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UC Davis Weed Science

HERBICIDE-RESISTANT WEEDS: THE BASICS

Definitions

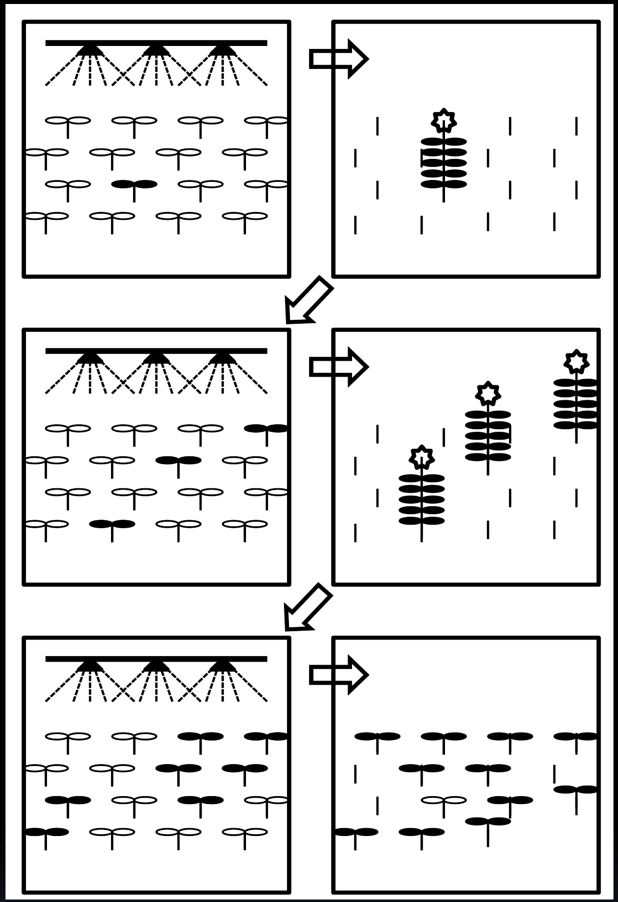
- **Herbicide tolerance:** the inherent ability of a species to survive and reproduce after herbicide treatment; implies no selection or genetic manipulation to make the plant tolerant
  - *"We've never gotten dependable control of this weed with this herbicide…"*

- **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…"*

Weed population shifts

- Weed populations in a field usually consist of a mixture of species
  - Relative proportion of individual species is dynamic and can vary over time in response to management practices
- Repeated use of a single control tactic can lead to weed populations dominated by species not controlled by that practice
    - Can be through tolerance, resistance, or avoidance

Selection pressure



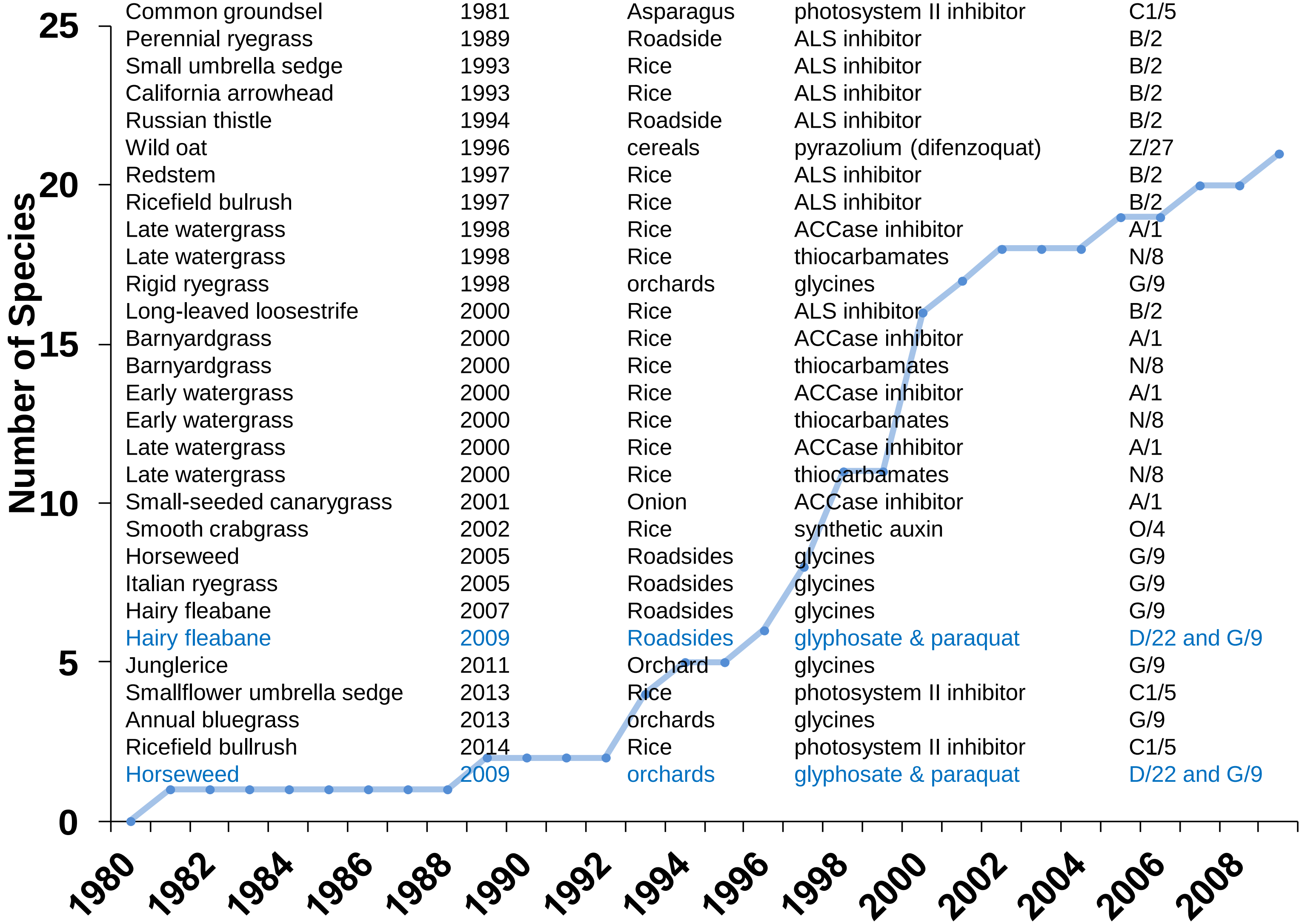
- Selection of HR is an evolutionary process
  - High genetic diversity in weed populations
  - Control measure removes susc. biotypes; leaves resistant plants to reproduce
- Pressure varies among systems
  - Cropping practices, herbicides, weeds

HRW comparison - US vs CA

- US
  - ~76 broadleaf weeds, ~52 monocots
  - 15 herbicide families
    - Dominated by ALS inhibitors, PSII inhibitors, and multiple-resistance - also ACCase and glyphosate
  - Mostly in agronomic crops
- CA
  - 6 broadleaf weed, 17 monocots (grass/sedge)
  - 8 modes of action
    - Dominated by ALS, glyphosate, and multiple-resistance
  - Mostly in specialty crops and non-crop areas
    - Dominated by rice, roadsides, and tree/vine
    - Very little in annual fruit/vegetable or range/pasture systems

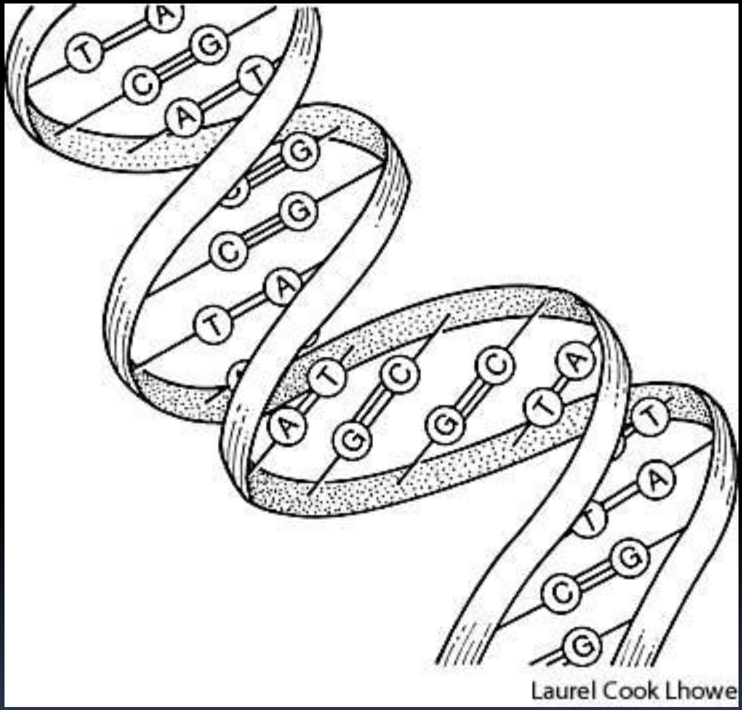
Resistance in California

Weed	Year	Situation	Herbicide MOA	MOA group
Common groundsel	1981	Asparagus	photosystem II inhibitor	C1/5
Perennial ryegrass	1989	Roadside	ALS inhibitor	B/2
Small umbrella sedge	1993	Rice	ALS inhibitor	B/2
California arrowhead	1993	Rice	ALS inhibitor	B/2
Russian thistle	1994	Roadside	ALS inhibitor	B/2
Wild oat	1996	cereals	pyrazolium (difenzoquat)	Z/27
Redstem	1997	Rice	ALS inhibitor	B/2
Ricefield bulrush	1997	Rice	ALS inhibitor	B/2
Late watergrass	1998	Rice	ACCase inhibitor	A/1
Late watergrass	1998	Rice	thiocarbamates	N/8
Rigid ryegrass	1998	orchards	glycines	G/9
Long-leaved loosestrife	2000	Rice	ALS inhibitor	B/2
Barnyardgrass	2000	Rice	ACCase inhibitor	A/1
Barnyardgrass	2000	Rice	thiocarbamates	N/8
Early watergrass	2000	Rice	ACCase inhibitor	A/1
Early watergrass	2000	Rice	thiocarbamates	N/8
Late watergrass	2000	Rice	ACCase inhibitor	A/1
Late watergrass	2000	Rice	thiocarbamates	N/8
Small-seeded canarygrass	2001	Onion	ACCase inhibitor	A/1
Smooth crabgrass	2002	Rice	synthetic auxin	O/4
Horseweed	2005	Roadsides	glycines	G/9
Italian ryegrass	2005	Roadsides	glycines	G/9
Hairy fleabane	2007	Roadsides	glycines	G/9
Hairy fleabane	2009	Roadsides	glyphosate & paraquat	D/22 and G/9
Junglerice	2011	Orchard	glycines	G/9
Smallflower umbrella sedge	2013	Rice	photosystem II inhibitor	C1/5
Annual bluegrass	2013	orchards	glycines	G/9
Ricefield bullrush	2014	Rice	photosystem II inhibitor	C1/5
Horseweed	2009	orchards	glyphosate & paraquat	D/22 and G/9



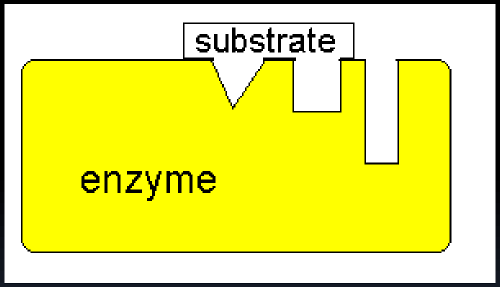
Resistance mechanisms

- 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

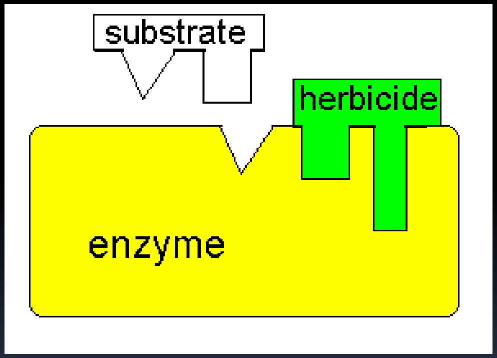


Target site resistance

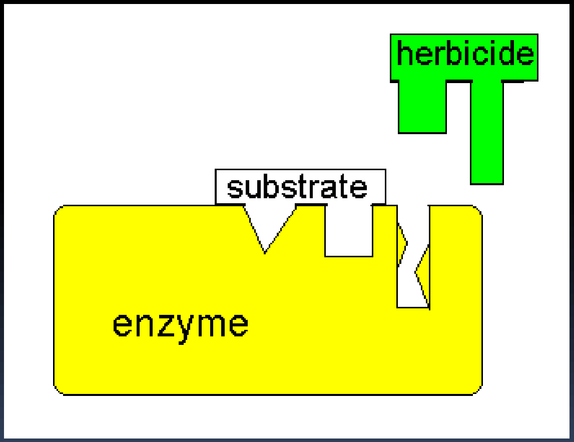
- Herbicides bind to an enzyme at a particular spot - “lock and key”
- Change in the shape or binding affinity at the binding pocket excludes the herbicide
- Cannot bind = does not inhibit the biochemical



Normal substrate binding to enzyme

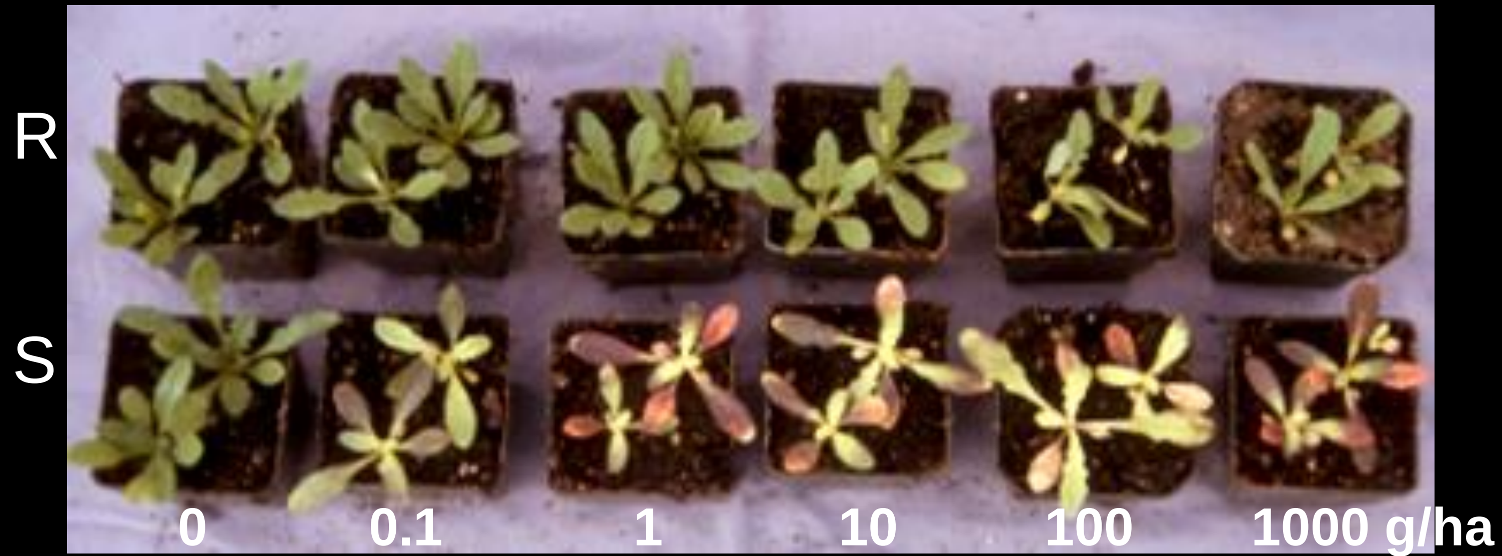


Herbicide inhibiting substrate binding

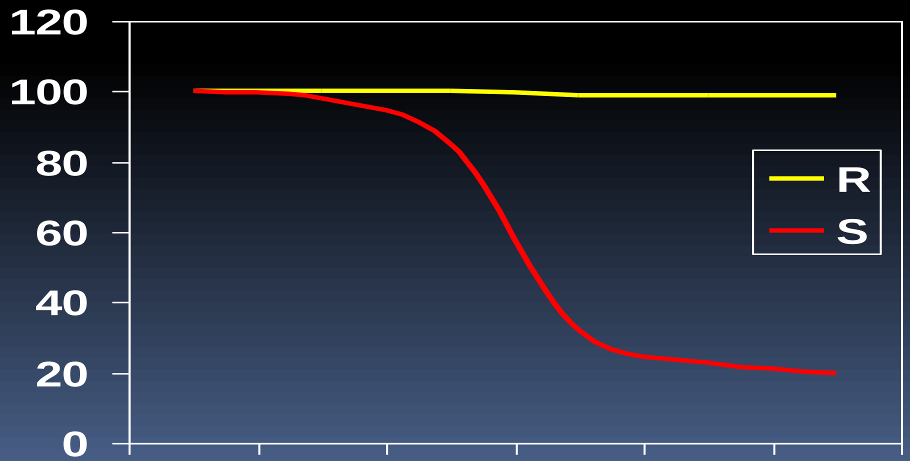


Altered herbicide binding pocket – herbicide cannot bind

Target site resistance



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

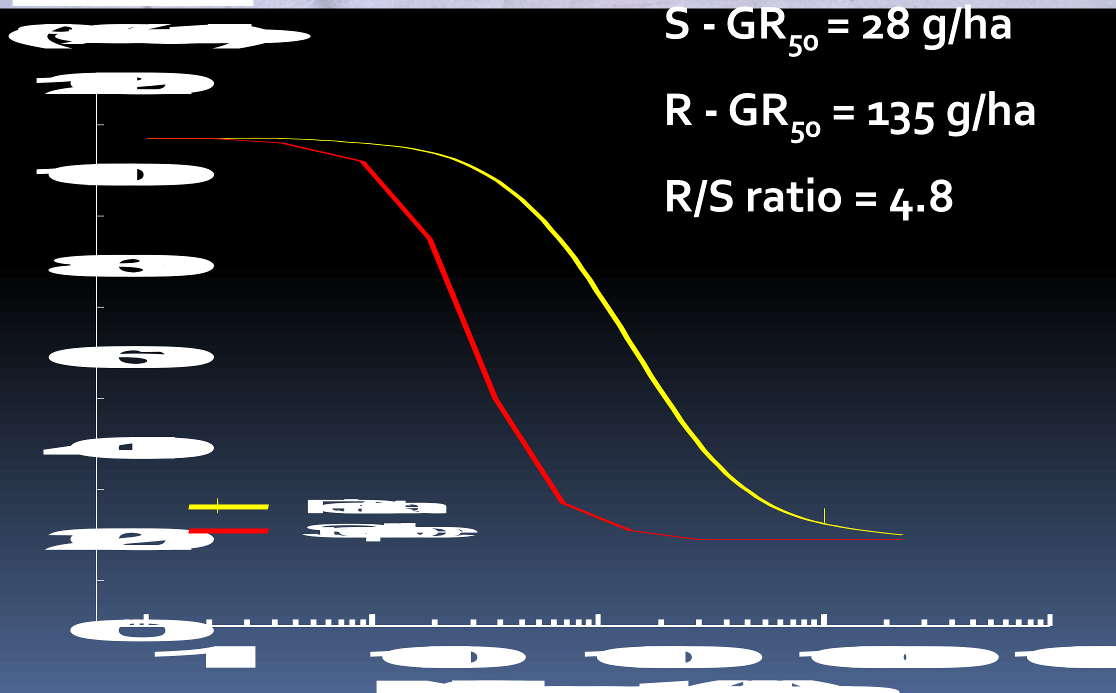


Metabolism-based resistance

Untreated -- 2,240 g/ha

R

S



S - GR_{50} = 28 g/ha

R - GR_{50} = 135 g/ha

R/S ratio = 4.8

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 surviviors
  - 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”

Short-term challenges

- No easy solutions to the current HRW
- Few major changes in selection pressure
  - Continued reliance on relatively few MOA in specialty crops
- New cases of resistance continue to be identified

Intermediate term challenges

- Resistance to additional MOA
  - Especially other POST herbicides (paraquat, glufosinate, etc)
- Non-target site resistance may impart tolerance to other herbicides and other abiotic stresses?
  - Drought, flooding, ozone, CO_2 levels, etc – unknown

Multiple-resistant fleabane - M. Moretti

Long-term challenges

- Economic and environmental cost/benefits of weed management practices
  - VOC, water quality, labor, dust, emissions, others?
- Changing production systems will impact weed management in unexpected ways
  - Esp. water management and tillage practices
    - Drought years will really highlight this!

Final points

- Weed management imposes selection pressure
  - Tolerance, resistance, shifting populations
- Understand herbicide mode of action and rotate herbicides and other management tactics to reduce selection pressure
- Monitor fields and control escapes to manage small problems rather than large ones!

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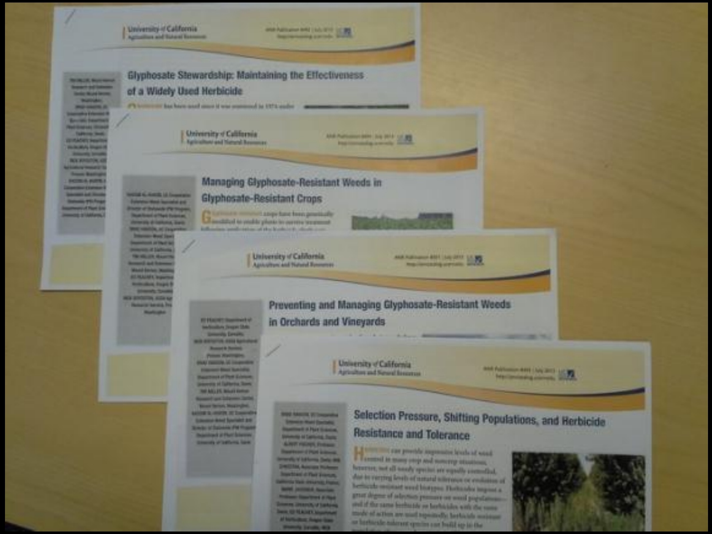
UC Davis Weed Research and Information Center
http://wric.ucdavis.edu/
http://ucanr.org/blogs/UCDWeedScience/

UC Davis Statewide Integrated Pest Management Program
http://www.ipm.ucdavis.edu/

Herbicide resistance publications



- UC IPM publication series:
  - ***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***
  - https://anrcatalog.ucanr.edu/ (type "glyphosate" in the search box)

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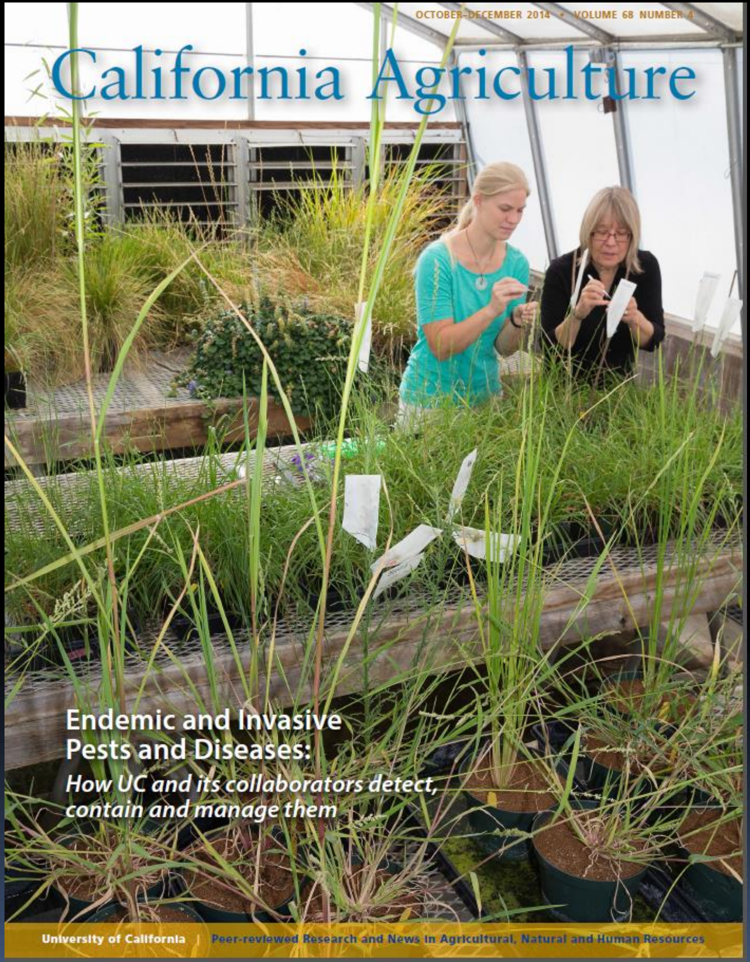
http://californiaagriculture.ucanr.org/issue.cfm?volume=68&issue=4



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
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