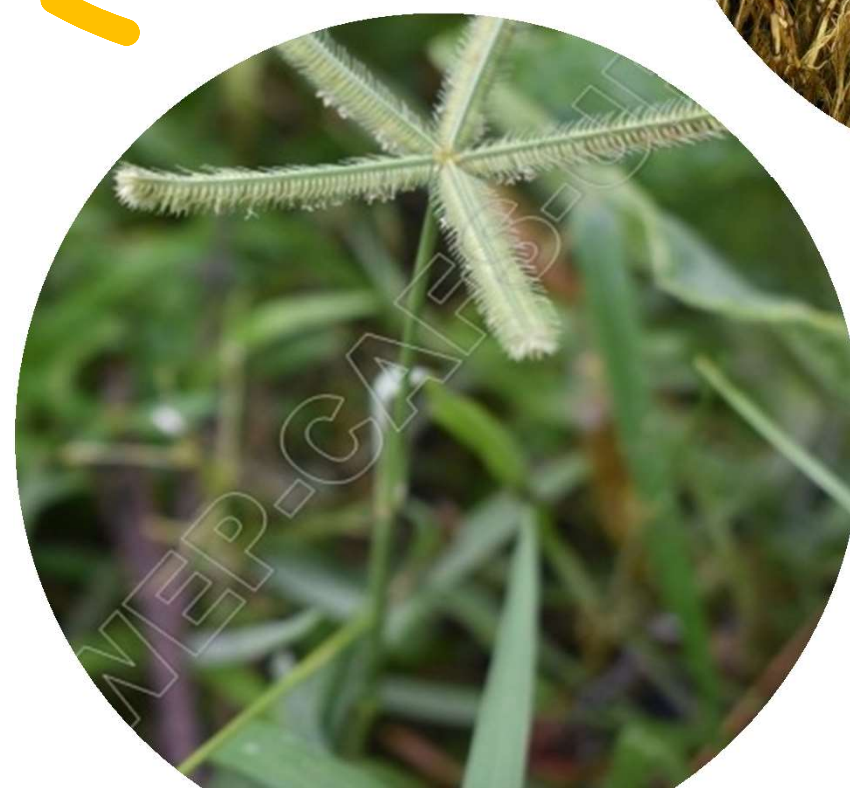
Source: Philippine Statistics Authority, 2017 Data

Common weeds of lowland vegetables

- Grasses
- Sedges
- Broadleaves

Characteristics of Grasses





Members of Poaceae family

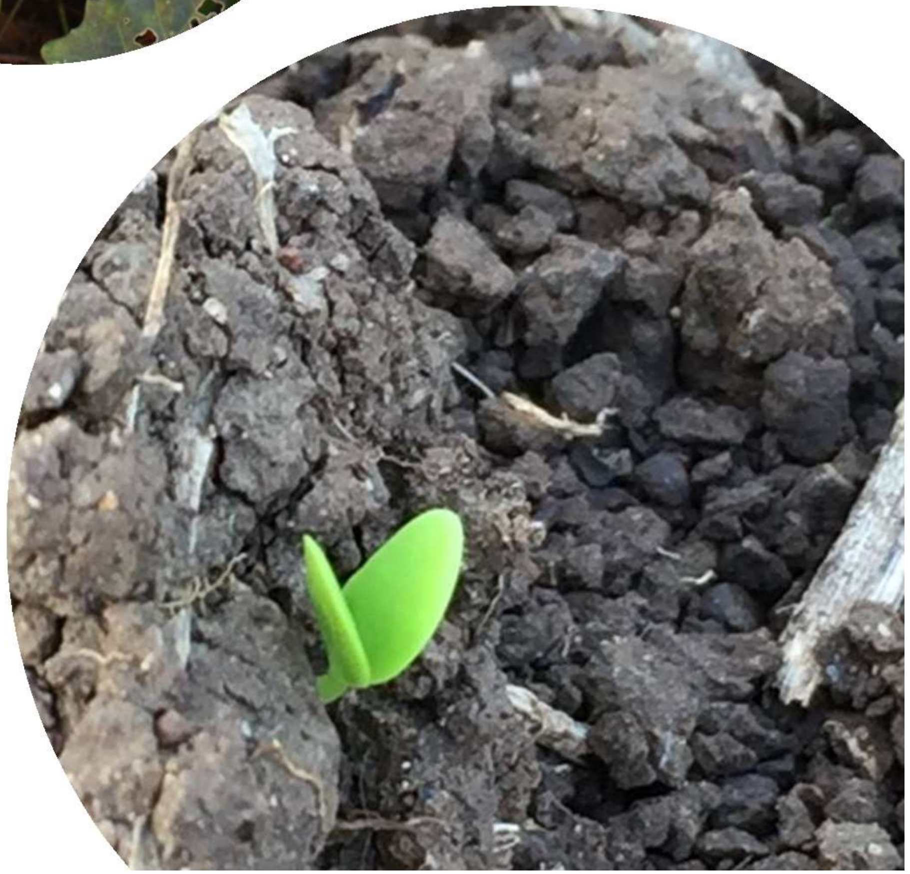
- Leaves are long and narrow, arising alternately in two rows from nodes
- Leaf veins are in parallel while leaf sheaths are split around the stem
- Stems are called culms with well-defined nodes and internodes
- Stems are round and hollow inside
- Ligules and sometimes auricles are present

Characteristics of Sedges

Members of Cyperaceae family

- Leaves are long and narrow but do not have ligules and auricles
- Leaf veins are also parallel but the leaf sheaths are continuous around the stem
- Stems are triangular in shape and have no nodes and internodes

Characteristics of Broadleaves



- Members belong to many families
- Leaves are fully expanded with netted veins for dicots, and parallel veins for monocots
- Leaves, flowers, stems, and branches are broadly arranged in various shapes, colors, and structures

Common grass weeds in lowland vegetables

Axonopus compressus
Carpet grass
Kulape
Perennial, Dryland

Paspalum conjugatum
Carabao grass
Kauat-kauat, Lakatan, Maligoy
Perennial, Dryland

Panicum repens
Torpedo grass or Creeping panic
Tagik-tagik, Buwag-buwag, Maralaya
Perennial, Dryland

- difficult to control especially when its stems had already formed and established thick, dense mats in the soil

Dactyloctenium aegyptium
Crowfoot grass
Krus-krusan, Damong-balang,
Barangan, Tugot-manok
Annual, Dryland

- C4 weed
- produce 65,800 seeds per plant
- growing with many agronomic and vegetable crops

Echinochloa colona
Jungle rice
Annual, Dryland

- C4 weed
- produce more than 8,000 seeds/plant
- one of the top 10 weed species in rice-based cropping systems

Cynodon dactylon
Bermuda grass
Bermuda, Bakbaka, Buku-buku, Kawad-kawad
Perennial, Dryland

- C4 weed
- well-adapted to moist and drier conditions
- can cause significant yield loss
- difficult to control owing since perennial
- easily affected by shading

Digitaria ciliaris
Large crabgrass
Baludgangan, Halos, Saka-saka
Annual, Dryland

- C4 weed
- produces an average of 1,700 seeds
- In rice, can reduce yield by as much as 62%

Eleusine indica
Goosegrass
Paragis, Bakis-bakisan, Palagtiki, Bikad-bikad, Sambali
Annual, Dryland

- produce as much as 50,000 seeds
- competitive ability against any crops in the Philippines are not known
- documents in other countries show that it can reduce yield of corn by 15%

Eragrostis tenella

Lovegrass or Canegrass

Bakinuk, Kaliraurau, Balisbis, Pagay-billit, Pulpulut, Sigsigid

Annual, Dryland

- C4 weed
- can produce more than 140,000 seeds per plant
- can cause yield loss to cultivated plants
- reported susceptible to tungro and rice grassy stunt viruses; and nematode such as *Meloidogyne spp.*

Polytrias amaura
Karpet grass
Perennial, Dryland

- difficult to control when its stems and roots had already formed and established thick, dense mats in the soil

Rottboellia cochinchinensis

Itch grass
Aguingay
Annual, Dryland

- C4 weed
- produce 2,000 seeds per plant
- very competitive weed against any agronomic and vegetable crops owing to its rapid growth, tillering capacity, and formation of numerous adventitious roots

Common sedge weeds in lowland vegetables

Cyperus iria

Rice flat sedge

Payong-payong, Siraw-siraw, Taga-taga

Annual, Dryland

- C4 weed
- produce 3,000 seeds per plant
- mainly a weed of rice but also of other crops especially those that are planted under rice-based cropping systems such as onion, corn, tomato, chilli pepper, etc.

Cyperus rotundus

Purple nutsedge
Barsanga, Mutha, Sudsud
Perennial, Dryland

- C4 weed, considered as the world’s worst weed
- a problem to many cultivated crops due to its prolific behavior in the soil, persistence in harsh environments, and competitive ability.
- full competition of *C. rotundus* has been reported to reduce yields of different crops from 6 to 100%

Fimbristylis miliacea

Fimbristylis

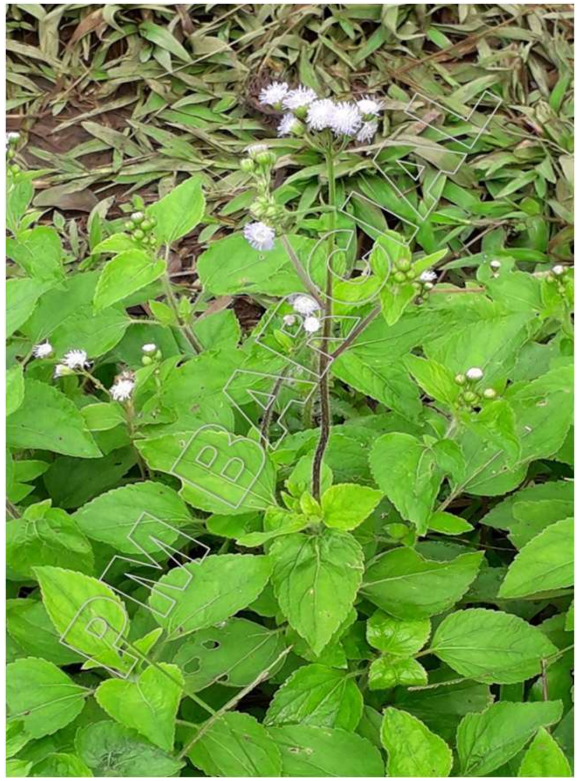
Bungot-bungot, Buntot-pusa, Gumi, Siraw-siraw, Sirisibayas, Sumpana-balik

Perennial, Dryland

- C4 weed, can produce more than 40,000 seeds per plant.
- mainly a weed of rice but it has been also observed growing and infesting rice-based crops

Common broadleaf weeds in lowland vegetables

Ageratum conyzoides
Tropic ageratum
Bulak-manok, Singilan, Bahug-bahug
Annual, Dryland



- short-lived weed
- highly adaptive to extreme conditions and can easily colonize cultivated areas

Aeschynomene indica
Indian jointvetch
Makahiyang lalaki
Perennial, Dryland

- is occasionally observed in orchards, field crops and vegetable plots
- recorded as an important alternative host of the pod-borer, *Helicoverpa armigera*

Boerhavia erecta
Erect boerhavia
Paanbalisbis
Annual, Dryland

- inflorescence is an axillary panicle and leafy at the base
- flowers are white or pale pink, and funnel-shaped

Borreria laevis
White broomweed
Akupao
Annual, Dryland

- leaves are oppositely arranged, oblong to oval-lanceolate in shape, and narrowed at the base to a short petiole
- flowers are white, tubular, and clustered in leaf axils

Borreria ocymoides
Purple-Leaved Button Weed
Landrina, Siksik-parang
Annual, Dryland

- leaves are oppositely arranged, ovate to elliptical or oblong, with short stalk.
- flowers are numerous, small, crowded, and white

Amaranthus spinosus

Spiny amaranth
Alayon, Ayang lalaki, Ayantoto, Kulitis, Uray
Annual, Dryland

- C4 weed, can produce 117,000 seeds/plant
- competitive ability against rice and rice-based crops has yet to be reported.
- reputed as an alternative host of *Meloidogyne graminicola* and *M. incognita* that cause root galls to cultivated crops

Amaranthus viridis

Slender amaranth
Alom-alom, Ayang babae, Halon, Kilitis, Uray Babae
Annual, Dryland

- C4 weed that can produce 7,000 seeds/plant
- reported as an alternative host of *Meloidogyne graminicola* and *M. incognita* that cause root galls.

Calopogonium mucunoides
Calopo
Balatong-aso, Iping-iping, Nipay-nipay, Kalopogonium, Mungo-mungo
Annual, Dryland


Donayre et al. 2019

Cardiospermum halicacabum
Balloon plant
Lubo-lobohan, Alalayon, Parol-parolan, Paltu-paltukan
Annual, Dryland


Donayre et al. 2019

Centrosema pubescens
Butterfly pea
Bagon-bagon, Balagon, Balbalaten, Dilang-butiki
Annual, Dryland


Donayre et al. 2019

- difficult to control when its stems and roots had already formed and established thick, dense mats on the soil surface

Cleome rutidosperma

Spindle top
Apoy-apoyan, Tantandok, Sili-silihan
Annual, Dryland

- have moderate economic impacts in a wide range of crops
- smothers and stunts young crop plants

Cleome viscosa

Asian spiderflower
Apoy-apoyan, Bala-balanoyan, Hulaya
Annual, Dryland

- fast-growing herb of humid and warm habitats
- commonly found growing as a weed in disturbed sites, gardens, rice paddies, pastures, orchards, abandoned lands, and along roadsides

Commelina benghalensis
Dayflower
Alikbangon, Gatilang, Kulasi
Annual, Dryland

- weed of the tropics and subtropics
- widely distributed in West Africa, East Africa, Central, Southern and South-East Asia extending as far as Japan, the Philippines and Australia

Commelina diffusa
Spreading dayflower
Alikbangon, Gatilang, Kulasi
Perennial, Dryland

- reported to reduce the number of leaves, chlorophyll content as well as nitrogen, phosphorus and iron contents of grains when allowed to compete with bean (*Phaseolus vulgaris* L.).

Corchorus aestuans

Jute mallow
Salsaluyot
Annual, Dryland

- grows smaller than *C. olitorius*
- has leaves that are ovate or ovate-oblong, finely toothed with rounded base
- flowers are yellow; capsules have 6 to 8 wings, elongated, and trifid beaks

Corchorus olitorius

Bush okra
Saluyot, Tagabang, Tugabang
Annual, Dryland

- has leaves that are ovate or ovatelanceolate, margins serrated, toothed, with clusters of small leaves near the axils.
- flowers are yellow and its ten-ribbed capsules are elongated and entirely beaked

Eclipta prostrata

Eclipta
Higis-manok, Tultulisan, Tinta-tinta
Annual, Dryland & wetland

- C3 weed; stems are fleshy, reddish, hairy, and rooting at the nodes
- flower heads measuring 1-cm-diameter bear small white flowers

Eclipta zippeliana

Higis-manok, Tultulisan, Tinta-tinta
Annual, Dryland & wetland

Donayre et al. 2019

- C3 weed; has the same morphological characteristics as *E. prostrata* except that its leaves are light green, oblong-obovate to lanceolate, has margins that are coarsely spinulose-toothed
- stems and leaves are much covered with many hairs

Euphorbia heterophylla
Mexican fireplant
Kanaka
Annual, Dryland

- stems are hollow with milky sap, single or branched, hairy or sometimes no hairs
- flowers are grouped consisting of several male flowers and one female enclosed in a cup with a funnel-shaped gland on one side

Euphorbia hirta
Garden spurge
Banbanilag, Botonis, Bolobotonis
Annual, Dryland

- produce white milky sap. Inflorescences are numerous, dense, axillary, shortstalked without petals

Euphorbia hypericifolia
Golden spurge
Gatas-gatas
Annual, Dryland

- stems produce white milky sap when snapped
- leaves have short petioles, oblong to wide lanceolate with an acute tip

Gomphrena celosioides
Bachelor's Button
Botonsilyong-gapang, Malauray
Annual, Dryland

- has a creeping or ascending growth habit
- stems are multibranched from the base; leaves are oppositely arranged, hairy on the blades

Hedyotis corymbosa
Diamond-Flower
Dalumbang, Kaddok-na-kalinga, Palarapdap, Pisak
Annual, Dryland

- stems are branched and slender; inflorescence has 2-8 small flowered umbels

Melochia concatenata
Redweed
Bankalanan, Kaliñgan, Marasaluyot
Perennial, Dryland

- an alternate host of plant parasitic nematodes such as *Pratylenchus* and *Rotylenchus*.

Macroptilium atropurpureum
Purple bush-bean
Bala-balatong, Mala-sitaw
Broadleaf, Annual, Dryland

- difficult to control manually when its stems had already multiplied and formed thick, dense mats

Macroptilium lathyroides
Wild bush-bean
Bala-balatong
Broadleaf, Annual, Dryland

- erect legume that has branchy and woody stems
- flowers are red-purple
- the weed also has green (young) to brown (mature), long and slender pods that bear seeds

Portulaca oleracea
Common purslane
Alusiman, Kantataba, Ngalug, Olasiman
Annual, Dryland

- prostrate or spreading growth
- stems are branched, succulent, smooth, and reddish
- leaves are fleshy
- flowers are yellow with 5 petals

Trianthema portulacastrum
Horse purslane
Alusiman, Ayam, Kantataba, Toston
Annual, Dryland

- C4 weed
- produce seeds at 6,940 per plant
- growing with other weeds had been reported to reduce yield of onion by as much as 90%
- reduced by 50 to 60% yield of mungbean when left untreated in the field

Synedrella nodiflora
Synedrella
Annual, Dryland

- host of many plant parasitic nematodes such as *Meloidogyne, Pratylenchus, Rotylenchus,* and *Xiphinema*

Tridax procumbens
Tridax
Dryland, Annual

- weed of 31 crops
- wide range of crop types are infested, including cereals, fibers, legumes, pastures, tree crops and vegetables

Helotropium indicum
Indian heliotrope
Annual, Dryland

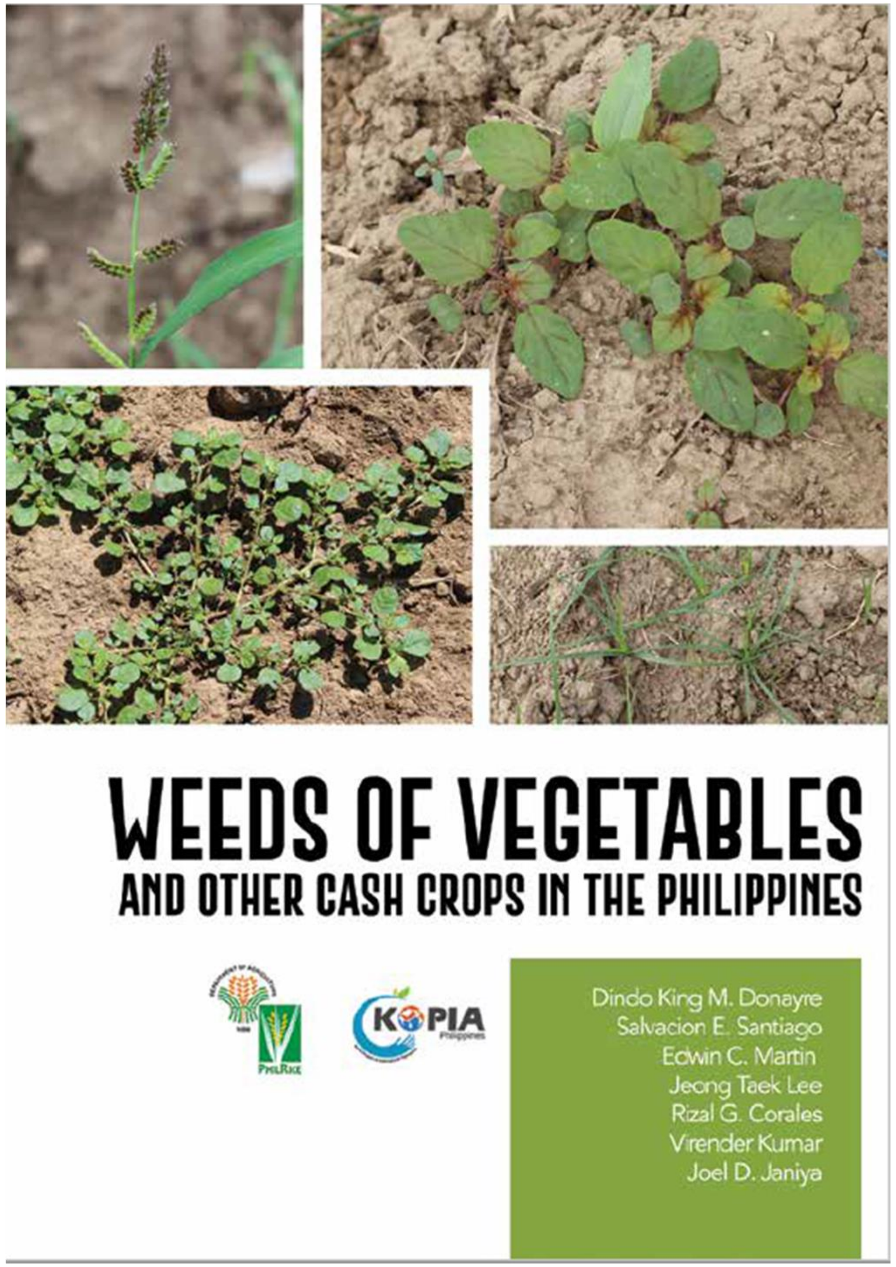
- has a stem that is covered with hairs
- leaves that are ovate to oblong-ovate with rough surfaces
- flowers that are positioned on one side with lavender to white corolla

Ipomoea triloba
Three-lobe morning glory
Kamkamote, Kupit-kupit, Aurora,
Annual, Dryland

- difficult to control manually when its stems had already multiplied and formed thick, dense mats

Mimosa pudica
Sensitive plant
Makahiya, Hibi-hibi, Huya-huya,
Perennial, Dryland

- has reddish-brown stems that are covered by less numerous spines
- leaves close when touched, digitately arranged at the end of each petiole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AND OTHER CASH CROPS IN THE PHILIPPINES
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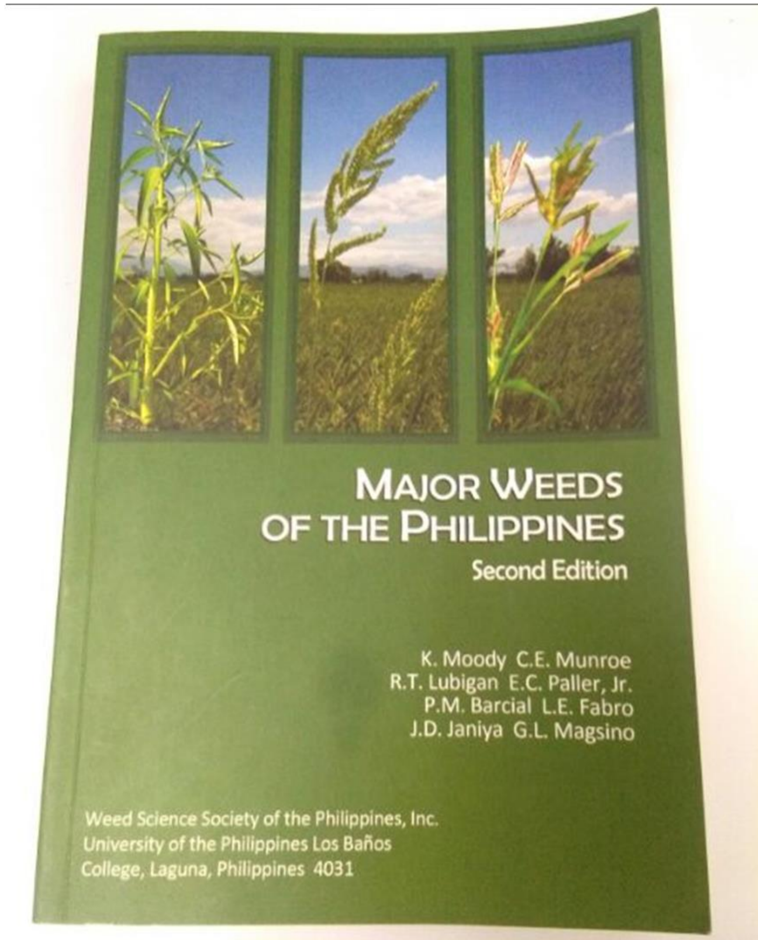
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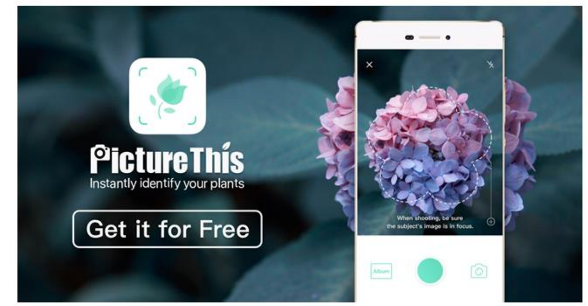
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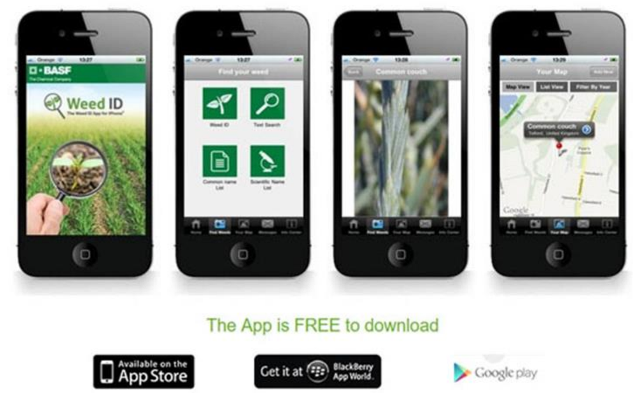
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Why do we need to control weeds?

- Weeds serve as **alternative hosts** of insects and pathogens which invariably damage the vegetable crops.

Cyperus rotundus
Purple nutsedge

White tip nematode

Cyanthillium cinereum
Little iron weed

Brown spot fungi

Synedrella nodiflora
Synedrella

Many plant parasitic nematodes such as *Meloidogyne, Pratylenchus, Rotylenchus,* and *Xiphinema*.

- Weeds also interfere with in-field operations, such as fertilizer application, harvesting, etc.

- Weeds compete with crops for nutrients, soil moisture and sunlight resulting to lower yield and economic losses.

Crops	Types of yield loss	Percent yield loss range
Bush bean/ sitao	Actual	0-20
	Potential	60-66
Mungbean	Actual	20
	Potential	10-100 ★
Soybean	Actual	37-71
	Potential	7-100 ★
Tomato	Actual	0-17
	Potential	58-93 ★
Onion	Actual	0-66
	Potential	38-96 ★
Sweet potato	Actual	11.4
	Potential	48.7
Cassava	Actual	5.3
	Potential	52.1
Upland Taro	Actual	4.3
	Potential	46.1

Estimated yield losses due to weeds in different vegetables and root crops based on the data generated from weed control experiments in the Philippines (Paller, 2002)

How to manage weeds in vegetable fields?

- No single weed management technique is effective against all types of weeds.
- It is important to use two or more techniques to achieve better weed control that is cost-effective, environment-friendly, and acceptable to farmers.
- Practice integrated weed management.

Weed management practices

Prevent introduction and spread of weeds

- Using **high-quality seeds** that are clean helps prevent entries of seeds and other asexual parts of the weeds into the field.
- High quality seeds also ensure **high germination rat**e and better growth of **healthy seedlings**.

How to do it?

- ✓ Buy and plant clean seed/ seedlings.
- ✓ Isolation of introduced livestock to prevent spread of weed seeds from their digestive tract.
- ✓ Use of clean farm equipment.
- ✓ Inspection of imported nursery stock for weeds, seeds, and vegetative reproductive organs.
- ✓ Inspection and cleaning of imported gravel, sand and soil.

Weed management practices

Practice thorough land preparation

- Suppress growth of weeds by burying them in the soil or exposing their seeds and other asexual parts under the heat of the sun, which eventually kills them by desiccation.

- Destroy weeds by separating their shoots and roots; and encouraging the germination or sprouting of their dormant seeds and asexual propagules buried in the soil.

Weed management practices

Do manual weeding

- Practice handweeding or use of small hand tools such as sickles or bolos.
- Very effective and efficient in removing weeds that grow within rows and hills of growing crops.
- Also effective in preventing the spread of resistant weed biotypes by uprooting the whole weed plant or removing the inflorescence that carries the weed seeds.

Weed management practices

Do mechanical weeding

- Involves bigger tools
- Best accomplished by inter-row cultivation (off-barring) or hilling-up using an animal- or tractor-drawn mechanical weeder.
- Growth of weeds is suppressed by cutting, trampling, burying, or exposing weeds under the heat of the sun.

Large Mantis

Small Mantis

Brush cutter

Source: Hauser et al. (2019)

Weed management practices

Mulching

- Excludes light and prevents shoot growth of weeds.
- Helps retain moisture needed by cultivated crops.
- Several different materials have been used for mulch, including straw, hay, manure and black plastic.

Weed management practices

Mulching

- Use of allelopathic crops as mulch material, example rye mulch.

FIGURE 2 | Field trial on rye mulch preceding a tomato crop in a biological farm (Schulz et al., 2013). Left, test plot with rye mulch left on the soil surface, showing the good weed suppression ability. Right, control plot without rye mulch, split into two treatments: left side, untreated sub-plot in which tomato plants are almost completely overgrown by weeds; right side, sub-plot with mechanical control by cultivation, in which tomato plants grow as well as those in the test plot.

Source: Cheng and Cheng, 2015 Frontiers in Plant Science

Weed management practices

Intercropping

- 30–60% weed control can be achieved in cassava by intercropping cassava with other crops: **soybean, mungbean, stringbean, peanut, corn, and melon.**

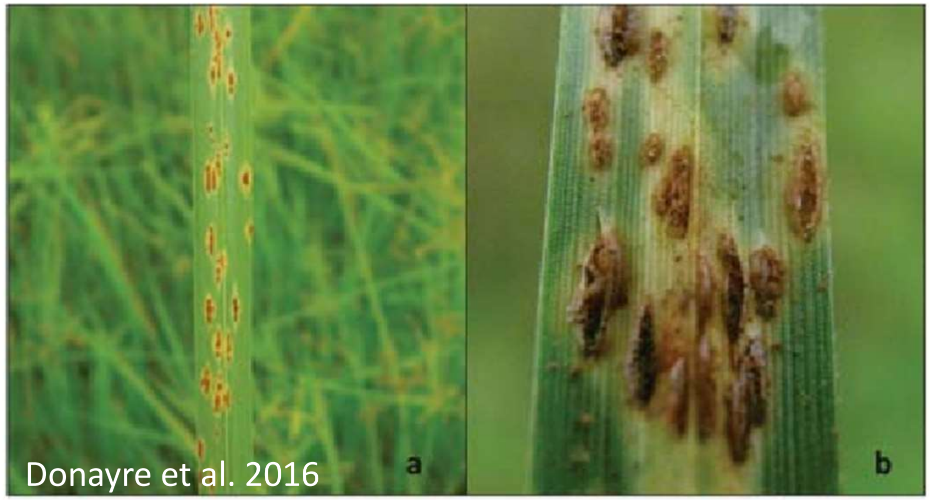
Source: Hauser et al. (2019)

Weed management practices

Enhance natural weed control by beneficial organisms

- Use of biological control agents against weeds such as insects and microorganisms.
- Helps minimize the time, effort, and money of farmers spent for weed control.
- Requires correct identification, and knowledge on the biology and ecology of host-specific beneficial organisms to effectively control the target weeds.
- Examples of such organisms are *Spoladea recurvalis* (insect) foraging on the leaves of *Trianthema portulacastrum,* and *Puccinia philippinensis* (fungus) infecting the leaves of *Cyperus rotundus*.

Ehsine and Aoun 2016



Donayre et al. 2016

Weed management practices

Chemical Control – use of herbicides

- Last recourse when other techniques cannot control the target weeds.
- Proper use of herbicides is strictly advised.
- Incorrect usage will endanger the health of the user as well as the people, domesticated animals, and the environment.
- Prolonged and continuous use of the same kind, incorrect dosage, and wrong timing will also result in herbicide-resistant weeds.

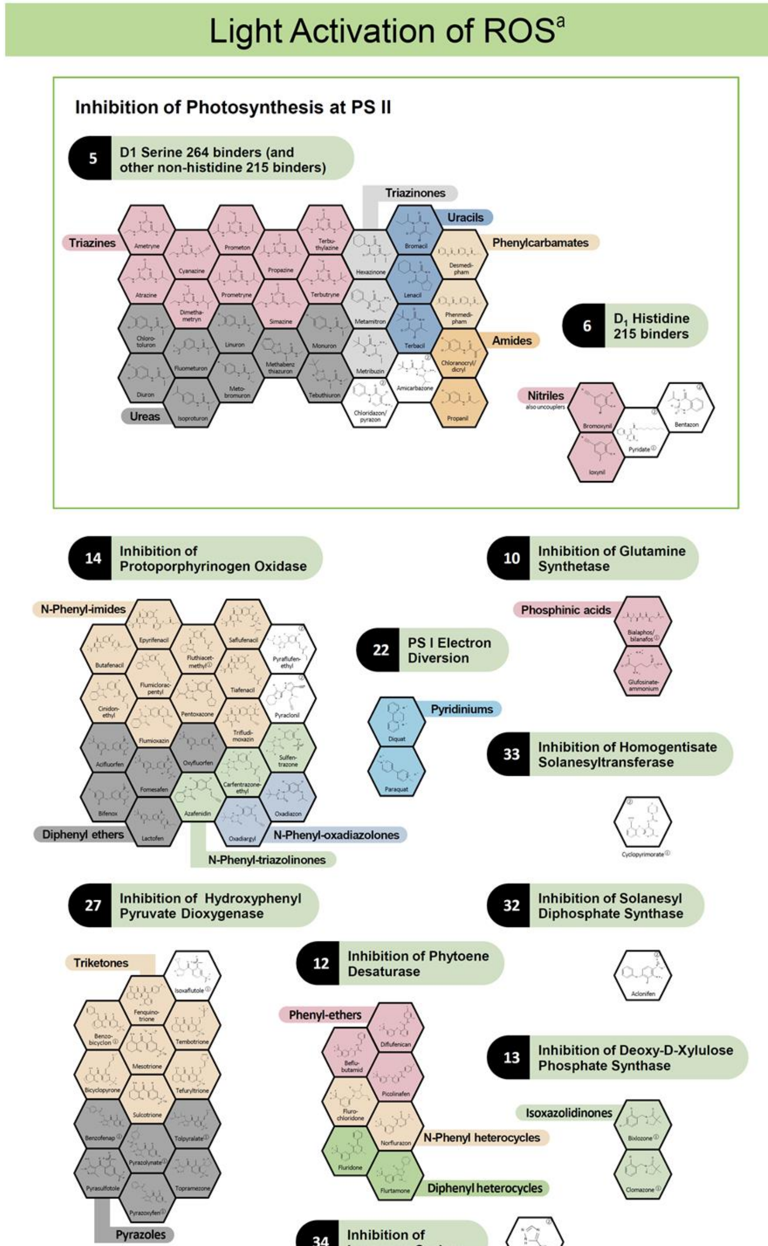
Herbicides and their target sites, modes of action and numerical classification according to WSSA and HRAC (new, updated June 2020).

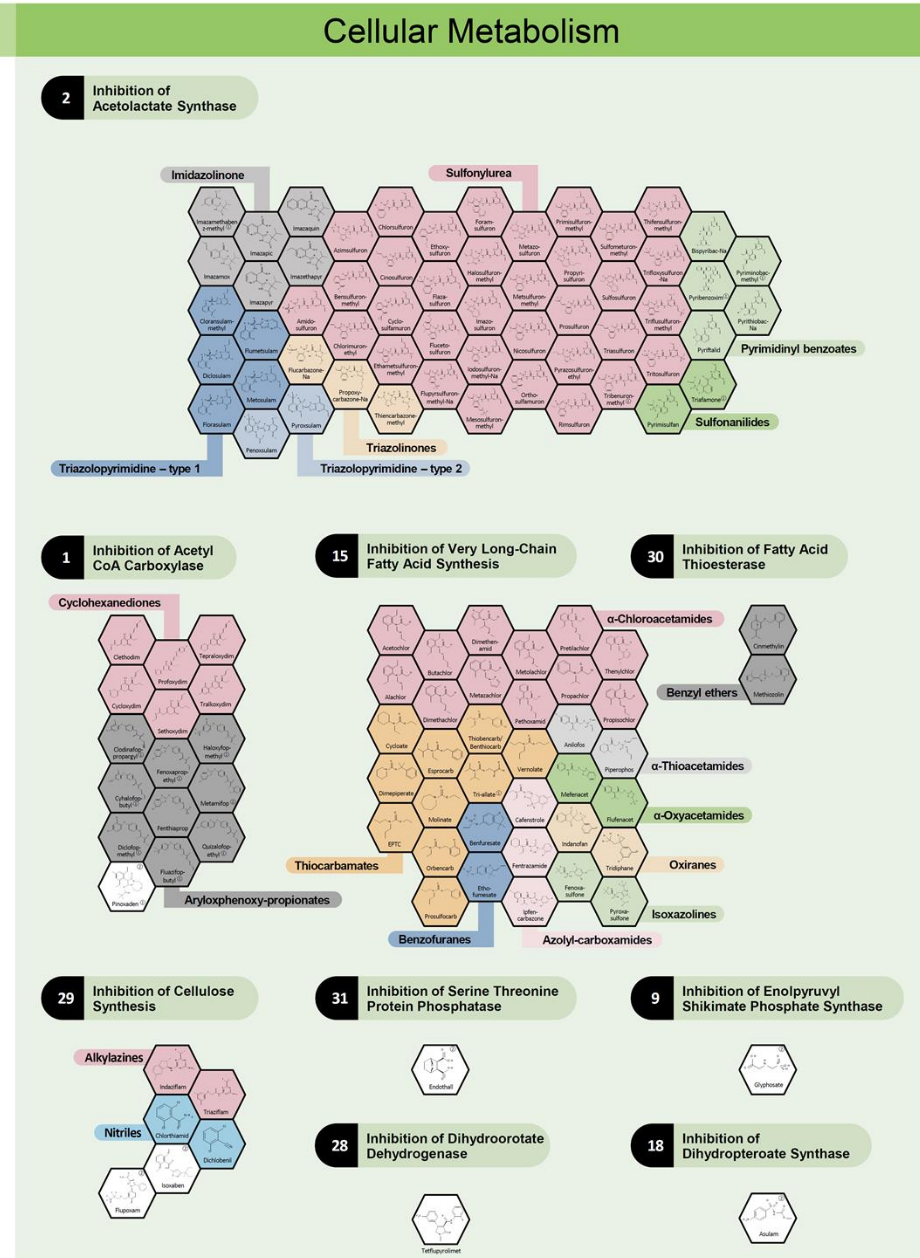
WSSA, HRAC Number	Target site (Enzyme inhibited)	Mode of action	Example (herbicide)
1	Acetyl CoA carboxylase (ACCase)	Inhibit fatty acid synthesis	fenoxaprop, cyhalofop
2	Acetolactate synthase (ALS)	Inhibit branched chain amino acid synthesis	bensulfuron, bispyribac, imazapyr
3	Microtubules	Inhibit microtubule assembly	pendimethalin
4	T1R1/AFB receptor proteins	Inhibit growth	2,4-D, dicamba, florpyrauxifen, halauxifen
5	Photosystem II, Serine binders	Inhibit photosynthesis	atrazine, monuron
6	Photosystem II, Histidine binders	Inhibit photosynthesis	bromoxynil, bentazon
9	Enolpyruvyl shikimate phosphate (EPSP) synthase	Inhibit aromatic amino acid synthesis	glyphosate
10	Glutamine synthetase	Inhibit glutamine synthesis	glufosinate, bialaphos
12	Phytoene desaturase (PDS)	Inhibit carotenoid biosynthesis	norflurazon, fluridone
13	Deoxy-D-xylulose phosphate synthase (DXP synthase)	Inhibit carotenoid biosynthesis	clomazone, bixlozone
14	Protoporphyrinogen oxidase (PPO)	Inhibit carotenoid biosynthesis	oxadiazon, oxyfluorfen, carfentrazone
15	VLCFA elongase	Inhibit very long chain fatty acid (VLCFA) synthesis	butachlor, thiobencarb fenoxasulfone, alachlor
18	Dihydropteroate dehydrogenase		asulam
19		Inhibit auxin transport	naptalam, diflufenzopyr
22	Photosystem I	Electron diversion	paraquat, diquat
23	Microtubules	Inhibit microtubule organization	propham, chlorpropham
24	Oxidative phosphorylation, Photophosphorylation	Uncouplers	dinosam, dinoseb
27	Hydroxyphenyl pyruvate dioxygenase (HPPD)	Inhibits carotenoid biosynthesis	Pyrazolynate, tolpyralate, mesotrione, isoxaflutole
28	Dihydroorotate synthase	Interferes with pyrimidine biosynthesis	Tetflupyrolimet
29	Cellulose synthase	Inhibits cellulose/cell wall synthesis	Isoxaben, Indaziflam, Triaziflam
30	Fatty acid thioesterase	Inhibits fatty acid synthesis	Cinmethylin, methiozolin
31	Serine threonine protein phosphatase	Interferes with microtubule cytoskeleton arrangement	Endothall
32	Solanesyl diphosphate synthase	Inhibits carotenoid/plastoquinone biosynthesis	Aclonifen
33	Homogentisate solanesyltransferase	Inhibits carotenoid/plastoquinone biosynthesis	Cyclopyrimorate
34	Lycopene cyclase	Inhibition of carotenoid synthesis	Amitrole
0	Unknown target site	Unknown mode of action	Bromobutide, cumyluron, quinoclamine, diphenamid

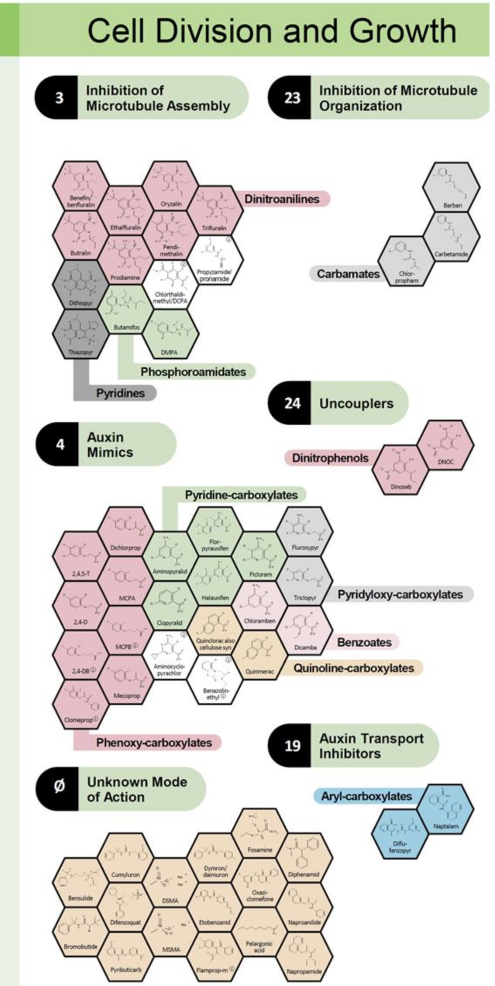
HRAC Mode of Action Classification 2022

Revised January 2022

HERBICIDE RESISTANCE ACTION COMMITTEE







HRAC	Legacy HRAC	
1	A	Inhibition of ACCase
2	B	Inhibition of ALS
3	K1	Inhibition of microtubule assembly
4	O	Auxin mimics
5	C1,2	Inhibition of photosynthesis PS II – Serine 264
6	C3	Inhibition of photosynthesis PS II – Histidine 215
9	G	Inhibition of EPSP synthase
10	H	Inhibition of glutamine synthetase
12	F1	Inhibition of PDS
13	F4	Inhibition of DOXP synthase
14	E	Inhibition of PPO
15	K3	Inhibition of VLCFAs
18	I	DHP inhibition

HRAC	Legacy HRAC	
19	P	Auxin transport inhibitors
22	D	PS I electron diversion
23	K2	Inhibition of microtubule organization
24	M	Uncouplers
27	F2	Inhibition of HPPD
28	none	Inhibition of dihydroorotate dehydrogenase
29	L	Inhibition of cellulose synthesis
30	Q	Inhibition of fatty acid thioesterase
31	R	Inhibition of serine threonine protein phosphatase
32	S	Inhibition of solanesyl diphosphate synthase
33	T	Inhibition of homogentisate solanesyltransferase
34	F3	Inhibition of lycopene cyclase
Ø	Z	Unknown mode of action

A free copy of this poster can be downloaded at www.hracglobal.com

[a] Reactive oxygen species

① Indicates pro-herbicide

② HRAC's recommendation is not to include a chemical family name when there is one active in the family. Actives without chemical family names are indicated with a white background

FPA approved herbicides for lowland vegetables

WSSA/ HRAC Code	Target Site (Enzyme Inhibited)	Herbicide	Aapplication	Target Weeds	Crops
1	**Acetyl-CoA Carboxylase**	Fluazifop-P-butyl	Systemic/ Selective (Post-emergence)	grasses; itchgrass, goosegrass, sour paspalum, jungle rice, crabgrasses, bermuda grasses & crowfort grass	Banana, Cacao, Citrus, Cotton, Coffee, Cassava, Oil palm, Ramie, Rubber, **Onion**, Pineapples, **Soybeans**, **Tomato**
		Haloxyfop-R-methyl Ester	Systemic (Postemergence)	annual and perennial grasses	**Onion**
3	**Microtubule Assembly**	Pendimethalin	Selective	grasses & broadleaf weeds	**Onion (transplanted)**
5	**Photosynthesis at PSII-Serine 264 Binders**	Linuron	Selective (Pre/Post-emergence)	annual weeds	**Soybeans, Beans, Peanut, Sweet peas,** Carrot, Celery, Corn, **Onion, Garlic,** Potato, Sugarcane, Tobacco, Pineapple
		Metribuzin	Selective	annual grasses and broadleaves	**Potato, Soybeans,** Sugarcane, **Tomato**
6	**Photosynthesis at PSII-Histidine 215 Binders**	Bentazon	Selective (Post-emergence)	perennial sedges, annual broadleaves and weeds	**Soybeans**
9	**Enolpyruvyl Shikimate Phosphate Synthase**	Glyphosate	Post-emergence	annual & perennial grasses, broadleaf weeds & sedges	**Vegetables**
14	**Protoporphyrinogen Oxidase**	Oxadiazon	Selective (Pre-emergence)	grasses, sedges & broadleaves	**Onion (transplanted)**
		Oxyfluorfen	Selective (Pre /Post Emergence)	Broadleaves, sedges & grasses	**Onion (Transplanted)**

How can **herbicide resistance develop** in weeds of lowland vegetables?

How does herbicide resistance develop?

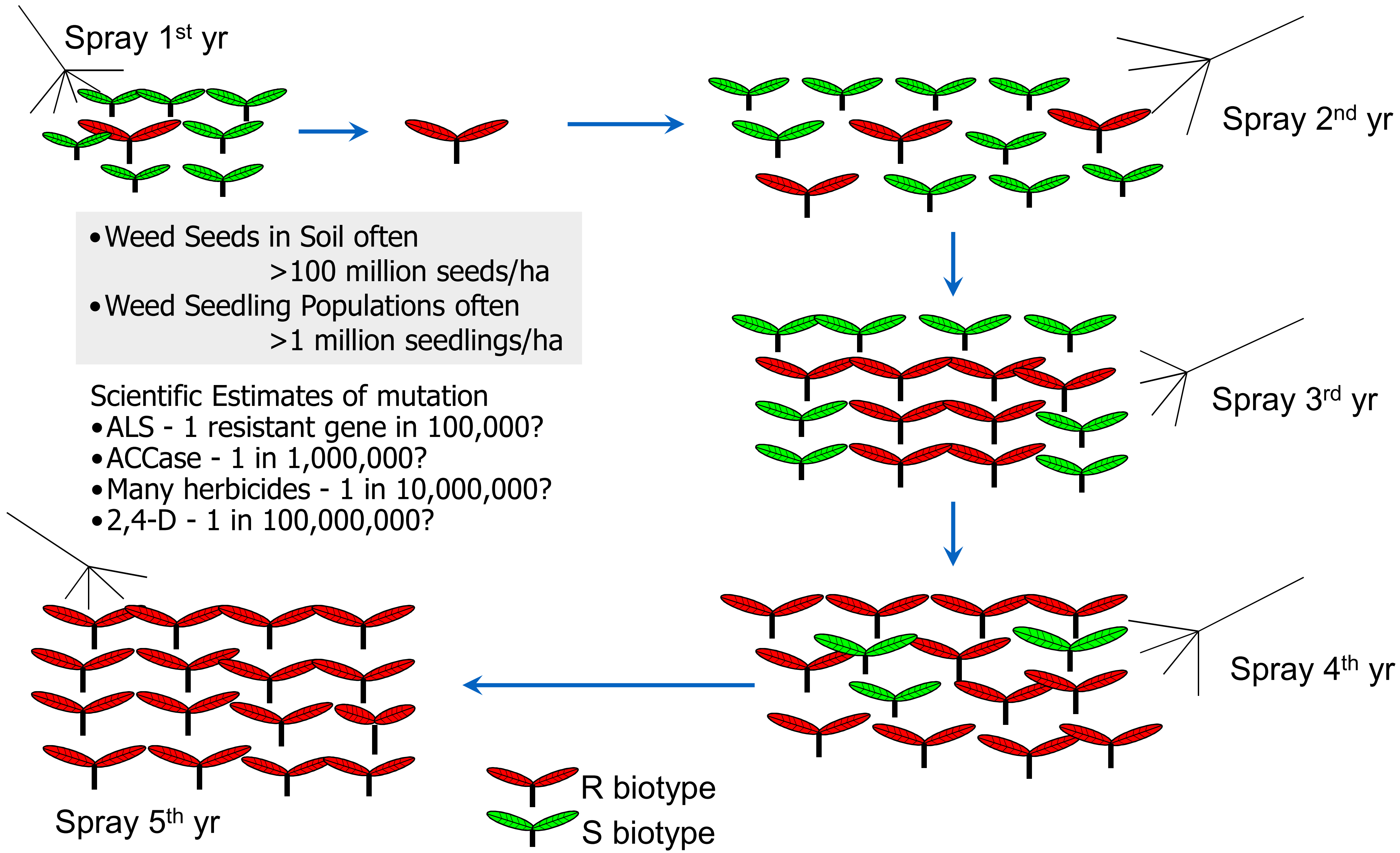
Genetic diversity (rare resistant mutant gene)

+ Selection pressure

(the repeated use of the same herbicide, or herbicides with the same mode of action)

= **RESISTANCE**

Development of herbicide-resistant weed biotypes

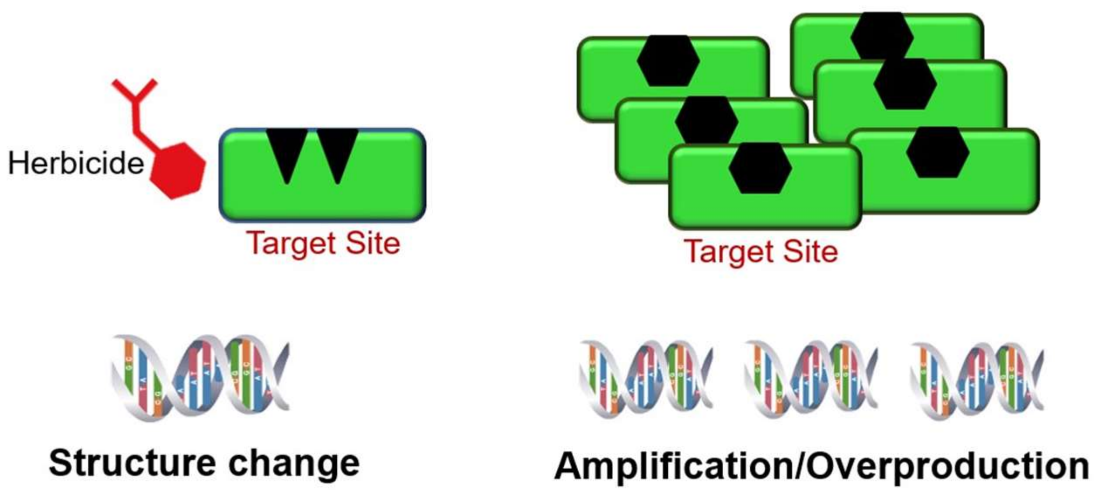


- Weed Seeds in Soil often
  >100 million seeds/ha
- Weed Seedling Populations often
  >1 million seedlings/ha

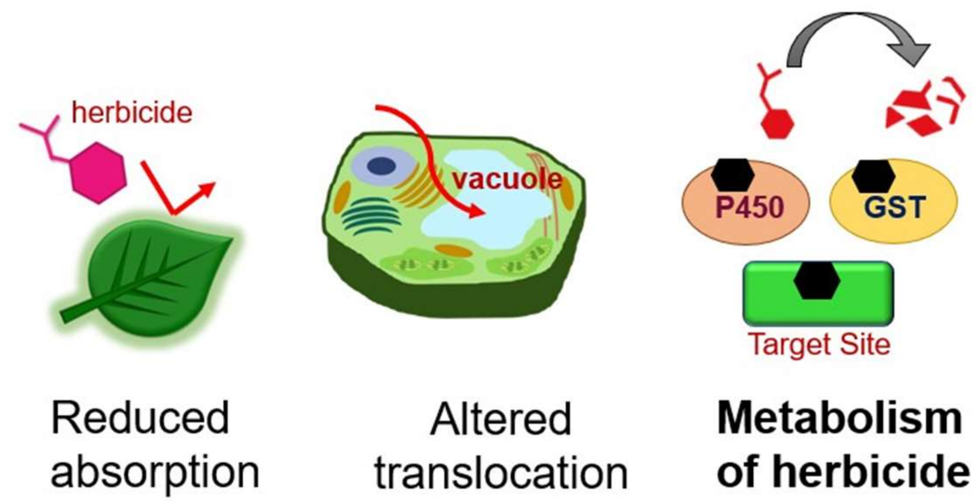
Scientific Estimates of mutation
- ALS - 1 resistant gene in 100,000?
- ACCase - 1 in 1,000,000?
- Many herbicides - 1 in 10,000,000?
- 2,4-D - 1 in 100,000,000?

Mechanisms of herbicide resistance in weeds

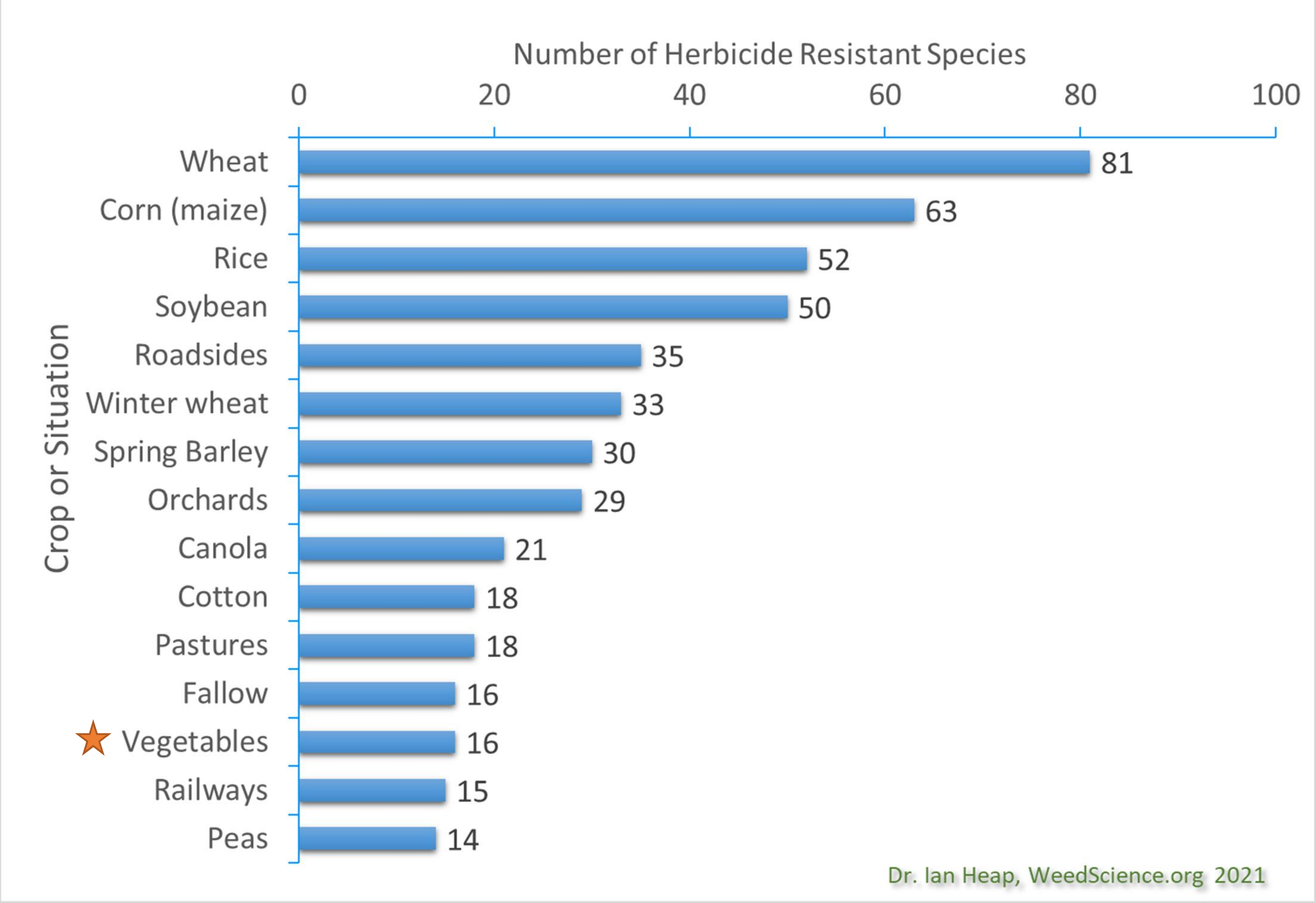
A. Target Site Resistance



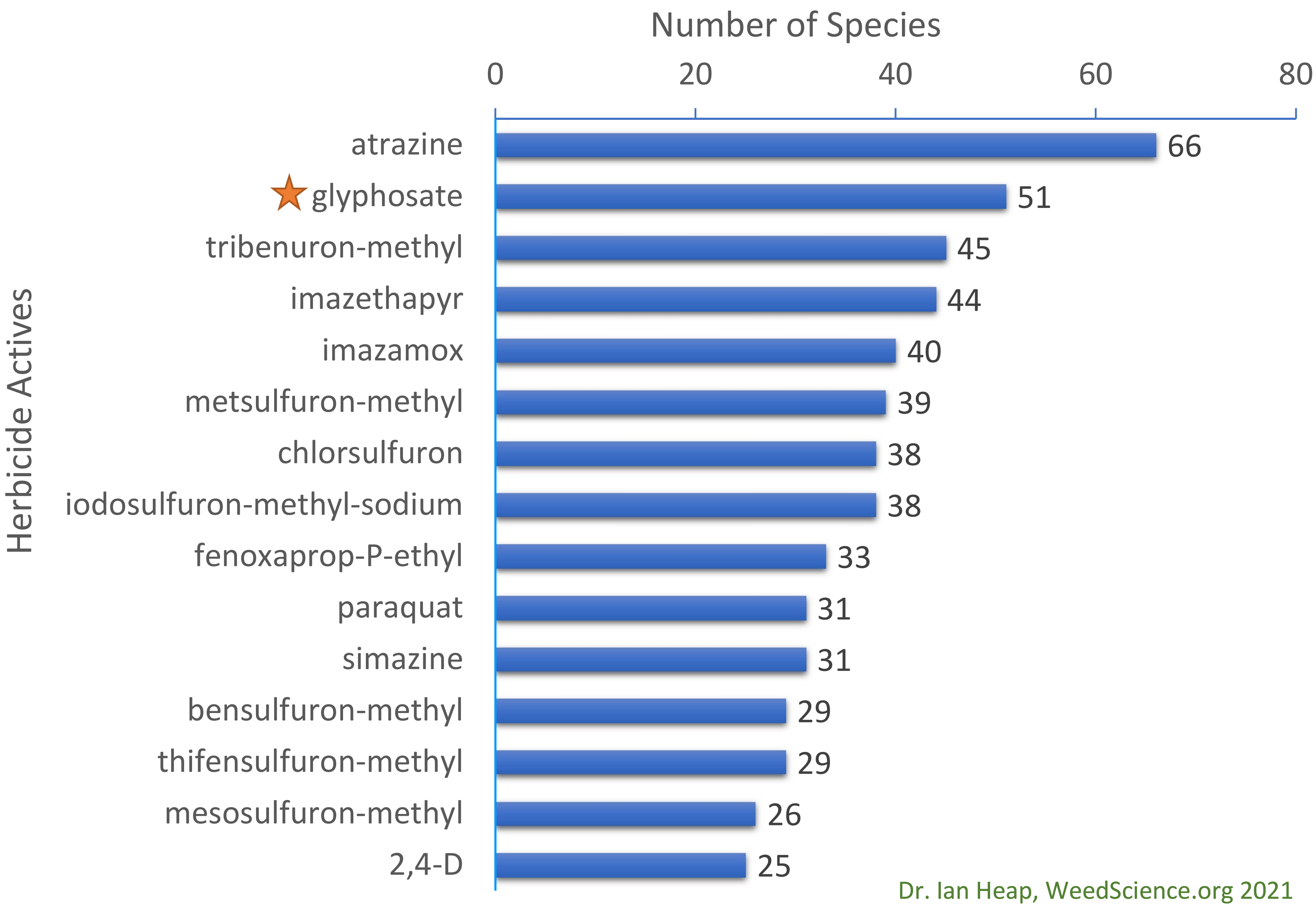
B. Non-Target Site Resistance



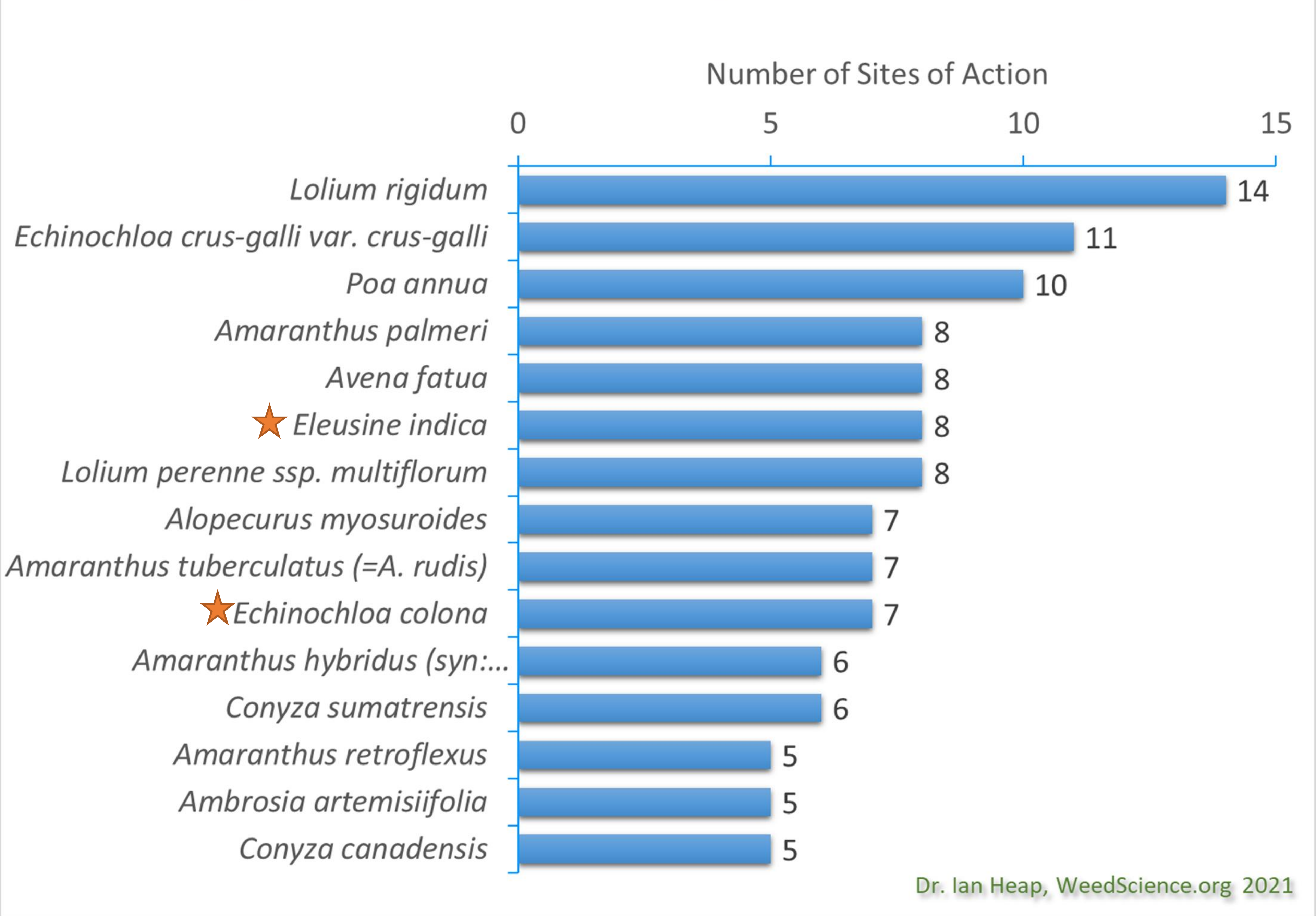
Number of herbicide resistant species by crops



Number of resistant species to individual active herbicides (Top 15)



Weed Species Resistance to Multiple Herbicide Sites of Action



Herbicide Resistance Cases in the Philippines

Resistant to
Butachlor and Propanil


Photo source: Donayre et al. 2018

Echinochloa crus-galli
Barnyardgrass

Resistant to
2,4-D

Sphenoclea zeylanica
Gooseweed

Dr. Ian Heap, Weedscience.org 2021

Herbicide Resistance Cases in the Philippines

- Herbicides which inhibit **ALS, ACCase, and EPSP synthase** are considered to have a high risk of evolving resistance.

- So far, there are no reports on weeds evolving resistance to ALS, ACCase, or EPSP synthase inhibitors in the country, except for a report on glyphosate-resistant goosegrass in southern Philippines (Kaundun et al, 2008).

Weed species exhibiting herbicide resistance in vegetables (Global Data)

Eleusine indica
Goosegrass
Paragis, Bakis-bakisan
Annual, Dryland

Country	Crops	Herbicides	MOA
Argentina, Bolivia, Brazil, USA	Soybean	**glyphosate**	EPSPS inhibitor
Brazil	Soybean	cyhalofop-butyl, fenoxaprop-ethyl, and sethoxydim	ACCase inhibitor
Malaysia	Vegetables	**fluazifop-butyl**, propaquizafop paraquat glufosinate-ammonium	ACCase inhibitor PS I Electron Diversion inhibitor Glutamine Synthetase Inhibitor
USA	Tomatoes	paraquat	PS I Electron Diversion inhibitor

Source: Heap, I. The International Herbicide-Resistant Weed Database 2022

Weed species exhibiting herbicide resistance in vegetables (Global Data)

Echinochloa colona
Jungle rice
Annual, Dryland

Country	Crops	Herbicides	MOA
Argentina	Corn and soybean	**glyphosate**	EPSPS inhibitor
Bolivia	Rice and soybean	cyhalofop-butyl, fenoxaprop-ethyl, **fluazifop-butyl**, and **haloxyfop-methyl**	ACCase inhibitor

Source: Heap, I. The International Herbicide-Resistant Weed Database 2022

Weed species exhibiting herbicide resistance in vegetables (Global Data)

Digitaria ciliaris
Large crabgrass
Baludgangan, Halos, Saka-saka
Annual, Dryland

Country	Crops	Herbicides	MOA
Brazil	Soybean	cyhalofop-butyl, fenoxaprop-ethyl, **fluazifop-butyl**, **haloxyfop-methyl**, propaquizafop, and sethoxydim	ACCase Inhibitor

Source: Heap, I. The International Herbicide-Resistant Weed Database 2022

Weed species exhibiting herbicide resistance in vegetables (Global Data)

Rottboellia cochinchinensis
Itch grass
Aguingay
Annual, Dryland

Country	Crops	Herbicides	MOA
USA	Soybean	**fluazifop-butyl**	ACCase inhibitor

Source: Heap, I. The International Herbicide-Resistant Weed Database 2022

Weed species exhibiting herbicide resistance in vegetables (Global Data)

Ageratum conyzoides
Tropic ageratum
Bulak-manok, Singilan
Annual, Dryland

Country	Crops	Herbicides	MOA
Brazil	Soybean	pyrithiobac-sodium, and trifloxysulfuron-Na	ALS inhibitor

Source: Heap, I. The International Herbicide-Resistant Weed Database

Weed species exhibiting herbicide resistance in vegetables (Global Data)

Amaranthus spinosus
Spiny amaranth
Alayon, Ayang lalaki, Ayantoto, Kulitis, Uray
Annual, Dryland

Country	Crops	Herbicides	MOA
USA	Soybean	imazethapyr, nicosulfuron, pyrithiobac-sodium, and trifloxysulfuron-Na	ALS inhibitor

Source: Heap, I. The International Herbicide-Resistant Weed Database

Weed species exhibiting herbicide resistance in vegetables (Global Data)

Portulaca oleracea
Common purslane
Alusiman, Kantataba, Ngalug, Olasiman
Annual, Dryland

Country	Crops	Herbicides	MOA
USA	Carrots and vegetables	atrazine and **linuron**	PS II inhibitor

Source: Heap, I. The International Herbicide-Resistant Weed Database

How to mitigate development of herbicide resistance?

Management of herbicide-resistant weeds

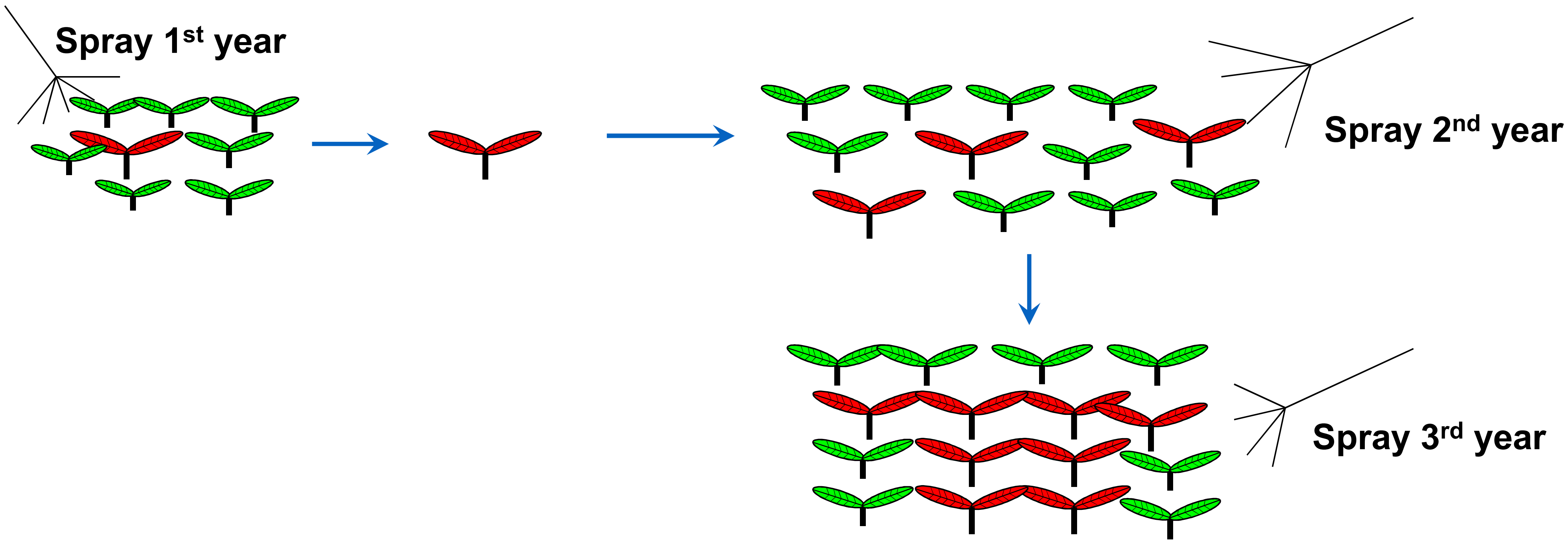
Before assuming that any weeds surviving an herbicide application are resistant, rule out other factors that might have affected herbicide performance:

- Misapplication
- Unfavorable weather conditions
- Improper herbicide application timing
- Weed flushes after application of a non-residual herbicide

Management of herbicide-resistant weeds

1. Recognizing or detecting herbicide resistance

Quickly respond to changes in weed populations to restrict the spread of weeds that may have been selected for resistance.



Management of herbicide-resistant weeds

2. Use alternative non-chemical control methods

Use mechanical weed control practices such as hand weeding, hand hoeing, mulching and cultivation.

Management of herbicide-resistant weeds

3. Knowledge of herbicides and their modes of action
4. Knowledge of weed characteristics or traits that contribute to evolution of resistance
5. Knowing the cropping patterns, history of herbicide use in a particular cropping situation, how resistance evolved

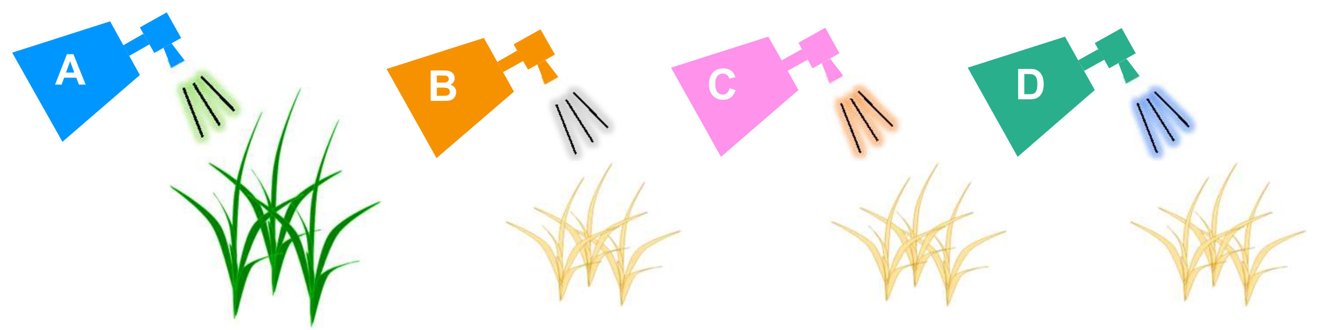
Management of herbicide-resistant weeds

6. Reduce selection pressure by rotating crops and herbicides

Don’t overuse one group of herbicide or mode of action.

7. Use of herbicide mixtures, sequential treatments and synergists

Apply herbicides in tank-mixed, prepackaged or sequential mixtures that include multiple sites of action. For this strategy to be effective, both herbicides must have substantial activity against potentially resistant weeds.



Herbicide rotation

Management of herbicide-resistant weeds

8. Prevent seed set of weeds surviving in the field after harvest

9. Reduce or deplete the weed seedbank

Weed seedbank depletion is generally accomplished by stimulating weed germination and emergence and then destroying weeds that have emerged. Preventing weed seeds from entering the seedbank can also be effective.

Stale seedbed technique is most appropriate to reduce the weed seed bank in the soil. In this technique, weeds are allowed to emerge for at least 2 weeks before being killed.

- Plow and harrow the field during fallow period
- Enhance/allow germination of weed seeds and other asexual parts by light irrigation or after rainfall
- Destroy germinating seeds and asexual parts through another round of harrowing, up to 3 times. Pre-plant herbicides can also be used to eliminate or suppress growing weeds.

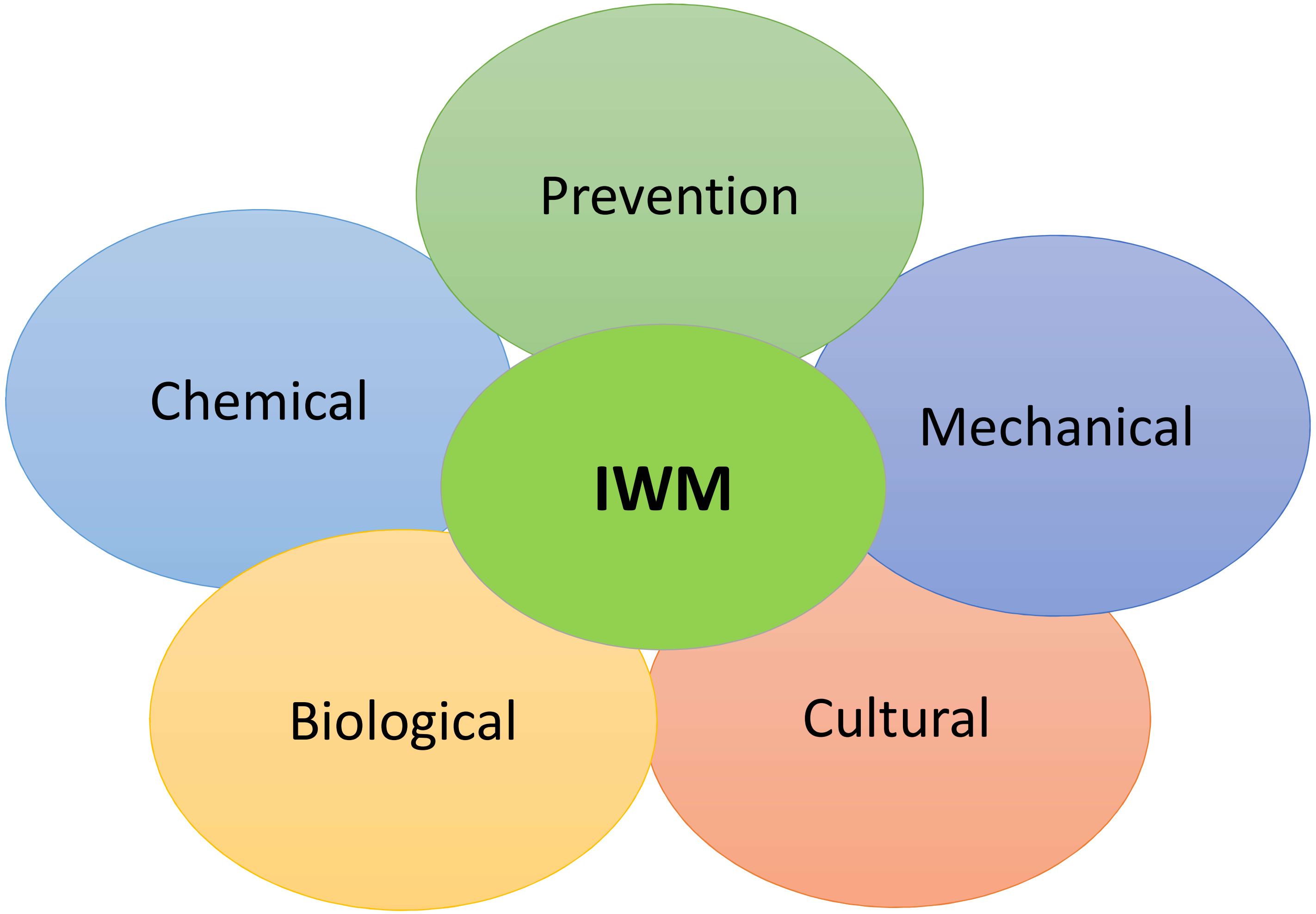
http://www.knowledgebank.irri.org/

Integrated Weed Management

Use of a combination of various weed control tactics

Harness the synergistic effect of each component tactic to achieve long-term management of weeds

Offset the impact of chemicals in the environment and the agroecosystem



End of presentation

Thank you for listening!

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