The Basics of Herbicide Resistance Development in Weeds

Muthukumar Bagavathiannan
Associate Professor (Weed Science)
Department of Soil and Crop Sciences
Texas A&M University

LATMC Conference, Feb 11, 2022

TEXAS A&M UNIVERSITY

What is herbicide resistance?

- Herbicide resistance: “Herbicide resistance is the **inherited** ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance may be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis.”

Weed Technology Volume 12, Issue 4 (October-December) 1998. p. 789.

TEXAS A&M UNIVERSITY

What is an enzyme?

- An enzyme is a protein with a function

ALS enzyme

Branched chain amino acids

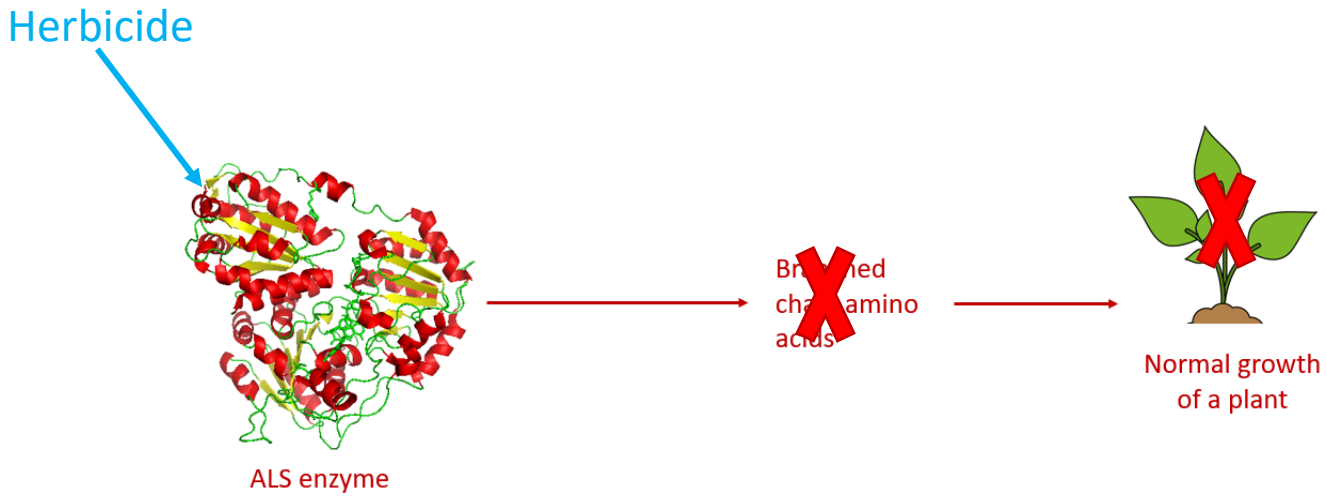
Normal growth of a plant

TEXAS A&M UNIVERSITY

What is herbicide mode of action (MOA)?

The **mode-of-action** is the overall manner in which a **herbicide** affects a plant at the tissue or cellular level.

Herbicides with the same **mode-of- action** will have the same translocation (movement) pattern and produce similar injury symptoms.



(Credit: Ross et al., Purdue Extension)

Example: Newpath (imazethapyr) and Beyond (imazamox) are imidazolinone family herbicides – affect the same enzyme (acetolactate synthase; ALS-inhibitors)

TEXAS A&M UNIVERSITY

Cross, Multiple Resistance

- Cross resistance: Resistance to different herbicide families that affect the same herbicide mode of action
  - E.g. Resistance to Newpath/Beyond and Londax (bensulfuron), both are ALS-inhibitors

- Multiple resistance: Resistance in a weed population to herbicides that inhibit different modes of action
  - E.g. Resistance to Newpath (ALS inhibitor) and Clincher (ACCase inhibitor)

TEXAS A&M AGRILIFE RESEARCH | EXTENSION

Herbicide Sites of Action in Rice

Seth Abugho[1], Vijay Singh[1], Jason Samford[2], Xin-Gen Zhou[3], Muthukumar Bagavathiannan[1]

[1]Texas A&M AgriLife Research, College Station, TX; [2]David Wintermann Rice Research and Extension Center, Eagle Lake, TX; [3]Texas A&M AgriLife Research and Extension Center, Beaumont, TX; E-mail for correspondence: muthu@tamu.edu

Herbicide-resistant weeds develop as a result of repeated use of herbicides that affect the same biochemical site of action (SOA) in plants. Effective resistance management requires diversified use of herbicides that affect different SOAs and non-chemical control tools in a program. This factsheet provides information on the SOA of various herbicides and premix products used in rice to assist with proper herbicide selection.

WSSA Group	Site of Action[1]	Active Ingredient	Trade Name[2]
1	ACCase inhibitors	cyhalofop	Clincher
		fenoxaprop	RiceStar HT
		quizalofop	Provisia
2	ALS inhibitors	bispyribac	Regiment
		bensulfuron- methyl	Londax
		halosulfuron	Permit, Halomax
		imazethapyr	Newpath
		imazamox	Beyond
		imazosulfuron	League
		orthosulfamuron	Strada
		penoxsulam	Grasp
3	Microtubule inhibitors	pendimethalin	Prowl
4	Synthetic auxins	florpyauxifen-benzyl	Loyant
		quinclorac	Facet
		triclopyr	Grandstand
		2,4-D amine	2,4-D
6	Photosystem II-inhibitors	bentazon	Basagran
7	Photosystem II-inhibitors	propanil	Propanil, Riceshot, SuperWham
8	Lipid synthesis inhibitors	thiobencarb	Bolero
13	Diterpene synthesis inhibitors	clomazone	Command
14	Protoporphyrinogen oxidase inhibitors	acifluorfen	Ultra Blazer
		saflufenacil	Sharpen
		carfentrazone	Aim
27	HPPD inhibitors	benzobicyclon	Rogue

Premix Product	Active Ingredients	WSSA Groups
Duet	propanil + bensulfuron methyl	7+2
Gambit	halosulfuron + prosulfuron	2+2
Grasp Xtra	penoxsulam + triclopyr	2+4
Obey	quinclorac + clomazone	4+13
Permit Plus	halosulfuron + thifensulfuron	2+2
RebelEX	penoxsulam + cyhalofop	2+1
RiceBeaux	propanil + thiobencarb	7+8
RiceOne	pendimethalin + clomazone	3+13
Rogue Plus	benzobicyclon + halosulfuron	27+2
Strada XT	orthosulfamuron + quinclorac	2+4
Storm	bentazon + acifluorfen	6+14

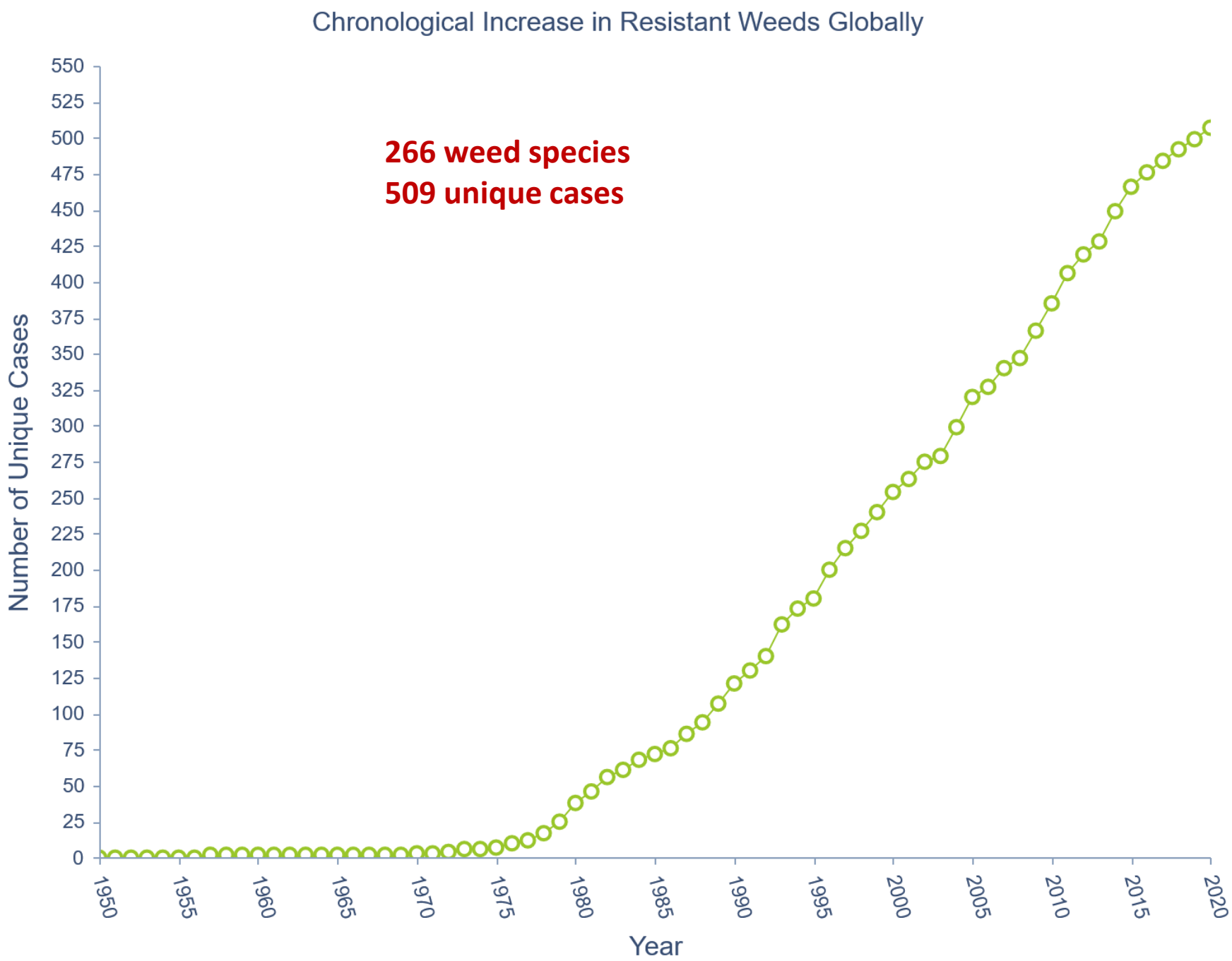
WSSA Group	Resistant Weeds in US Rice[3]
1	Barnyardgrass, Amazon sprangletop, late watergrass
2	Barnyardgrass, junglerice, weedy rice, rice flatsedge, yellow nutsedge, small flower umbrella sedge, California arrowhead, redstem, ricefield bulrush
3	None reported
4	Barnyardgrass, smooth crabgrass
6, 7	Barnyardgrass, junglerice, smallflower umbrella sedge, ricefield bulrush
8	Barnyardgrass, late watergrass, early watergrass
13	Barnyardgrass
14	None reported
27	None reported

[1]The site of action is the biological location on the target plant that is affected by the herbicide. The site of action group is developed by the Weed Science Society of America (WSSA).

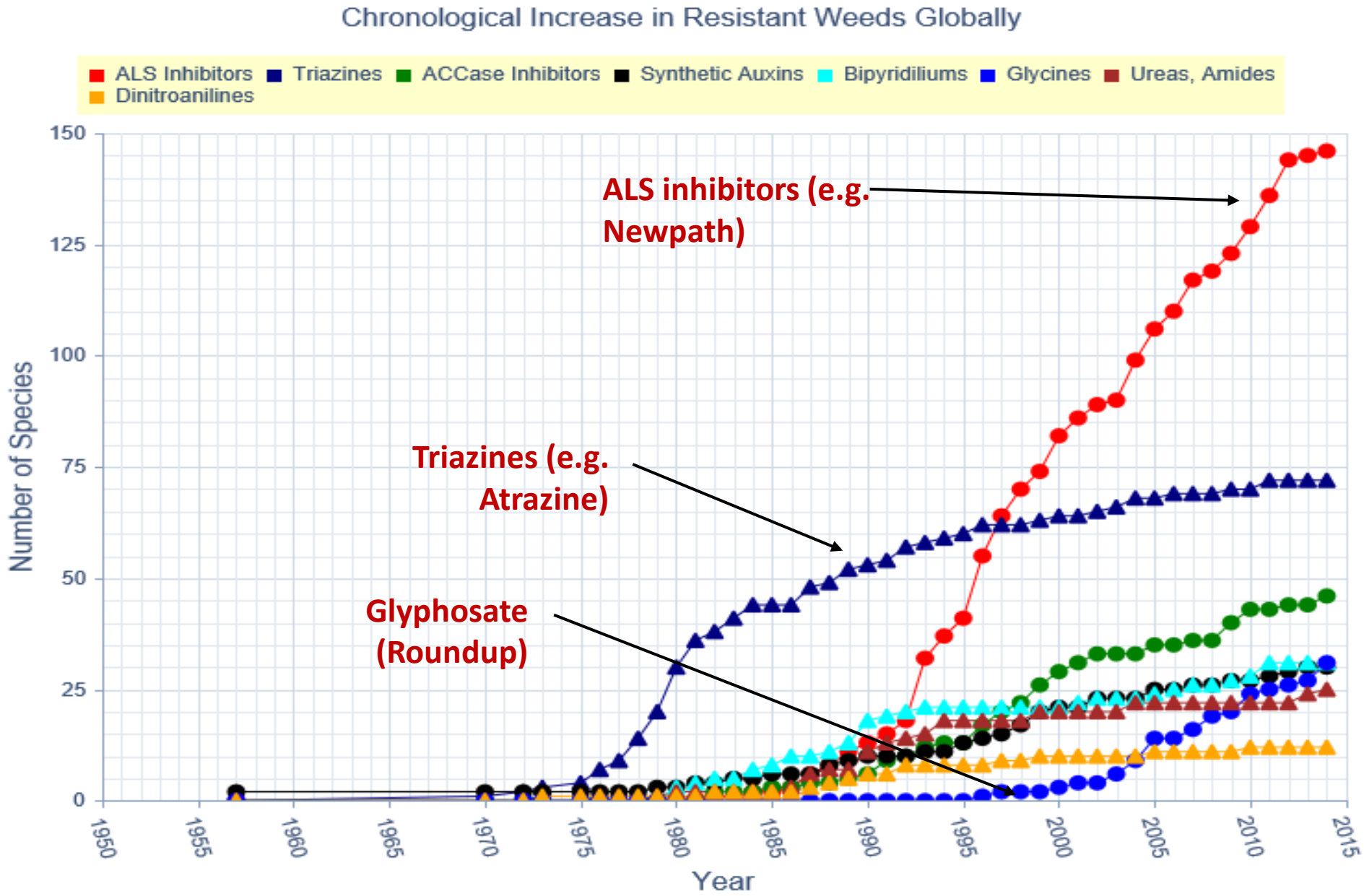
[2]Label and SDS (Safety Data Sheet) can be downloaded from www.cdms.net (or) www.greenbook.net

[3]Based on reports of herbicide-resistant weeds in rice documented at www.weedscience.org

Herbicide-Resistant Barnyardgrass

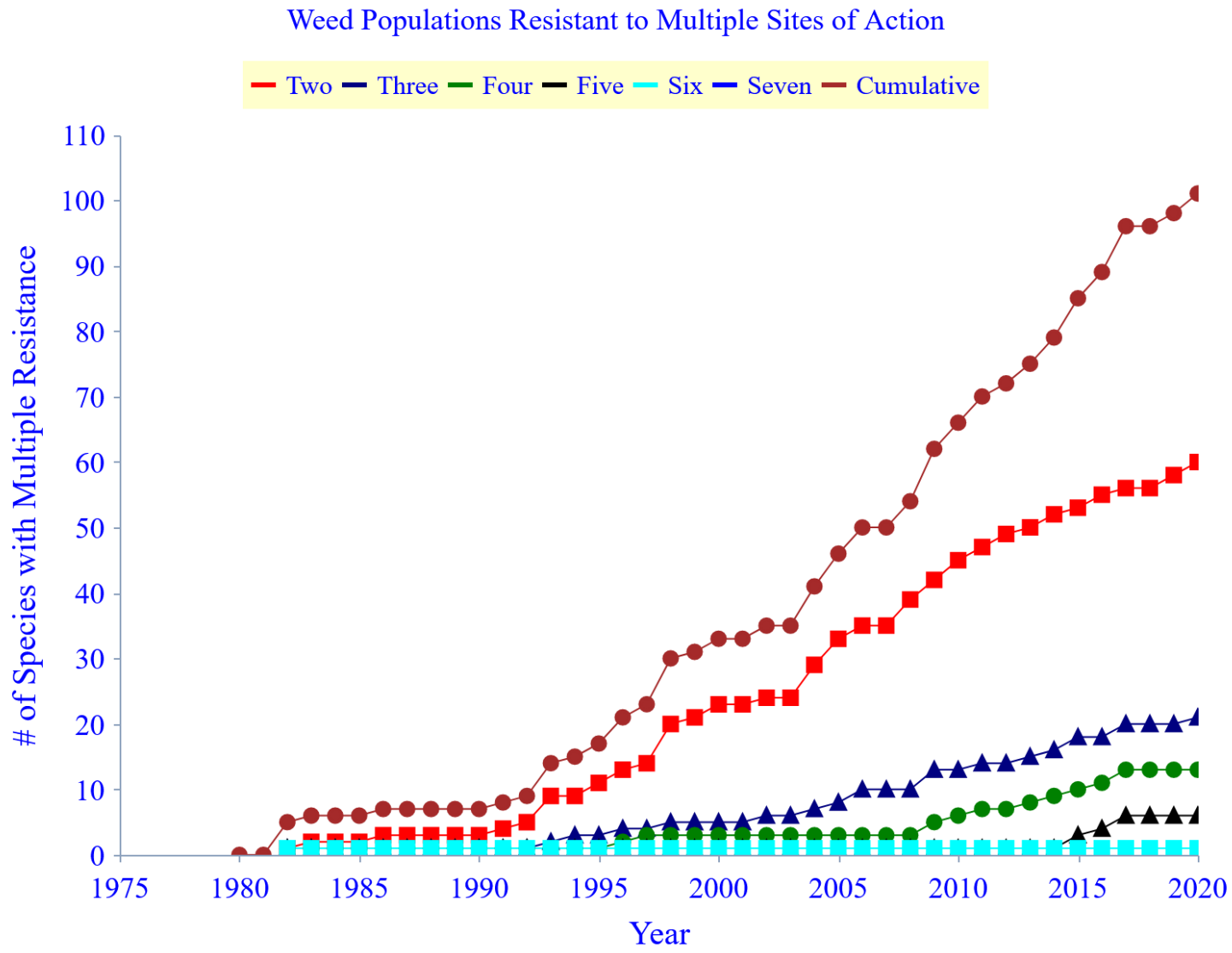


Heap (2022)


Chronological Increase in Resistant Weeds Globally
ALS Inhibitors
Triazines
ACCase Inhibitors
Synthetic Auxins
Bipyridiliums
Glycines
Ureas, Amides
Dinitroanilines
ALS inhibitors (e.g. Newpath)
Triazines (e.g. Atrazine)
Glyphosate (Roundup)
Number of Species
Year
0
25
50
75
100
125
150
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Heap (2022)

Multiple Resistance



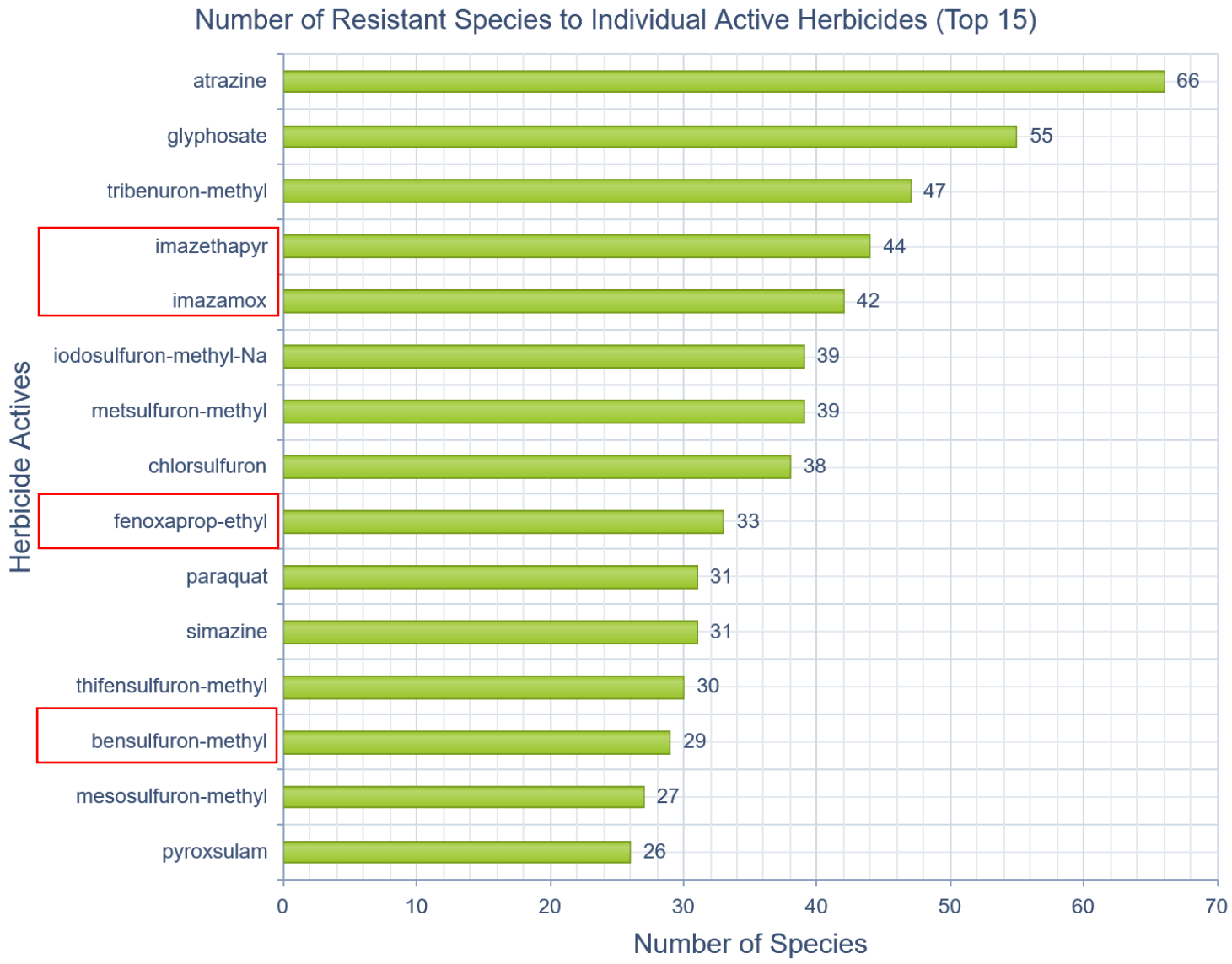
Heap (2022)

Multiple Resistance: barnyardgrass, 4-way resistance (Mississippi)

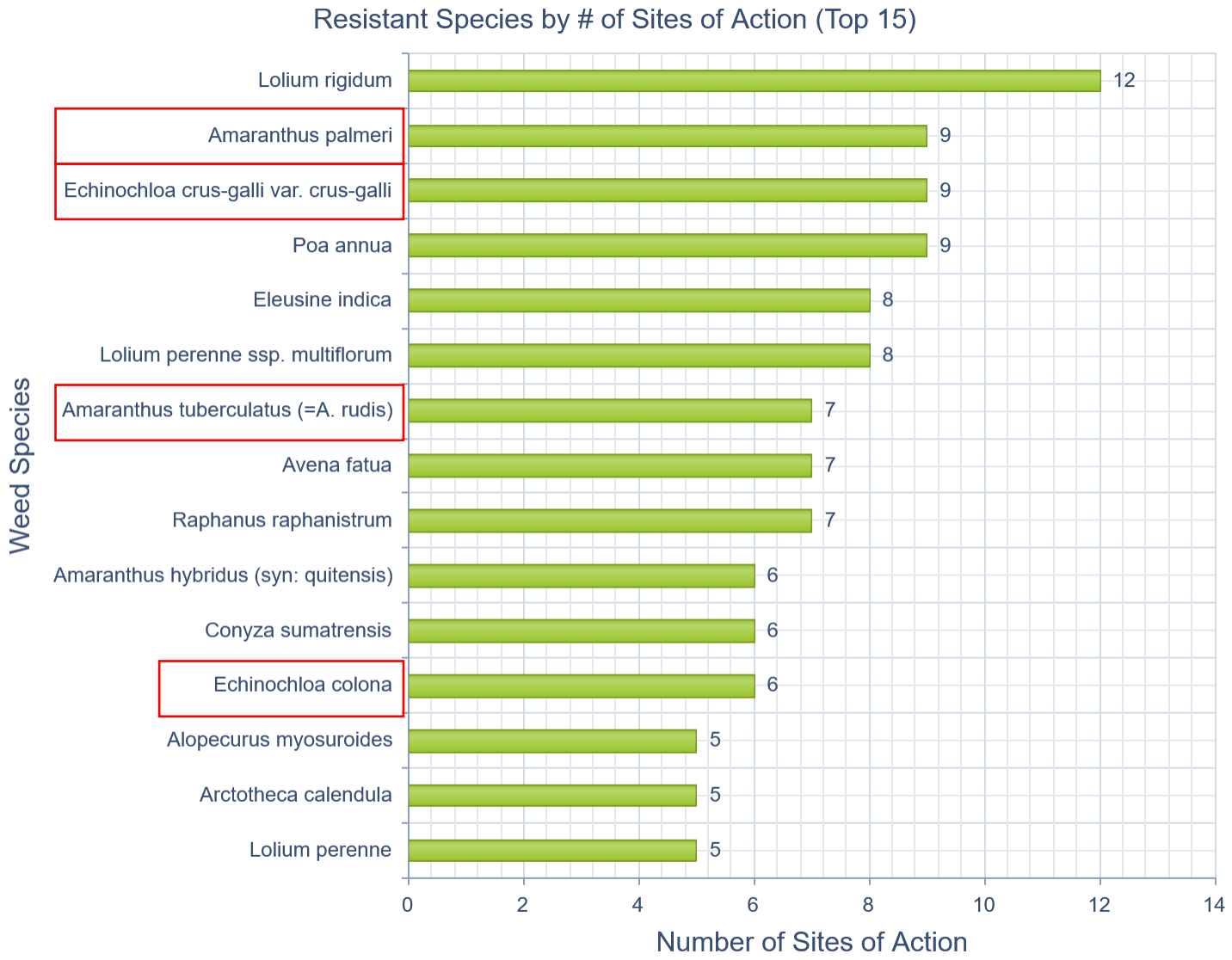
1. Propanil
2. Newpath/Beyond
3. Facet
4. Ricestar

Heap (2022)

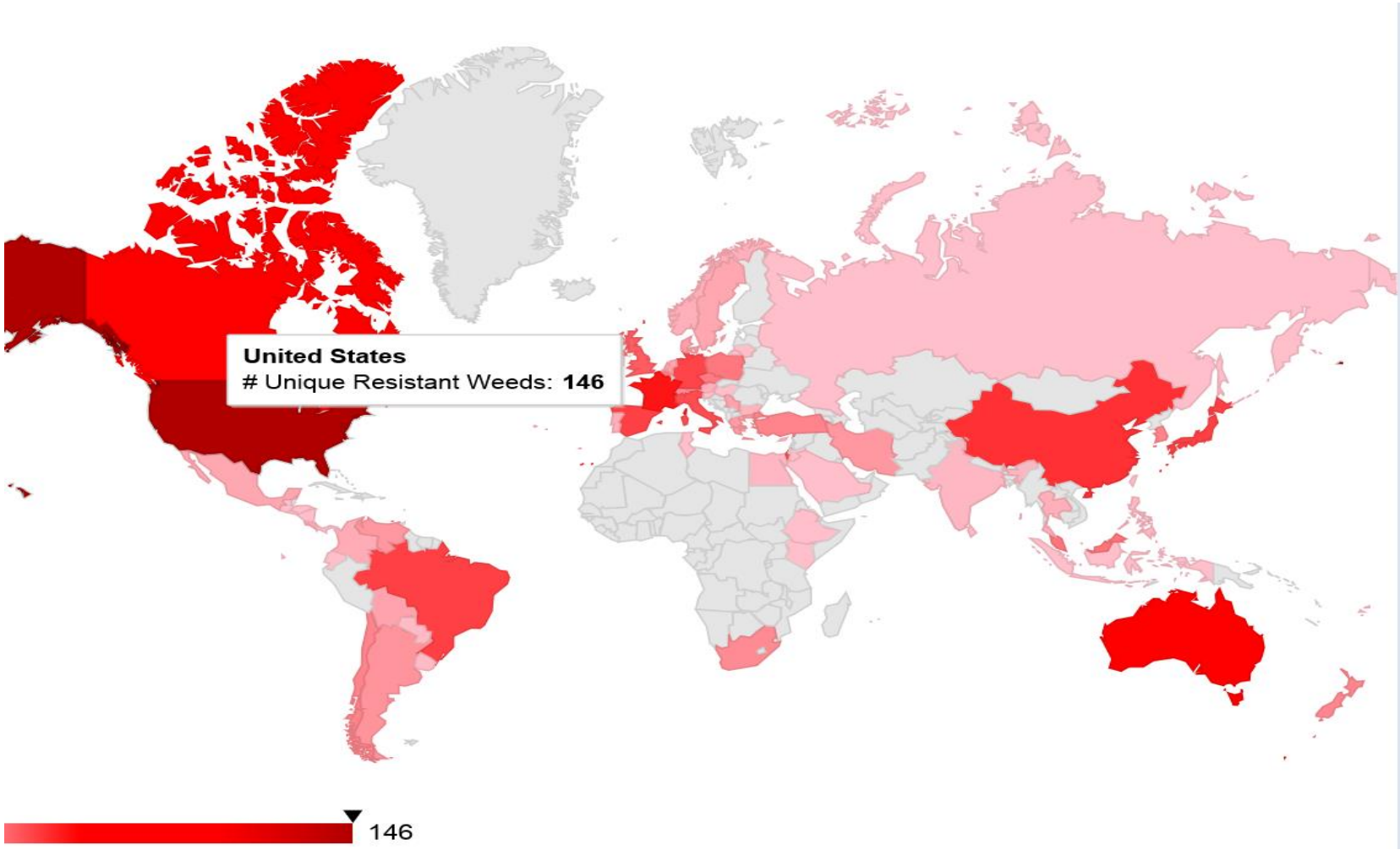
Top 15 herbicides to select for resistance



Top 15 weed species



Global distribution of resistance



If you lost a herbicide to resistance, when can you go back and use it again on that weed?

-Almost never

How many “new herbicide actives” are coming into the market each year?

- Almost none
- Last herbicide (HPPD, early 1990s)

Main reasons for resistance

- Herbicides don’t cause weed resistance, but the way how we use them
  - Repeated use of the same management tool (lack of diversity), selection pressure
  - Sub-lethal application rates

Selection Pressure

Selection Pressure

Rice

Barnyardgrass

Barnyardgrass

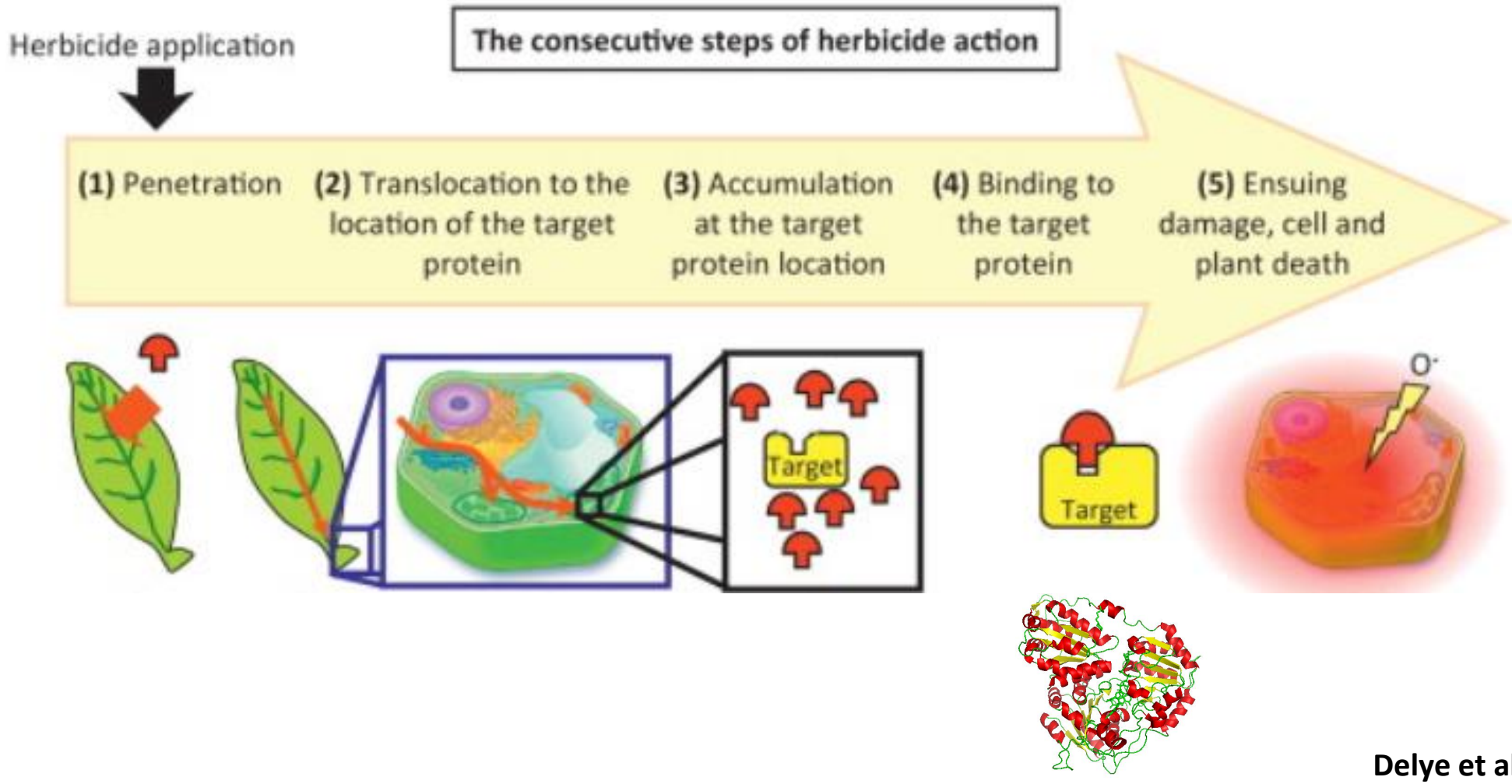
Barrett (1983)

Resistance to hand weeding

Two kinds of resistance

- 1) Target-site resistance (TSR)
  - Changes in the physiological site (enzyme) at which a herbicide impacts
  - Point mutation on the target site or overexpression of the target site enzyme
- 2) Non-target site resistance (NTSR)
  - Reduced absorption, translocation, metabolic detoxification

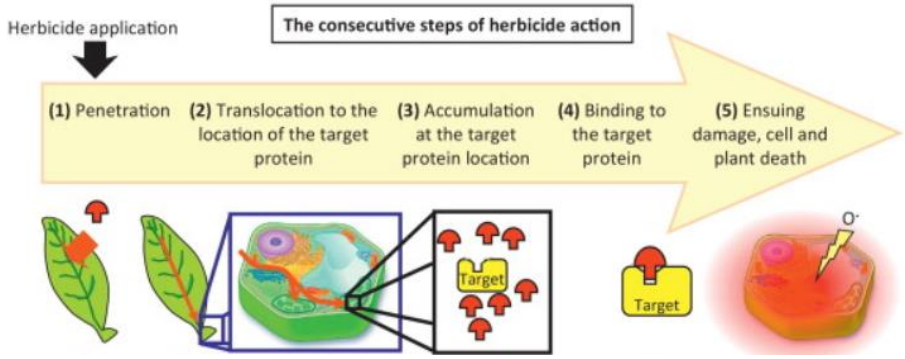
Mechanism of herbicide activity



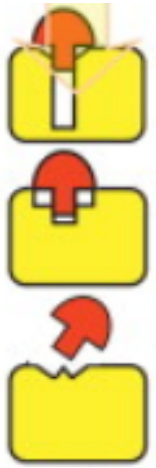
Delye et al. (2013)

Target-site resistance: mutation

Susceptible



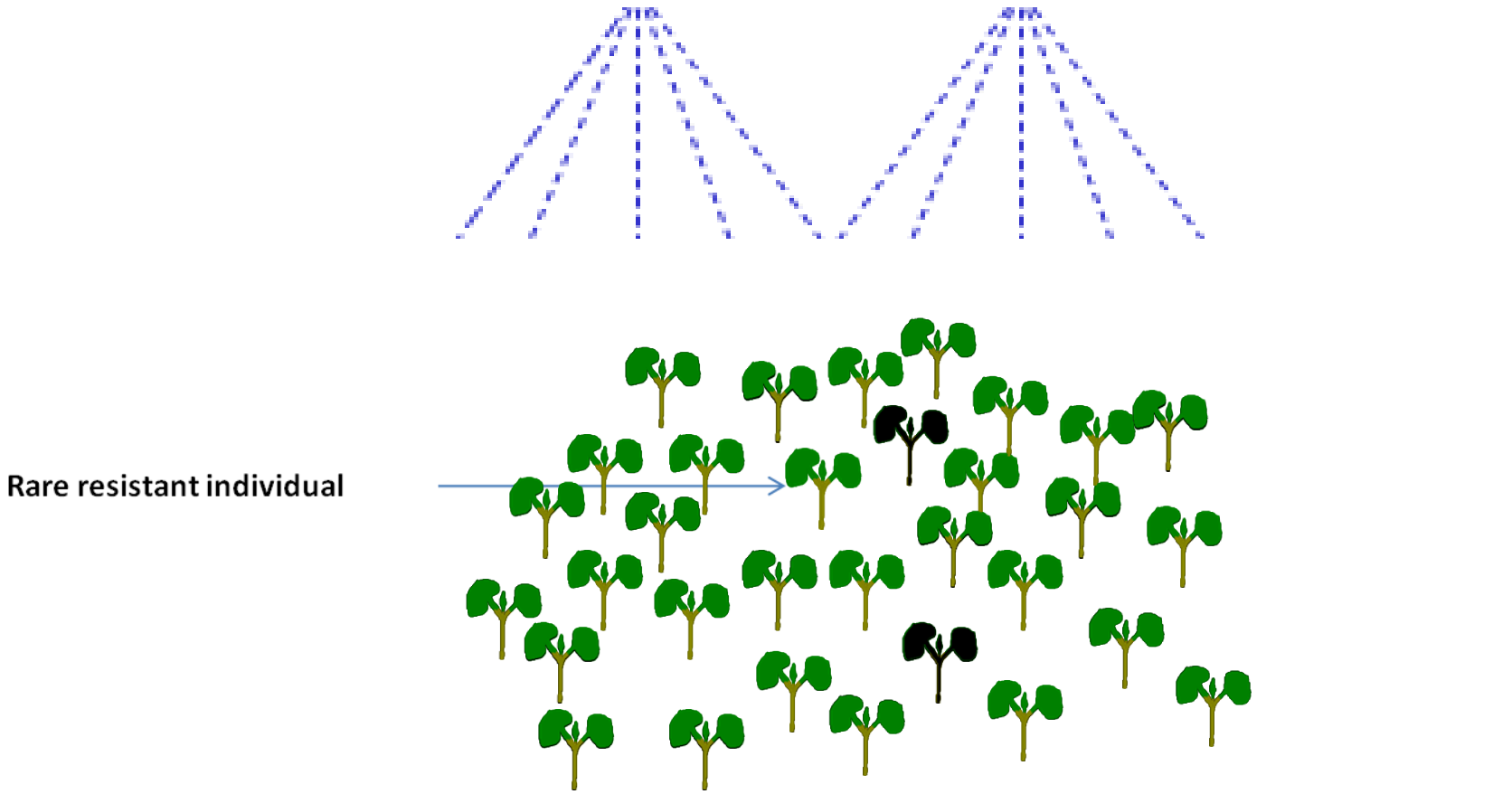
Resistant



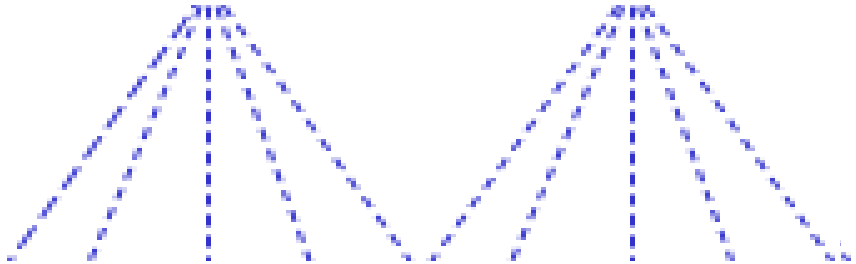
Target-site mutation

Delye et al. (2013)

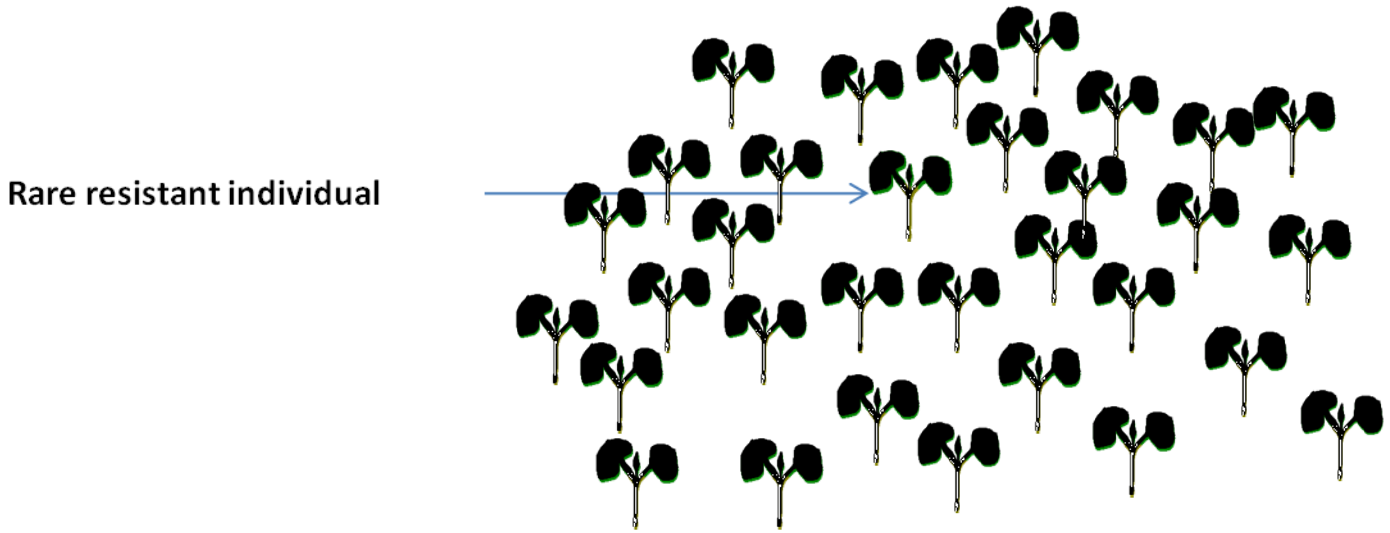
Evolution in Action (Target-Site Resistance)



Diversification



Different Herbicide
MOA or tactic

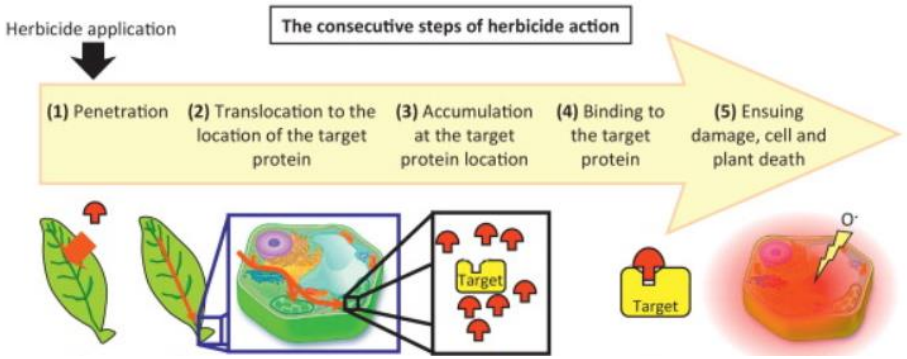


Resistant individuals → Regular selection → Resistant population

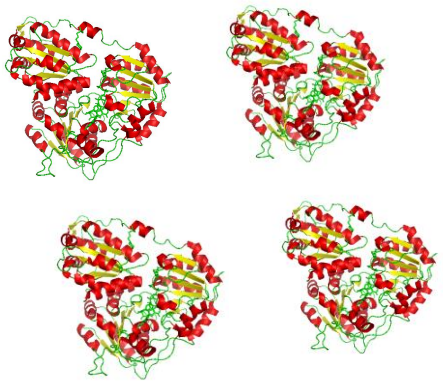
TEXAS A&M UNIVERSITY

Target-site resistance: overproduction of the enzyme

Susceptible



Resistant

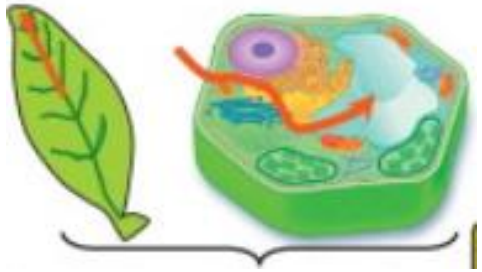


Target-site overproduction

Delye et al. (2013)

Non-target site resistance

(a) Reduced absorption



(b) Reduced/altered translocation

(c) Metabolic detoxification

Delye et al. (2013)

Non-target site resistance

- Does not usually lead to high levels of resistance to start with
- Resistance builds through accumulation of minor effect alleles over time (known as recurrent selection)
- Cutting herbicide rates is not recommended
- Non-target site resistance can automatically lead to multiple resistance to several herbicide chemistries/MOA
- There may already be resistance to a herbicide yet to be discovered

Diversification of Management

- Alternating/rotating herbicides
  - Different Herbicide SOA
  - Tank-mix and sequential (Tank-mix is better than sequential applications)
- Crop rotation
  - Allow rotation of herbicides
- Non-chemical approaches

Take Home Message

- Resistance is an evolutionary process – repeated use of a single management tactic will lead to resistance

- Diversification of tactics – multiple approaches are effective
  1) Use multiple herbicide mechanisms of action (sequential or in tank-mix), full application rates
  2) Integrate preemergence, soil residual herbicides
  3) Crop and trait rotation (to allow for use of diverse herbicide options)
  4) Integration of non-chemical tools

TEXAS A&M UNIVERSITY

Acknowledgment

Texas Rice Research Foundation

muthu@tamu.edu

TEXAS A&M UNIVERSITY