Managing glyphosate-resistant weeds in orchard crops

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UC DAVIS
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UC-IPM
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4-24-19

My program at UC Davis

- 100% Cooperative Extension Appt.
  - Weed science research and extension
- Statewide program focused in tree and vine crops
  - Herbicide efficacy
  - Herbicide resistance (esp. glyphosate)
  - Herbicide symptomology and crop safety
  - Weed biology/physiology
  - IR4 Pesticide Registration Program
  - Environmental fate of herbicides
  - Soil fumigants
  - Non-herbicidal weed management
- Some contributions to weed issues in annual crops, aquatics, rangelands

Pesticide resistance

- Resistance to pesticides is not restricted to herbicides:
  - Insecticides – reported in 1908
  - Fungicides – reported in 1940
  - Rodenticides – reported in 1950's
  - Herbicides – reported in 1957
    - 1957 2,4-D resistant spreading dayflower in Hawaii
    - 1981 atrazine resistant common groundsel in California

Resistance definitions

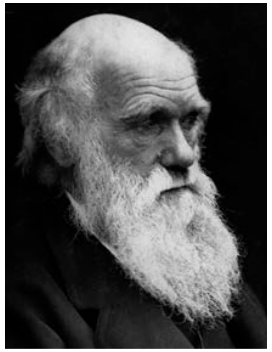
- **Herbicide tolerance:** the inherent ability of a species to survive and reproduce after herbicide treatment; implies no selection or genetic manipulation to make the plant tolerant
  - "We've never gotten dependable control of this weed with this herbicide…"

- **Herbicide resistance:** the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type
  - "We used to be able to control this weed with this treatment but it doesn't work as well anymore…"

Cause of resistance

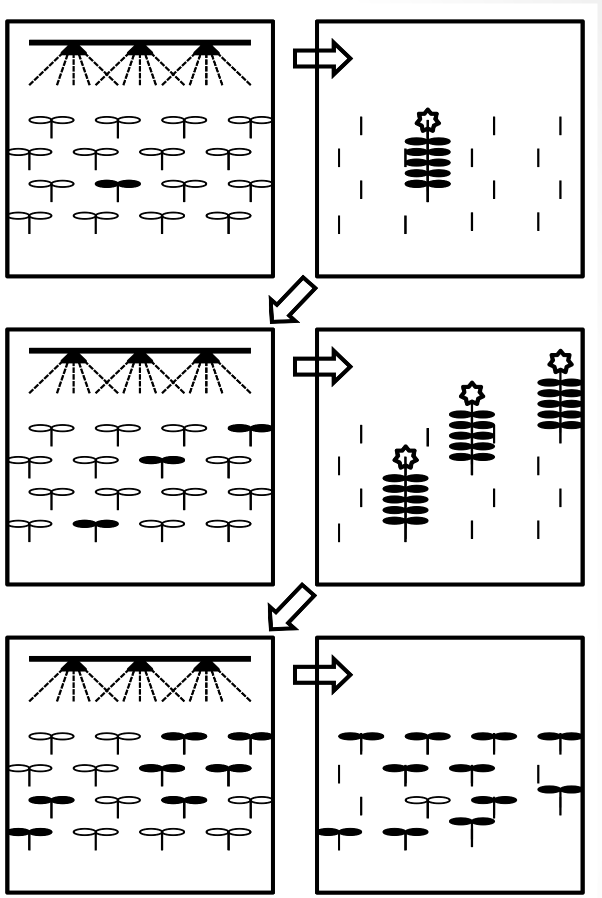
- Pesticides do not CAUSE resistance
  - There is tremendous genetic diversity in weed populations
  - There are a very few cases of ‘escape’ from HRC
- Herbicides impose high “selection pressure” on a mix of genotypes
    - Darwinism in real life!

      …. survival of the fittest

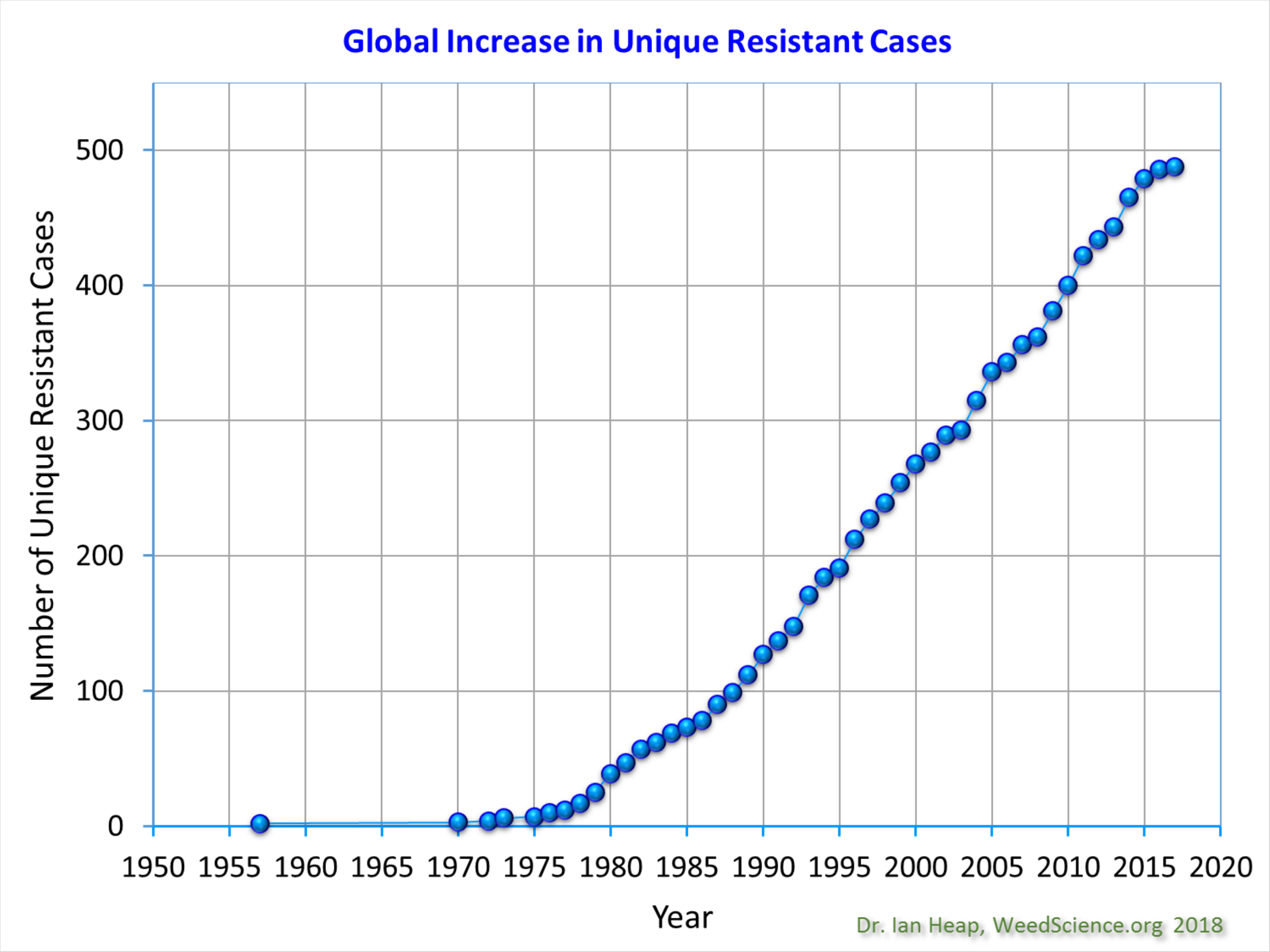


Selection pressure

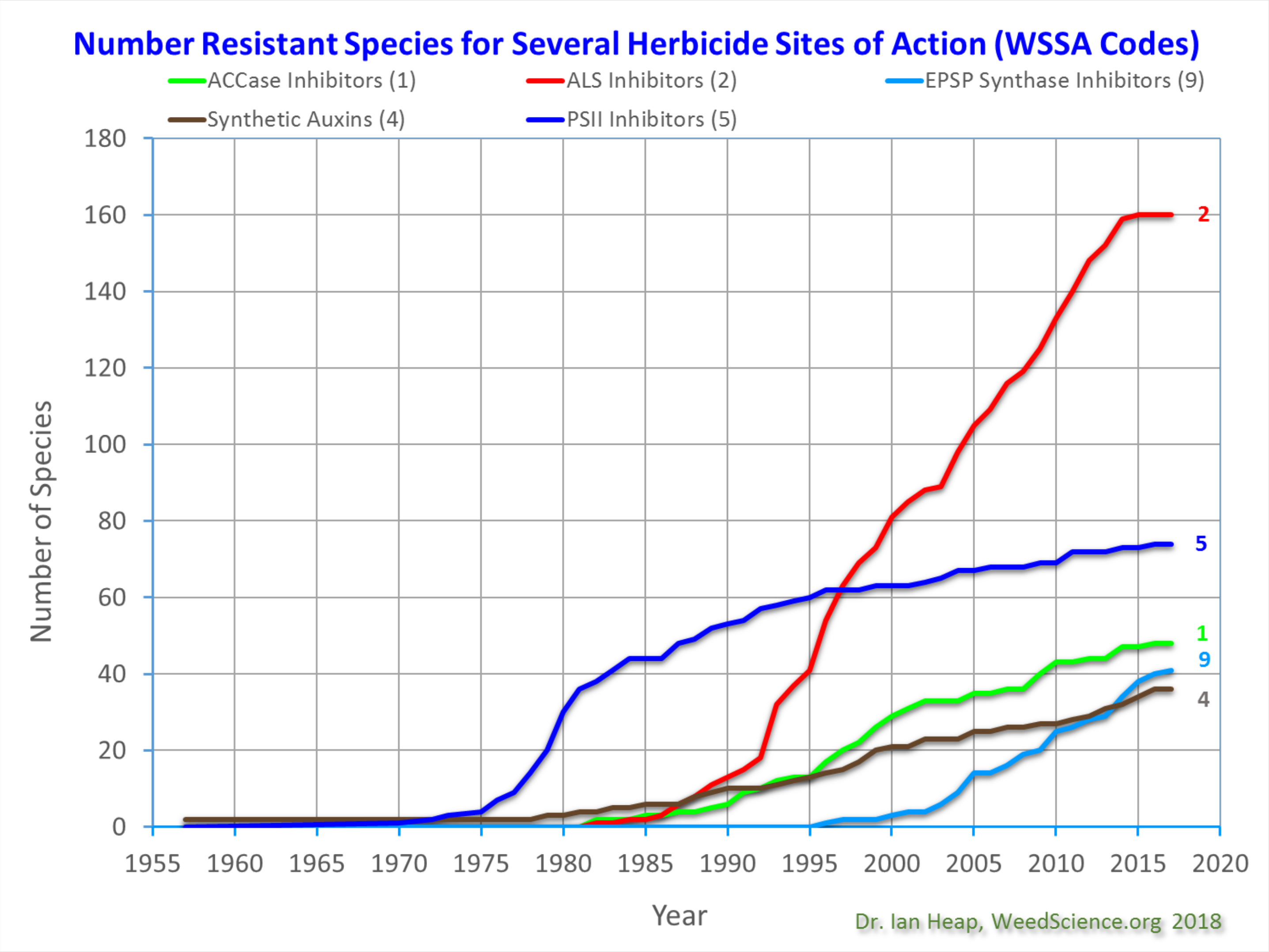
- Selection of HR is an evolutionary process
  - High genetic diversity in weed populations
  - Control measure removes susc. biotypes; leaves resistant plants to reproduce
- Pressure varies among systems
  - Cropping practices, herbicides, weeds



Poll question #4

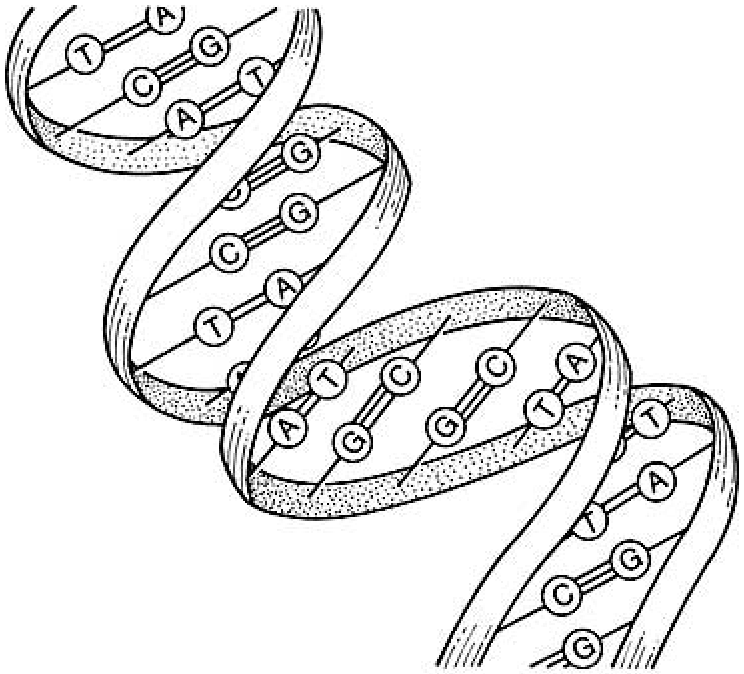


Poll question #1


Number Resistant Species for Several Herbicide Sites of Action (WSSA Codes)
ACCase Inhibitors (1)
ALS Inhibitors (2)
EPSP Synthase Inhibitors (9)
Synthetic Auxins (4)
PSII Inhibitors (5)
Number of Species
Year
180
160
140
120
100
80
60
40
20
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2
5
1
9
4
Dr. Ian Heap, WeedScience.org 2018

Resistance mechanisms

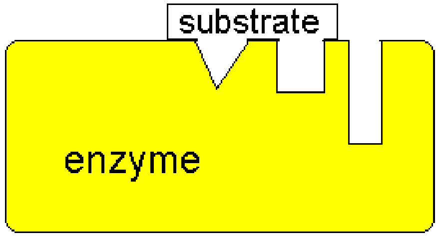
- Target site
  - Modification at the herbicide binding site (often an enzyme)
  - Often a single base pair mutation in the gene
- Non-target site
  - Enhanced metabolism
  - Reduced translocation
  - Sequestration
  - Increased amount of the target



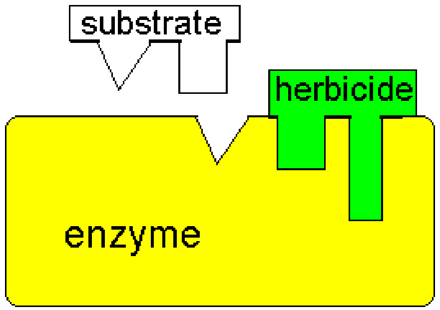
Laurel Cook Lhowe

Target site resistance

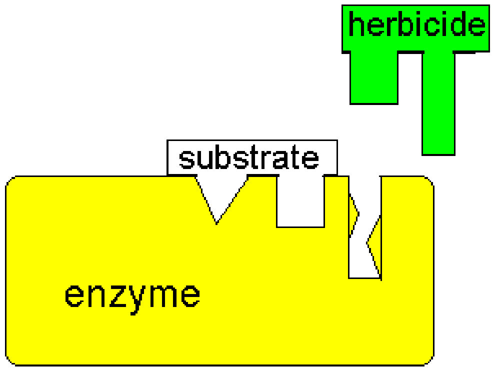
- Herbicides bind to an enzyme at a particular spot - “lock and key”
- Change in the shape or binding affinity at the binding pocket excludes the herbicide
- Cannot bind = does not inhibit the biochemical process



Normal substrate binding to enzyme



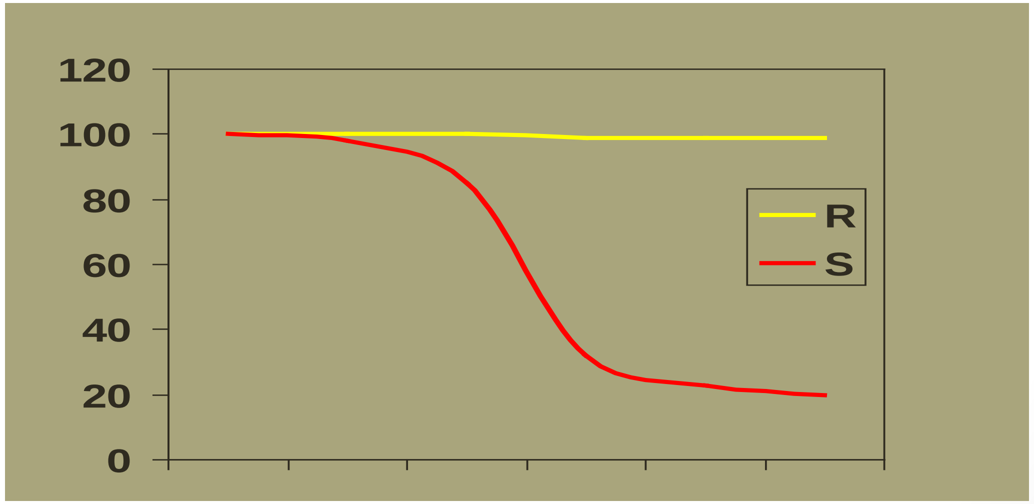
Herbicide inhibiting substrate binding



Altered herbicide binding pocket – herbicide cannot bind

Target site resistance

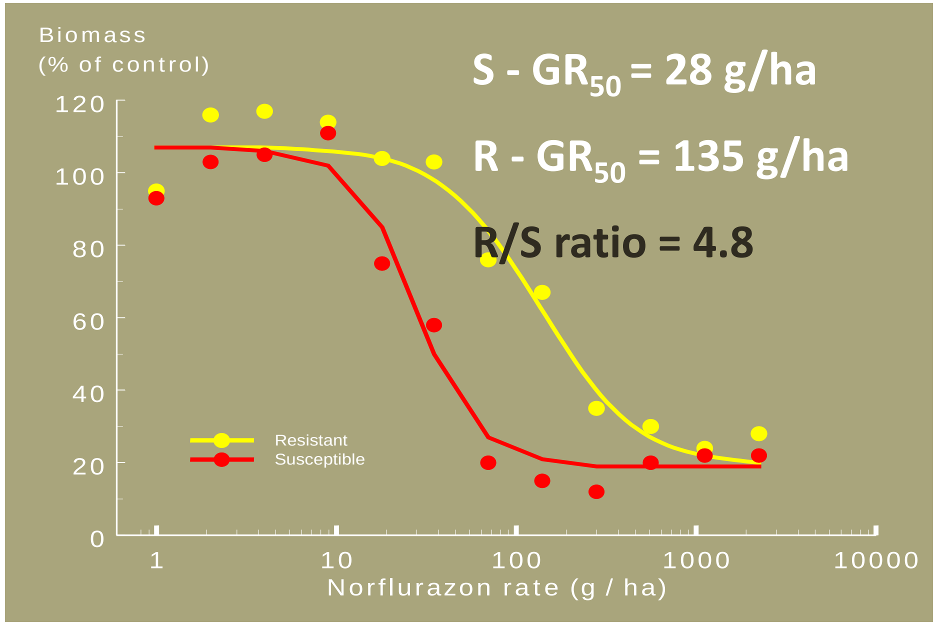
Generalized dose-response relationship for target site resistant and susceptible species



Enhanced metabolism

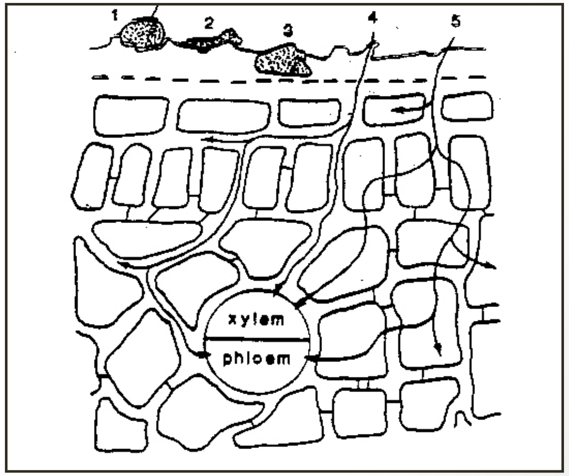
- Up-regulated activity of enzymes that metabolize and detoxify herbicides
- Can be fairly specific
  - Aryl-acylamidase that detoxifies propanil in junglerice
  - Glutathione-S-transferase detoxifies atrazine in velvetleaf and others
- Or more general
  - Cytochrome p450 monoxygenases
    - Family of enzymes in animals and plants that detoxify xenobiotics (thousands of p450 species)
    - Catalyze many reactions including epoxidation, N-dealkylation, O-deaklylation, S-oxidation, and hydroxylation

Metabolism-based resistance



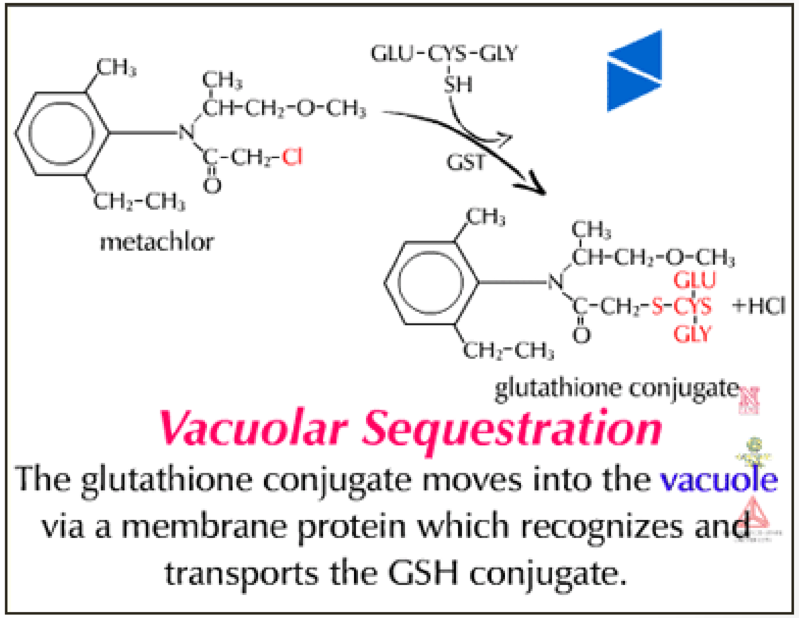
Decreased translocation

- For a herbicide to have a toxic effect, it must reach the target site (enzyme, etc)
    - Cross into the living parts of the plant
        - Adjacent cells or systemically through the plant
- Various mutations can affect herbicide transport
    - Apoplast, symplast, pH, cross-membrane transporters, etc



Sequestration

- Herbicide is “tied up” and cannot get to its site of action
  - Partition into surface waxes
  - Stored in vacuole or another organelle
    - often in a complex with another molecule (ie. conjugated with glucose)



Other

- Gene overexpression
  - Upregulation of a gene that encodes an enzyme target of a herbicide
- Increased gene copy number
  - Multiple copies of a gene that encodes for the herbicide target enzyme
    - Eg. some glyphosate-resistant Palmer amaranth have hundreds of extra copies of the EPSPS enzyme scattered within and among chromosomes
    - Several species have clear correlation between number of copies and level of resistance
    - Complicated in polyploid weeds

Poll question #2

Mitigation - TSR

- Cases of target site resistance
  - Usually high, consistent levels of resistance
  - Conferred by gene mutations, major genes:
    - Resistance selection favored by high herbicide rates

  - Management recommendations:
    - Alternate or combine different herbicide modes of action (with overlapping weed spectrum)

Mitigation - NTSR

- Cases of non-target site or multifactorial resistance
  - Usually low to moderate levels of resistance
    - Sometimes variable among environments or stages
  - Often conferred by interchange and exchange of minor genes (hybridization and recombination)
  - Resistance selection favored by low herbicide rates
    - Individual changes lead to incremental shifts in population response
      - Low-level resistance (creeping resistance) should ring an alarm… but often is dismissed

NTS resistance mitigation

- Management recommendations:
  - Use full label rates
    - Eliminates moderately resistant individuals
    - Control escapes to eliminate both TS and NTS survivors
  - Avoid sub-lethal doses and treatments
    - Late applications (plants too big)
    - Reduced rate programs (ie chemical mowing)
    - Poor sprayer calibration
- Problems:
  - Cross and multiple resistance concerns
- Truly need “integrated practices”

Orchard resistance issues

- Herbicide resistance
  - Glyphosate
  - Other herbicides
  - “multiple” resistance

- How did we get to where we are with resistance?

CA tree nut herbicide use

	Top active ingredients (by acres)	2016 treated acreage
1	glyphosate	2,245,900
2	oxyfluorfen (Goal, Goaltender)	1,284,287
3	paraquat (Gramoxone Inteon)	639,373
4	saflufenacil (Treevix)	628,698
5	glufosinate (Rely)	596,641
6	pendimethalin (Prowl)	332,913
7	indaziflam (Alion)	55,898
8	rimsulfuron (Matrix)	247,308
9	carfentrazone (Shark)	152,204
10	2,4-D	119,606
11	penoxsulam (Pindar GT)**	118,565
12	flumioxazin (Chateau)	106,242

Data are combined treated acreage for almond, pistachio, walnut during 2016 - CDPR

Glyphosate resistance in CA orchards

Confirmed

- Broadleaves
  - Horseweed (mostly winter)
  - Fleabane (mostly winter)
  - Palmer amaranth (summer)
- Grasses
  - Ryegrass (fall/winter)
  - Annual bluegrass (fall/winter)
  - Junglerice (summer)

Suspected or questionable

- Broadleaves
  - Lambsquarters (summer)
- Grasses*
  - Threespike goosegrass (spring)
  - Feather fingergrass (summer)
  - Windmillgrass (summer)
  - Sprangletop (summer)
  - Witchgrass (summer)

*Resistance in the world in several other Elusine, Chloris, Leptocloa, Echinocloa, Eragrastis spp.

Conyza species (Erigeron)

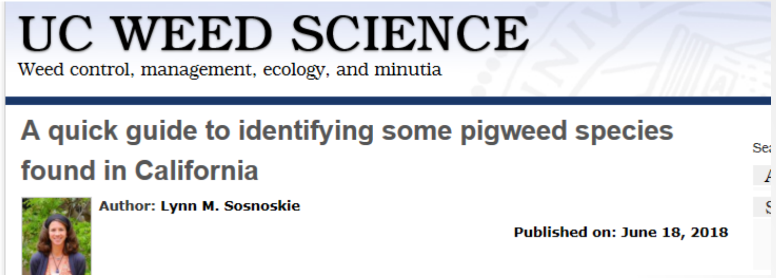
Hairy fleabane

- Gly-R widespread
- Shorter, more branched vs horseweed. Shorter lifecycle

Horseweed / marestail

- Gly-R widespread
- Taller, single-to-few stems vs fleabane

Palmer amaranth



- Yes, still another pigweed species!
  - Look also for common waterhemp which may be spreading
- Male and female plants. Can be very large stature. Prolific.
- Palmer amaranth confirmed as Gly-R in California
  - Larger issues in SJV. More problems on roadsides and RR crops, but some T&V

Photo: Lynn Sosnoskie

Lolium (ryegrasses)

- Highly prone to resistance worldwide
- Gly-R ryegrass widespread in CA
- Recent reports and confirmation of resistance to paraquat, glufosinate, ACCase inhibitors, ALS inhibitors
  - So far, not extremely widespread in T&V
  - Increasingly an issue in cereals (M. Galla)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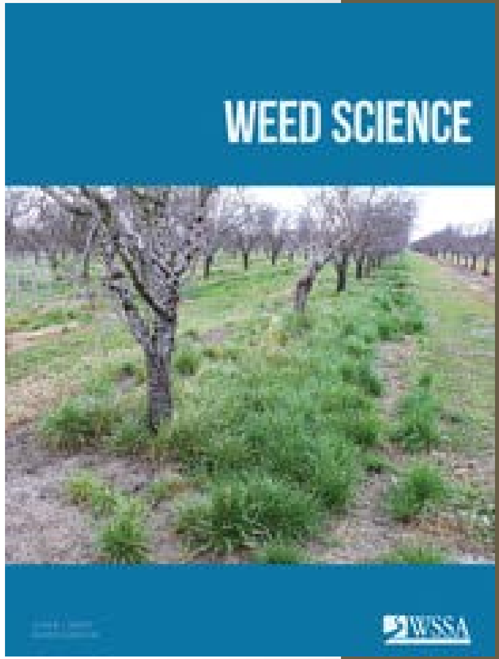
Weed control, management, ecology, and minutia

Herbicide Resistant Ryegrass in Winter Cereals

Author: Mariano Galla

Published on: September 27, 2018



Junglerice

- *Echinochloa colona*
- Summer annual grass
  - (related to barnyardgrass and the rice watergrasses)
- Gly-R populations around CA
- Orchards, RR crops

Multiple resistance

- Increasing issues with “stacked” resistance
- Widespread glyphosate-resistance in some species
- Starting to see gly-R plus resistance to some one or more other chemistries
  - Conyza, Lolium, Poa so far.
  - Paraquat, ACCase, some glufosinate reports

Poll question #5

Threespike goosegrass vs goosegrass (*E. trystachya* v *E. indica*)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Weed control, management, ecology, and minutia

A tale of two goosegrasses

Author: Brad Hanson

Published on: October 11, 2013

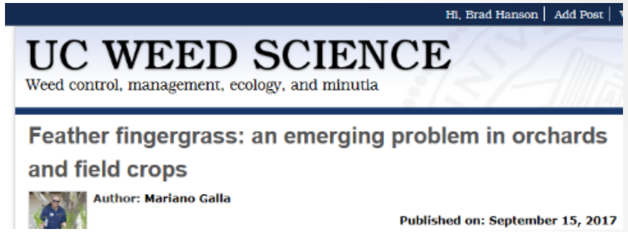
In the past couple of years, I've gotten a lot of questions about goosegrass in orchard production systems, particularly about suspected glyphosate-resistant biotypes.

From a California orchard standpoint, we have two main goosegrasses (Eleusine spp) to deal with:

Threespike goosegrass

- Annual to short-lived perennial
- Emerges in early spring – early summer
- Low growing stature but very prolific
- Tolerant of glyphosate, especially once established
- Early-stage problem, but can be found SJV-Sac Valley

Other summer grasses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Weed control, management, ecology, and minutia

Feather fingergrass: an emerging problem in orchards and field crops

Author: Mariano Galla

Published on: September 15, 2017

- Increasing questions about several summer grasses including:
- Mexican sprangletop, witchgrass, feather fingergrass.
  - SJV, also some orchards and alfalfa in Sac Valley



Poll question #3

OK, how do we manage all these weeds?

- Back to the basics
  - Monitor and scout fields to identify problems
    - Weed ID!
  - Reduce weed seed production
  - Use multiple herbicide MOA – PRE and POST
  - Do not cut glyphosate rates (no chemical mowing!)
  - Tankmix POST herbicides (overlapping spectrum)
  - Treat at appropriate (small) growth stages
  - Include mechanical weed control when/where poss.

Management of resistant weeds in orchards

- Several POST options
  - Glufosinate, saflufenacil, sethoxydim, 2,4-D
- Preemergence herbicides
  - IMO best alternative available
    - (more and different modes of action)
- Greater focus on middles management
  - Seed bank/reservoir

T&V herbicide registrations

Herbicide Registration on California Tree and Vine Crops *-(updated May 2018 - UC Weed Science)*

	Herbicide- Common Name *(example trade name)*	Site of Action Group[1]	Almond	Pecan	Pistachio	Walnut	Apple	Pear	Apricot	Cherry	Nectarine	Peach	Plum / Prune	Avocado	Citrus	Date	Fig	Grape	Kiwi	Olive	Pomegranate
			----- tree nut -------				- pome-		--------- stone fruit ---------												
Preemergence	**dichlobenil** (*Casoron)*	L / 20	N	N	N	N	R	R	N	R	N	N	N	N	N	N	N	R	N	N	N
	diuron *(Karmex,Diurex)*	C2 / 7	N	R	N	R	R	R	N	N	N	R	N	N	R	N	N	R	N	R	N
	EPTC *(Eptam)*	N / 8	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N
	flazasulfuron *(Mission)*	B / 2	R	N	R	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
	flumioxazin *(Chateau)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	NB	NB	N	NB	R	N	R	R
	indaziflam *(Alion)*	L / 29	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	N
	isoxaben *(Trellis)*	L / 21	R	R	R	R	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	NB	R	NB	NB	NB
	mesotrione (*Broadworks)*	F2/27	R	R	R	R	N	N	N	N	R	N	R	N	R	N	N	N	N	N	N
	napropamide *(Devrinol)*	K3 / 15	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	N
	norflurazon *(Solicam)*	F1/ 12	R	R	N	R	R	R	R	R	R	R	R	R	R	N	N	R	N	N	N
	oryzalin (*Surflan)*	K1/ 3	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	oxyfluorfen (*Goal, GoalTender)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	R	NB	R	R	R	R	R	R
	pendimethalin *(Prowl H2O)*	K1/ 3	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	R
	penoxsulam *(Pindar GT)*	B / 2	R	R	R	R	N	N	N	R	R	R	R	N	N	N	N	N	N	R	R
	pronamide *(Kerb)*	K1/ 3	N	N	N	N	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	rimsulfuron *(Matrix)*	B / 2	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	sulfentrazone *(Zeus)*	E/ 14	N	N	R	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
	simazine *(Princep,Caliber 90)*	C1/ 5	R	R	N	R	R	R	N	R[2]	R	R	N	R	R	N	N	R	N	R	N
	trifluralin *(Treflan)*	K1/ 3	R	R	N	R	N	N	R	N	R	R	R	N	R	N	N	R	N	N	N
Postemergence	**carfentrazone** *(S hark)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	clethodim (*SelectMax)*	A / 1	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	R	N	N	NB	N	NB	N
	2,4- D *(Clean- crop, Orchard Master)*	O / 4	R	R	R	R	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	diquat *(Diquat)*	D / 22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
	fluazifop - p- butyl *(Fusilade)*	A / 1	NB	R	NB	NB	NB	NB	R	R	R	R	R	NB	R	NB	NB	R	N	NB	NB
	glyphosate *(Roundup)*	G / 9	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	glufosinate *(Rely 280)*	H / 10	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	N
	halosulfuron *(Sandea)*	B / 2	N	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	paraquat (*Gramoxone)*	D / 22	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	pelargonic acid *(Scythe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N
	pyraflufen *(Venue)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	R	R	R	R
	saflufenacil *(Treevix)*	E/ 14	R	N	R	R	R	R	N	N	N	N	N	N	R	N	N	N	N	R	R
	sethoxydim *(Poast)*	A / 1	R	R	R	R	R	R	R	R	R	R	NB	NB	R	NB	NB	R	N	NB	NB
Organic	**Caprilic/Capric acid** *(Suppress)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	N	R
	ammoniated fatty acids *(Final- San-*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	d- limionene *(AvengerAG)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	Ammonium nanoate *(Axxe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N

Notes: R = Registered, N = Not registered, NB = nonbearing. This chart is intended as a general guide only. Always consult a current label before using any herbicide as labels change frequently and often contain special restrictions regarding use of a company's product.

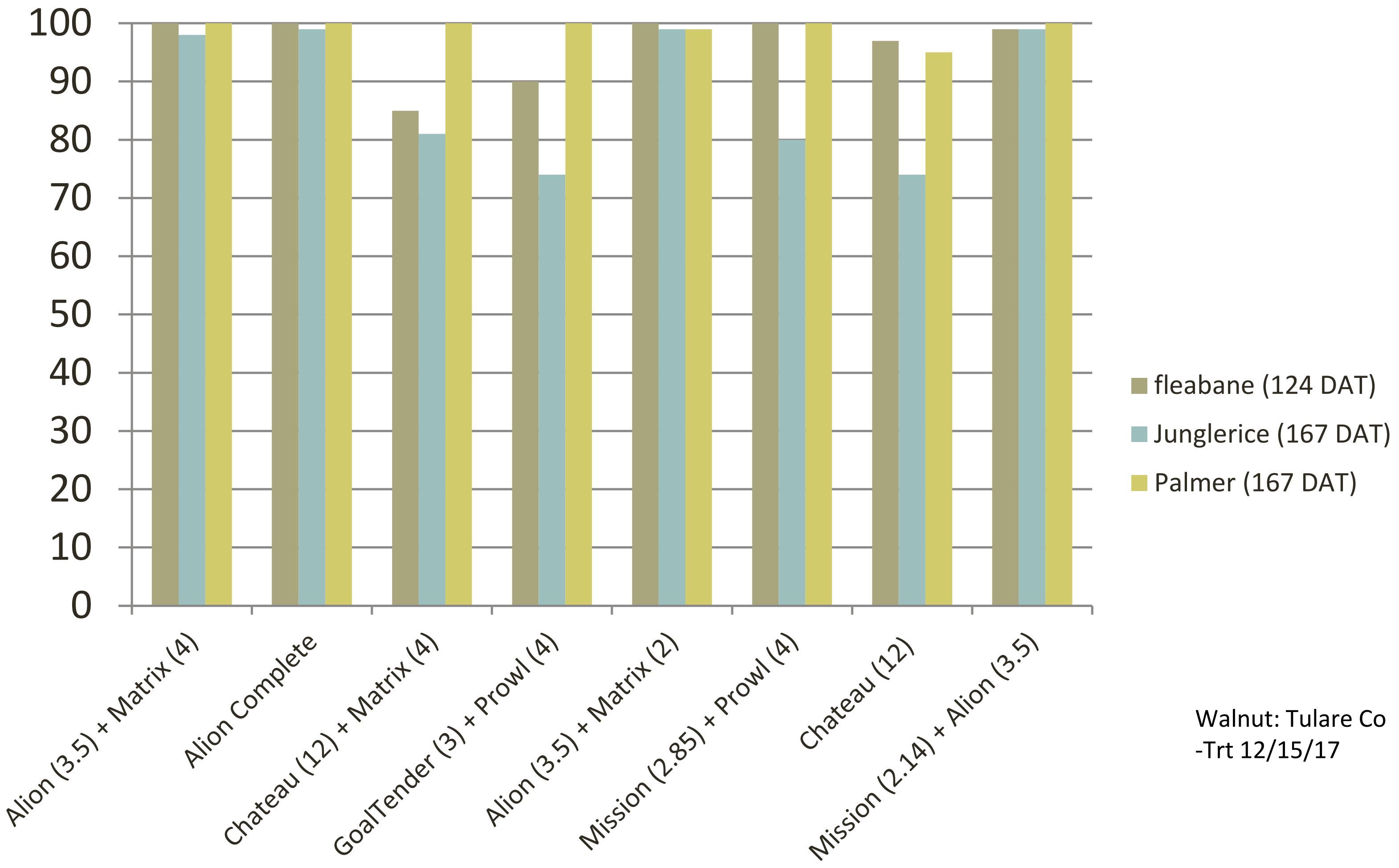
[1] Herbicide site of action designations are according to the Herbicide Resistance Action Committee (letters) and the Weed Science Society of America (number) systems. NC = no accepted site of action classification; these contact herbicides are general membrane disruptors.

[2] Simazine is registered on only tart cherry in CA.

Weed susceptibility information and the most up to date version of this table can be found at the Weed Research and Information Center (http://wric.ucdavis.edu)

Updated annually. Available online - easiest way is to find it is on the UC Weed Science blog or on WRIC site.

PRE tankmix trial (Tulare)



Walnut: Tulare Co
-Trt 12/15/17

Example of a sequential approach

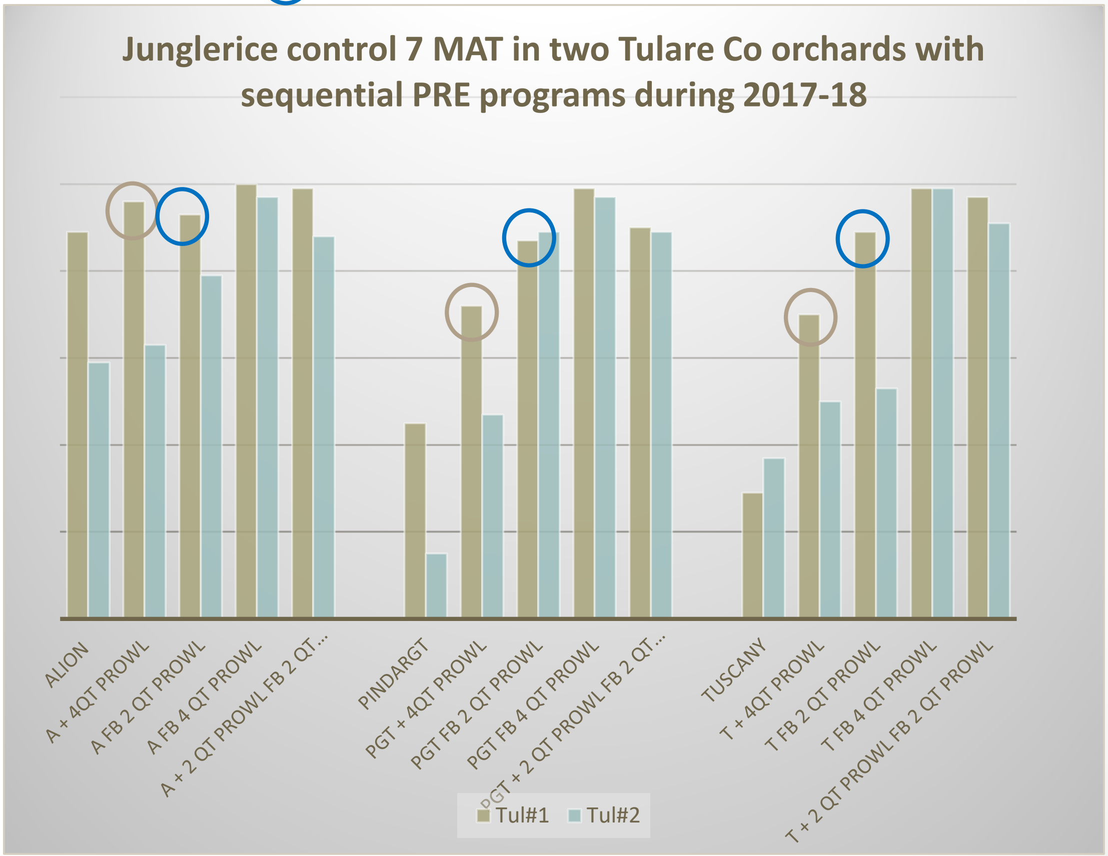
- Goal:
- 1. control of winter weed complex
- 2. and control of summer-emerging grasses

- Evaluated:
- Sequential approach using a targeted PRE
- Alion, PindarGT, and Tuscany as foundation
- Added Prowl to help with grasses
  - 4 qt in winter with foundation
  - 2 qt in March
  - 4 qt in March
  - 2 qt in winter + 2 qt in spring

- -junglerice emerges ~May-Aug
  -pendimethalin is effective on many grasses, but a high rate of pendimethalin in Dec is needed for it to "last" until July
- ? Can we use a lower rate but apply it later to achieve the same outcome (with economic and environmental benefits)?

= foundation prog. tankmix w 4 qt Prowl H2O

= foundation prog. & seq 2 qt Prowl H2O



Integrated weed management

- Basing control decisions on actual weed problems
  - Control the weeds you KNOW you have (or will have)
- Identify new weed problems when they are small
  - New invasive species, resistant biotypes, etc.
  - Can use more intensive control strategies on the pockets that need it rather than field-wide
- Avoid ineffective treatments
  - Using the wrong tool for the job wastes time and money
  - Will likely have to be retreated or controlled some other way
- Avoid overtreatment
  - Wastes money and time
  - Puts a higher than necessary load of pesticide in the environment (+ regulatory burden)
  - Increases crop safety concerns

Herbicides and IWM

- All weed management choices, including doing nothing, have consequences
- Herbicides are tools that can provide efficient and effective weed control
    - However, should not be the only tool considered
- Instead herbicides better as part of an integrated management plan that fully considers the specific situation and recognizes the tradeoffs and opportunities of the available options

Poll question #6

Developing an IWM

- Understand the problem
  - Identity and biology
- Understand the ecosystem
  - Crop biology
  - Management cost/benefit, tolerance to weeds
- Evaluate management options
  - Cultural
  - Mechanical
  - Chemical
- Refine IWM as needed (keep records)

Resistant weeds = superweeds?

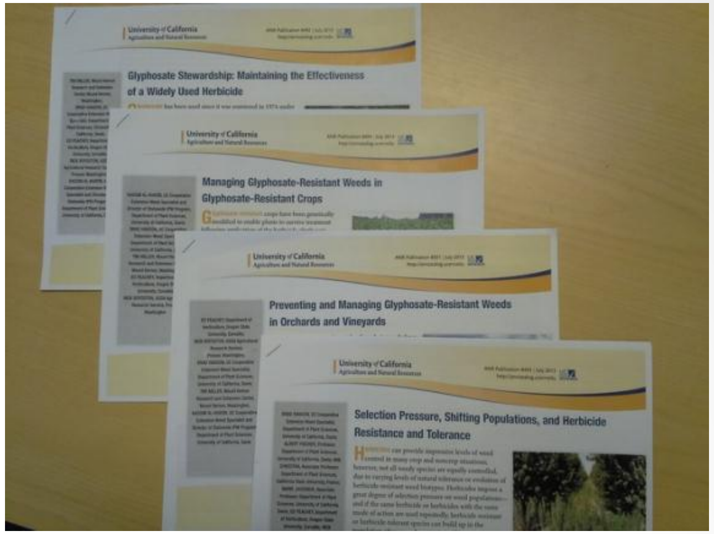
- Superweeds?
  - No.
- Serious management challenge?
  - Yes.

  - CA-PCA quote
    "We're trying to convince our growers that the days of $10/A weed control are over for orchards and vineyards"
    The same is probably true for most of our agricultural crops and non-crop areas as well

K. Hembree in *US News and World Report article*

Poll question #7

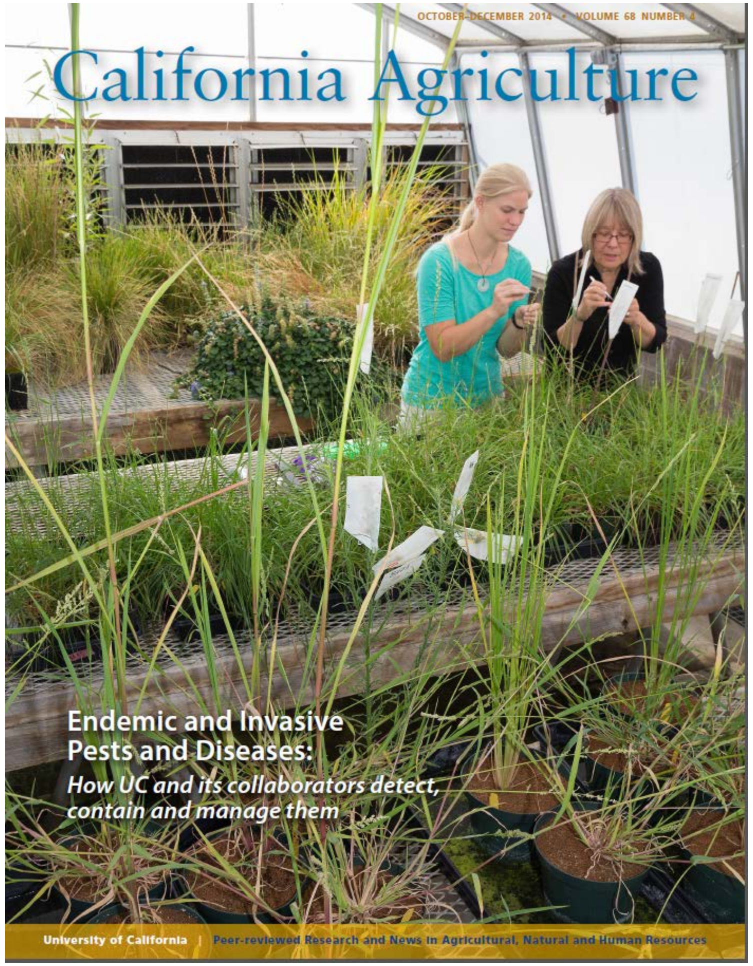
Herbicide resistance publications

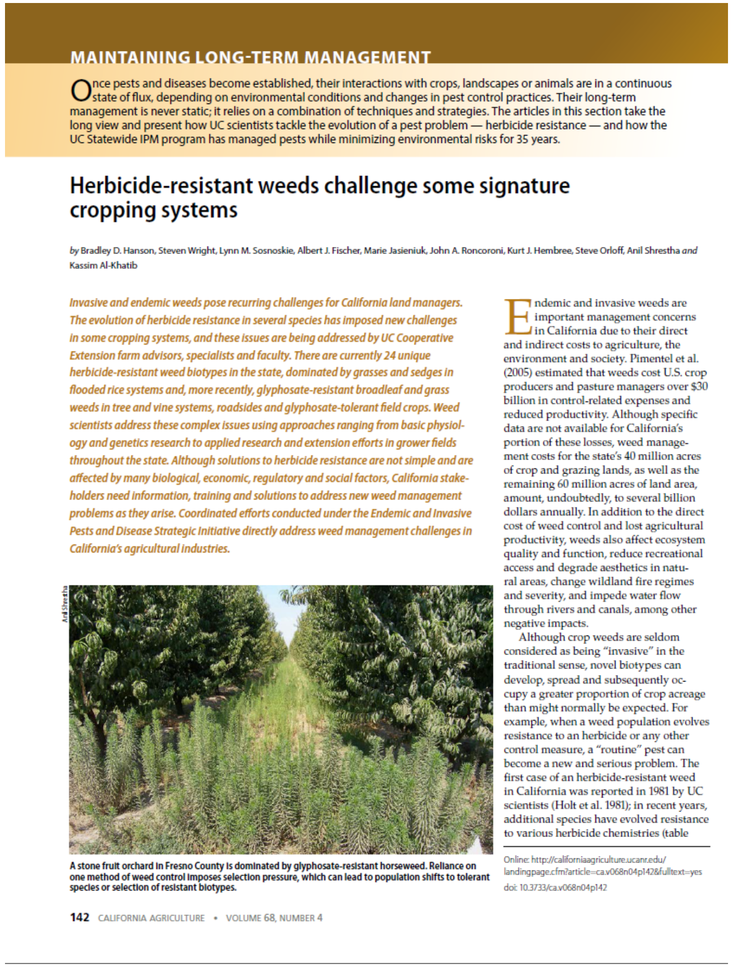


- 2013 series of UC IPM publications
  - Selection Pressure, Shifting Populations, and Herbicide Resistance and Tolerance
  - Glyphosate Stewardship: Maintaining the Effectiveness of a Widely Used Herbicide
  - Preventing and Managing Glyphosate-Resistant Weeds in Orchards and Vineyards
  - Managing Glyphosate-Resistant Weeds in Glyphosate-Resistant Crops
  - http://anrcatalog.ucdavis.edu/ (type "glyphosate" in the search box)

California Agriculture. Vol 68. Oct-Dec 2014

http://californiaagriculture.ucanr.org/issue.cfm?volume=68&issue=4





MAINTAINING LONG-TERM MANAGEMENT

Once pests and diseases become established, their interactions with crops, landscapes or animals are in a continuous state of flux, depending on environmental conditions and changes in pest control practices. Their long-term management is never static; it relies on a combination of techniques and strategies. The articles in this section take the long view and present how UC scientists tackle the evolution of a pest problem — herbicide resistance — and how the UC Statewide IPM program has managed pests while minimizing environmental risks for 35 years.

Herbicide-resistant weeds challenge some signature cropping systems

by Bradley D. Hanson, Steven Wright, Lynn M. Sosnoskie, Albert J. Fischer, Marie Jasieniuk, John A. Roncoroni, Kurt J. Hembree, Steve Orloff, Anil Shrestha *and* Kassim Al-Khatib

Invasive and endemic weeds pose recurring challenges for California land managers. The evolution of herbicide resistance in several species has imposed new challenges in some cropping systems, and these issues are being addressed by UC Cooperative Extension farm advisors, specialists and faculty. There are currently 24 unique herbicide-resistant weed biotypes in the state, dominated by grasses and sedges in flooded rice systems and, more recently, glyphosate-resistant broadleaf and grass weeds in tree and vine systems, roadsides and glyphosate-tolerant field crops. Weed scientists address these complex issues using approaches ranging from basic physiology and genetics research to applied research and extension efforts in grower fields throughout the state. Although solutions to herbicide resistance are not simple and are affected by many biological, economic, regulatory and social factors, California stakeholders need information, training and solutions to address new weed management problems as they arise. Coordinated efforts conducted under the Endemic and Invasive Pests and Disease Strategic Initiative directly address weed management challenges in California's agricultural industries.

Anil Shrestha

A stone fruit orchard in Fresno County is dominated by glyphosate-resistant horseweed. Reliance on one method of weed control imposes selection pressure, which can lead to population shifts to tolerant species or selection of resistant biotypes.

Endemic and invasive weeds are important management concerns in California due to their direct and indirect costs to agriculture, the environment and society. Pimentel et al. (2005) estimated that weeds cost U.S. crop producers and pasture managers over $30 billion in control-related expenses and reduced productivity. Although specific data are not available for California's portion of these losses, weed management costs for the state's 40 million acres of crop and grazing lands, as well as the remaining 60 million acres of land area, amount, undoubtedly, to several billion dollars annually. In addition to the direct cost of weed control and lost agricultural productivity, weeds also affect ecosystem quality and function, reduce recreational access and degrade aesthetics in natural areas, change wildland fire regimes and severity, and impede water flow through rivers and canals, among other negative impacts.

Although crop weeds are seldom considered as being "invasive" in the traditional sense, novel biotypes can develop, spread and subsequently occupy a greater proportion of crop acreage than might normally be expected. For example, when a weed population evolves resistance to an herbicide or any other control measure, a "routine" pest can become a new and serious problem. The first case of an herbicide-resistant weed in California was reported in 1981 by UC scientists (Holt et al. 1981); in recent years, additional species have evolved resistance to various herbicide chemistries (table

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v068n04p142&fulltext=yes
doi: 10.3733/ca.v068n04p142

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UC Davis Weed Research and Information Center

http://wric.ucdavis.edu/
http://ucanr.org/blogs/UCDWeedScience/

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College of Agricultural and Environmental Sciences

T&V herbicide registrations

Herbicide Registration on California Tree and Vine Crops *-(updated May 2018 - UC Weed Science)*

	Herbicide- Common Name *(example trade name)*	Site of Action Group[1]	Almond	Pecan	Pistachio	Walnut	Apple	Pear	Apricot	Cherry	Nectarine	Peach	Plum / Prune	Avocado	Citrus	Date	Fig	Grape	Kiwi	Olive	Pomegranate
			----- tree nut -------				- pome-		--------- stone fruit ---------												
Preemergence	**dichlobenil** *(Casoron)*	L / 20	N	N	N	N	R	R	N	R	N	N	N	N	N	N	N	R	N	N	N
	diuron *(Karmex,Diurex)*	C2 / 7	N	R	N	R	R	R	N	N	N	R	N	N	R	N	N	R	N	R	N
	EPTC *(Eptam)*	N / 8	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N
	flazasulfuron *(Mission)*	B / 2	R	N	R	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
	flumioxazin *(Chateau)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	NB	NB	N	NB	R	N	R	R
	indaziflam *(Alion)*	L / 29	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	N
	isoxaben *(Trellis)*	L / 21	R	R	R	R	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	NB	R	NB	NB	NB
	mesotrione *(Broadworks)*	F2/27	R	R	R	R	N	N	N	N	R	N	R	N	R	N	N	N	N	N	N
	napropamide *(Devrinol)*	K3 / 15	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	N
	norflurazon *(Solicam)*	F1/ 12	R	R	N	R	R	R	R	R	R	R	R	R	R	N	N	R	N	N	N
	oryzalin *(Surflan)*	K1/ 3	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	oxyfluorfen *(Goal, GoalTender)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	R	NB	R	R	R	R	R	R
	pendimethalin *(Prowl H2O)*	K1/ 3	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	R
	penoxsulam *(Pindar GT)*	B / 2	R	R	R	R	N	N	N	R	R	R	R	N	N	N	N	N	N	R	R
	pronamide *(Kerb)*	K1/ 3	N	N	N	N	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	rimsulfuron *(Matrix)*	B / 2	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	sulfentrazone *(Zeus)*	E/ 14	N	N	R	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
	simazine *(Princep,Caliber 90)*	C1/ 5	R	R	N	R	R	R	N	R[2]	R	R	N	R	R	N	N	R	N	R	N
	trifluralin *(Treflan)*	K1/ 3	R	R	N	R	N	N	R	N	R	R	R	N	R	N	N	R	N	N	N
Postemergence	**carfentrazone** *(S hark)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	clethodim *(SelectMax)*	A / 1	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	R	N	N	NB	N	NB	N
	2,4- D *(Clean- crop, Orchard Master)*	O / 4	R	R	R	R	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	diquat *(Diquat)*	D / 22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
	fluazifop- p- butyl *(Fusilade)*	A / 1	NB	R	NB	NB	NB	NB	R	R	R	R	R	NB	R	NB	NB	R	N	NB	NB
	glyphosate *(Roundup)*	G / 9	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	glufosinate *(Rely 280)*	H / 10	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	N
	halosulfuron *(Sandea)*	B / 2	N	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	paraquat *(Gramoxone)*	D / 22	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	pelargonic acid *(Scythe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N
	pyraflufen *(Venue)*	E/ 14	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	R	R	R	R
	saflufenacil *(Treevix)*	E/ 14	R	N	R	R	R	R	N	N	N	N	N	N	R	N	N	N	N	R	R
	sethoxydim *(Poast)*	A / 1	R	R	R	R	R	R	R	R	R	R	NB	NB	R	NB	NB	R	N	NB	NB
Organic	**Caprilic/Capric acid** *(Suppress)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	N	R
	ammoniated fatty acids *(Final- San-*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	d- limionene *(AvengerAG)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	Ammonium nanoate *(Axxe)*	NC[4]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N

Notes: R = Registered, N = Not registered, NB = nonbearing. This chart is intended as a general guide only. Always consult a current label before using any herbicide as labels change frequently and often contain special restrictions regarding use of a company's product.

[1] Herbicide site of action designations are according to the Herbicide Resistance Action Committee (letters) and the Weed Science Society of America (number) systems. NC = no accepted site of action classification; these contact herbicides are general membrane disruptors.

[2] Simazine is registered on only tart cherry in CA.

Weed susceptibility information and the most up to date version of this table can be found at the Weed Research and Information Center (http://wric.ucdavis.edu)

Updated annually. Available online - easiest way is to find it is on the UC Weed Science blog or on WRIC site.

- The right tools, used well, and at the right time, make orchard weed management a much easier, cheaper, and effective proposition