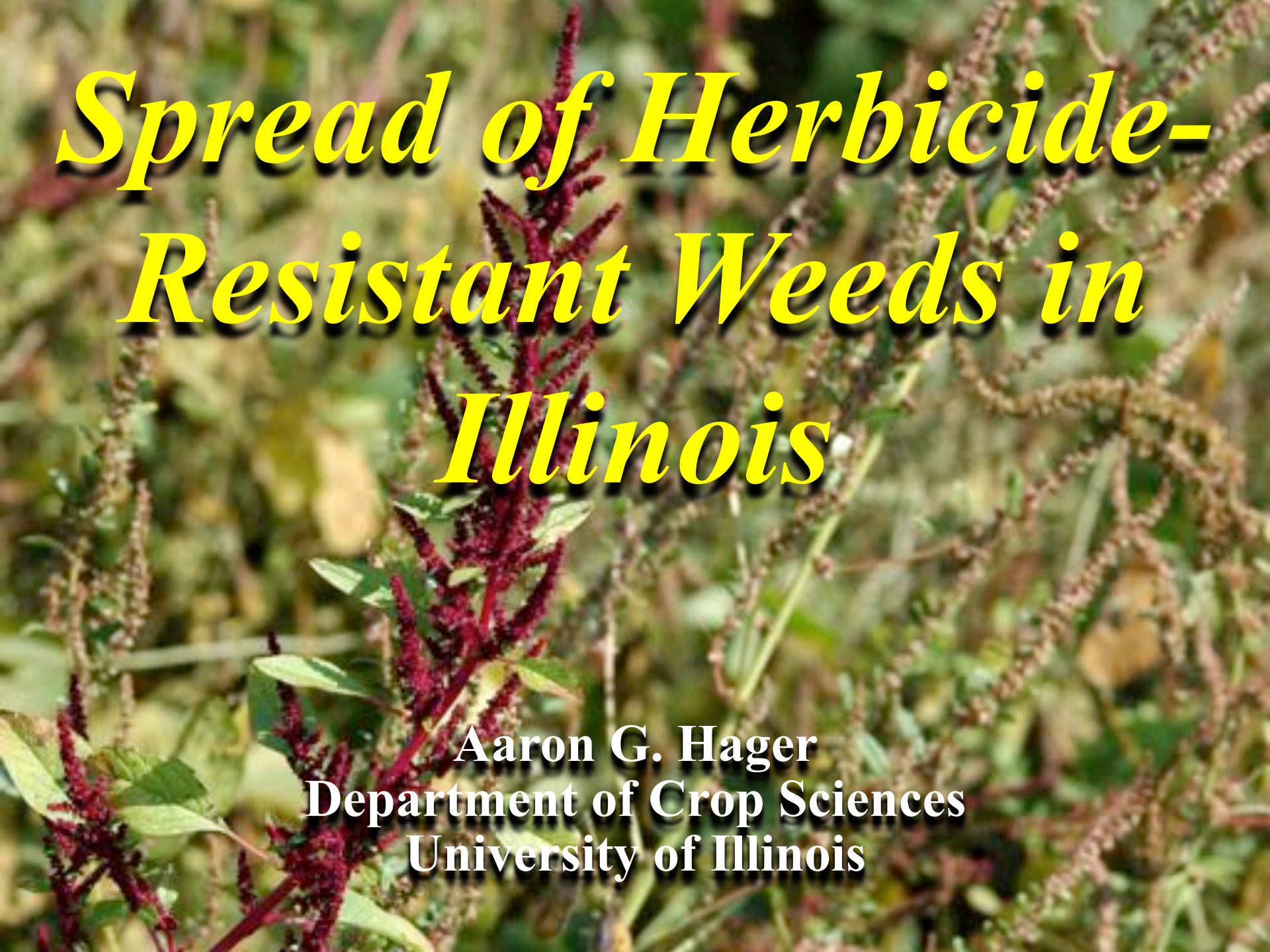


Spread of Herbicide-Resistant Weeds in Illinois

Aaron G. Hager
Department of Crop Sciences
University of Illinois

Home | Summaries | Resistant Weeds | Add New Case | Herbicides | Researchers | Literature | Help

Comment/Question/Report Error

FAQ

Login
FAQ
About Us
Cite this Site
Add New Case
Add Documents

Summaries

US State Map
European Map
Recent Cases
Countries
Sites of Action
All Species by SOA Table
Herbicides
Glyphosate Resistant Weeds
ALS Mutation Database
Graphs
Global Maps
Herbicide Poster
Herbicide Classification System

Resistant Weeds

By Site of Action
By Crop
By Species
By Country

Herbicide-Resistant Weeds by US State

Move mouse over state for information, click on a state for details.

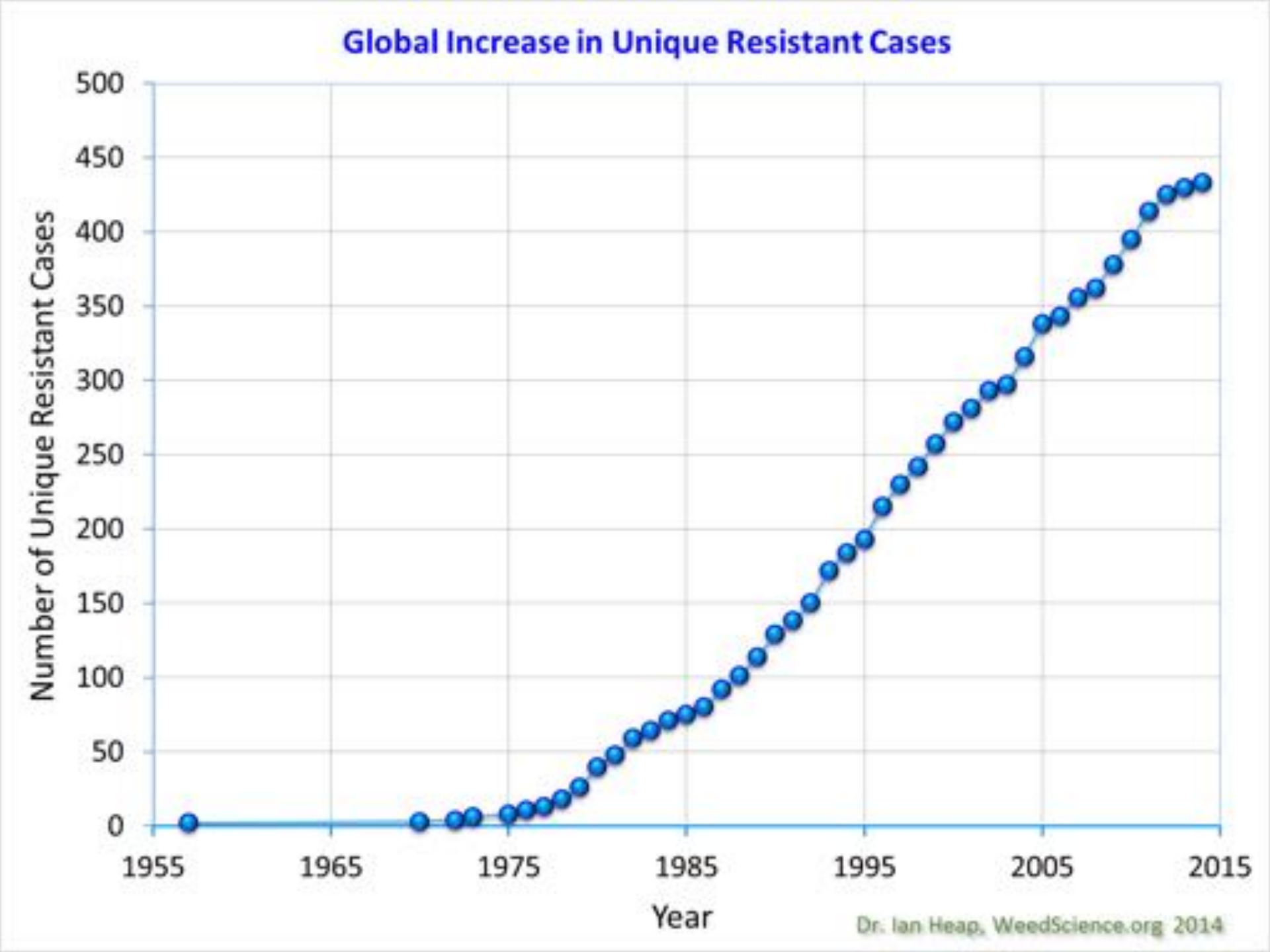
Number of unique cases of herbicide-resistant weeds*

26

27

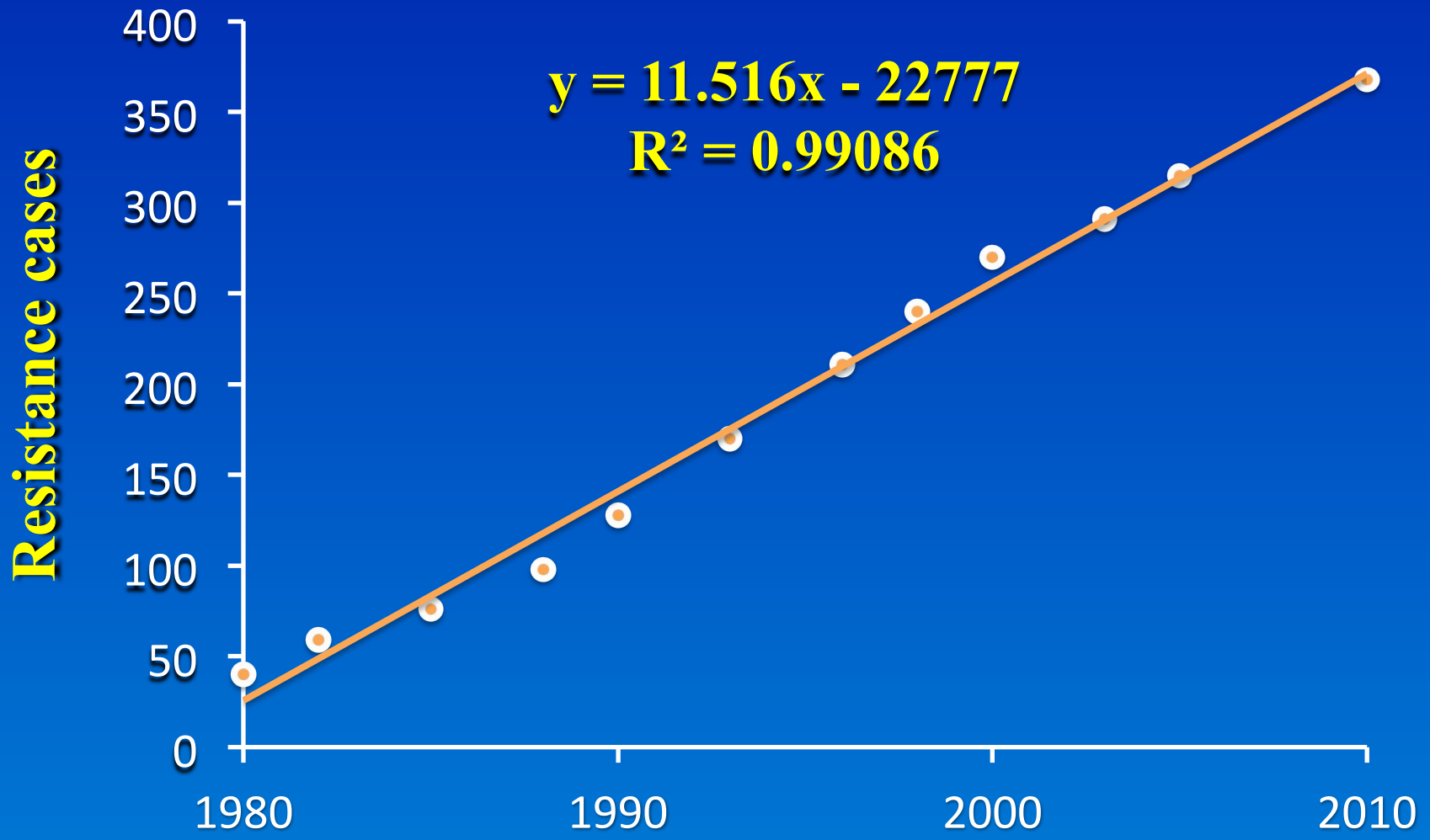
25

***Unique cases = species x site of action**

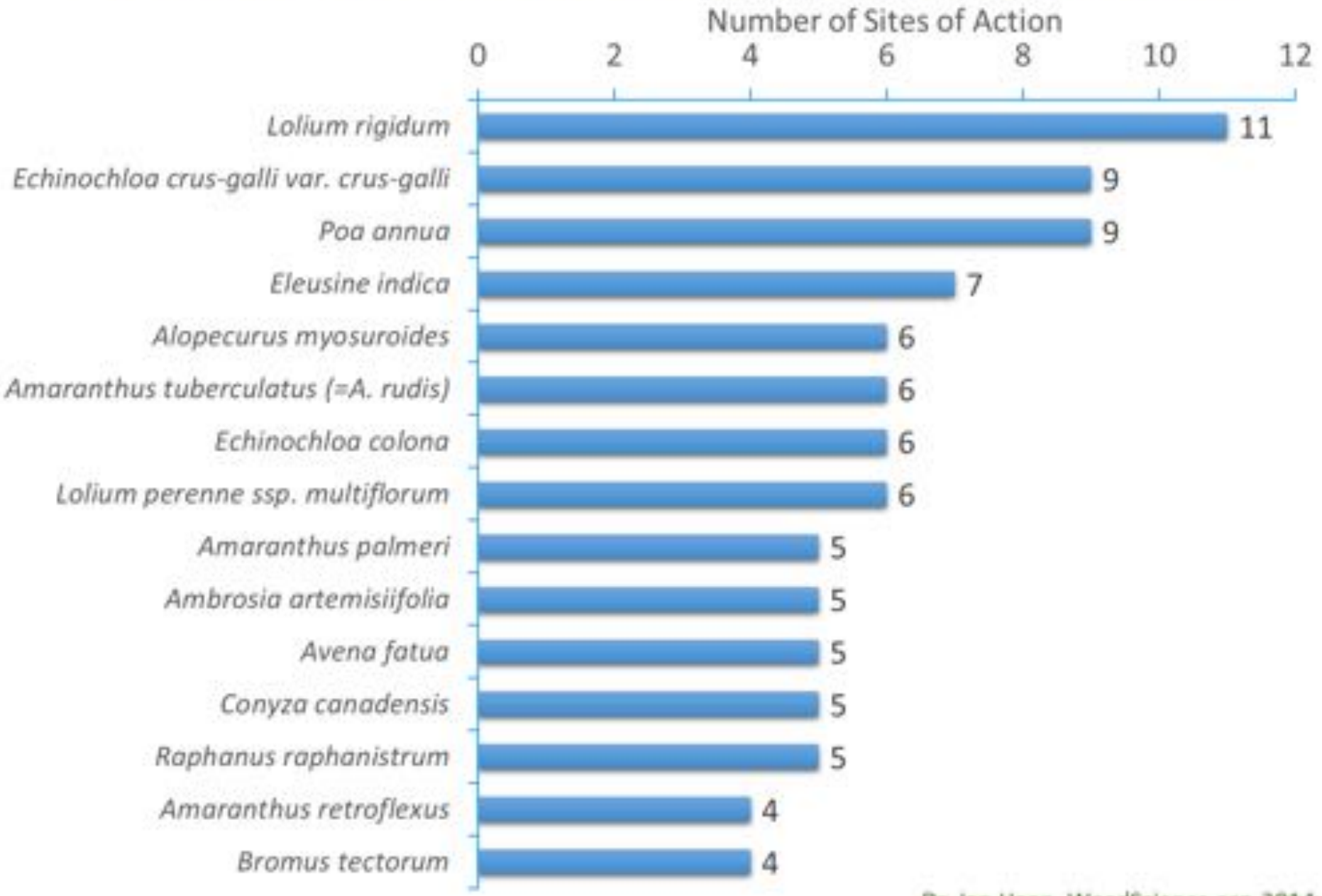

Global Increase in Unique Resistant Cases
Number of Unique Resistant Cases
500
450
400
350
300
250
200
150
100
50
0
1955
1965
1975
1985
1995
2005
2015
Year
Dr. Ian Heap, WeedScience.org 2014

Herbicide Resistance Worldwide

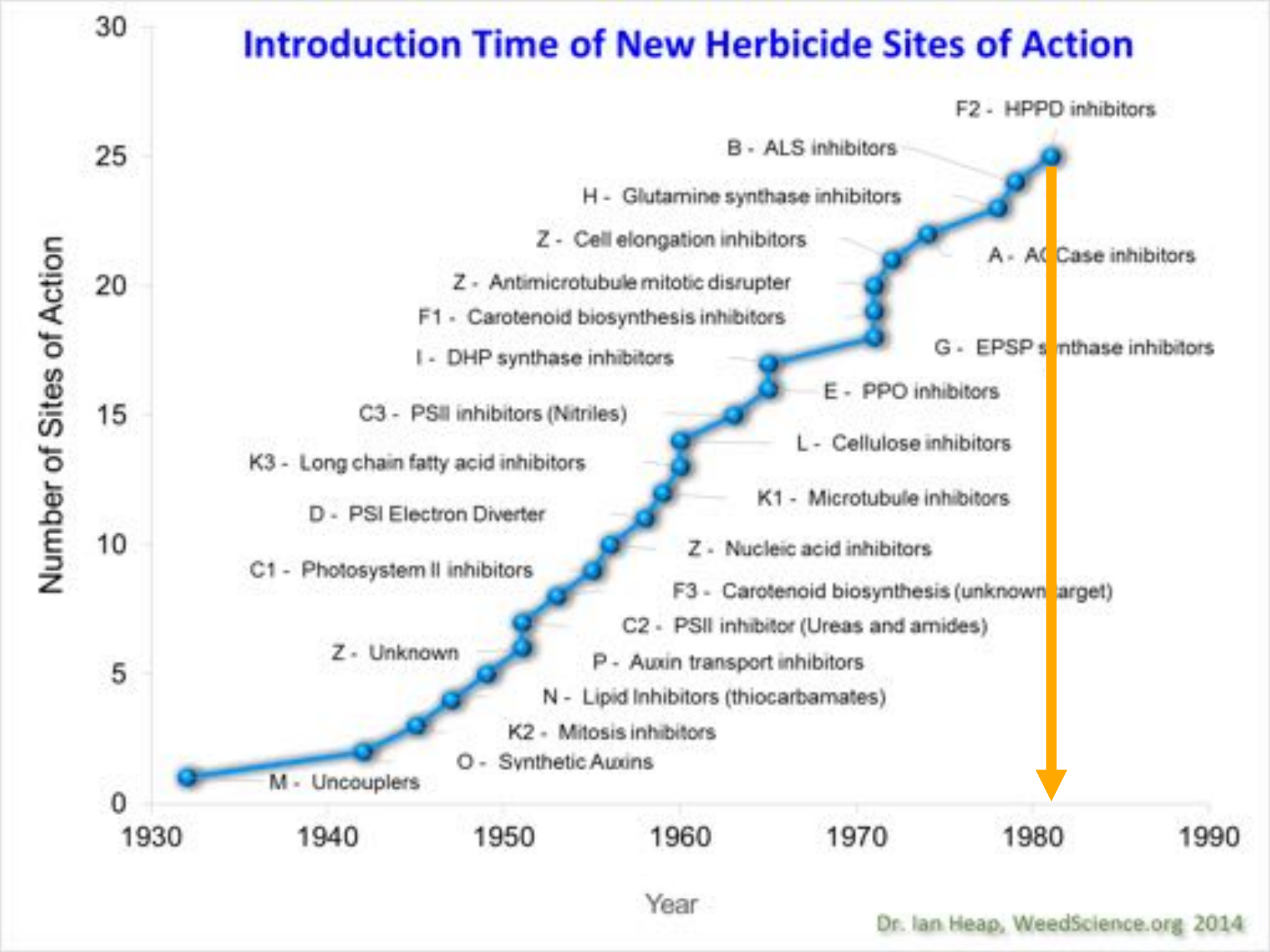
461 unique cases within 247 species



Weed Species Resistant to Multiple Herbicide Sites of Action



Dr. Ian Heap, WeedScience.org 2014


Introduction Time of New Herbicide Sites of Action
Number of Sites of Action
Year
0
5
10
15
20
25
30
1930
1940
1950
1960
1970
1980
1990
M - Uncouplers
O - Synthetic Auxins
K2 - Mitosis inhibitors
N - Lipid Inhibitors (thiocarbamates)
P - Auxin transport inhibitors
Z - Unknown
C2 - PSII inhibitor (Ureas and amides)
F3 - Carotenoid biosynthesis (unknown target)
Z - Nucleic acid inhibitors
C1 - Photosystem II inhibitors
K1 - Microtubule inhibitors
D - PSI Electron Diverter
L - Cellulose inhibitors
K3 - Long chain fatty acid inhibitors
E - PPO inhibitors
C3 - PSII inhibitors (Nitriles)
G - EPSP synthase inhibitors
I - DHP synthase inhibitors
F1 - Carotenoid biosynthesis inhibitors
Z - Antimicrotubule mitotic disrupter
A - ACCase inhibitors
Z - Cell elongation inhibitors
H - Glutamine synthase inhibitors
B - ALS inhibitors
F2 - HPPD inhibitors
Dr. Ian Heap, WeedScience.org 2014

Common cocklebur
ALS inhibitors

Common ragweed
ALS inhibitors

Giant ragweed
ALS inhibitors

Kochia
ALS inhibitors
Triazines
ALS + Triazine

Smooth pigweed
ALS inhibitors
Triazines

Waterhemp
ALS inhibitors
Triazines
PPO
Glyphosate
HPPD inhibitors

Horseweed
Glyphosate
ALS

Common lambsquarters
Triazines

E. Black Nightshade
ALS inhibitors

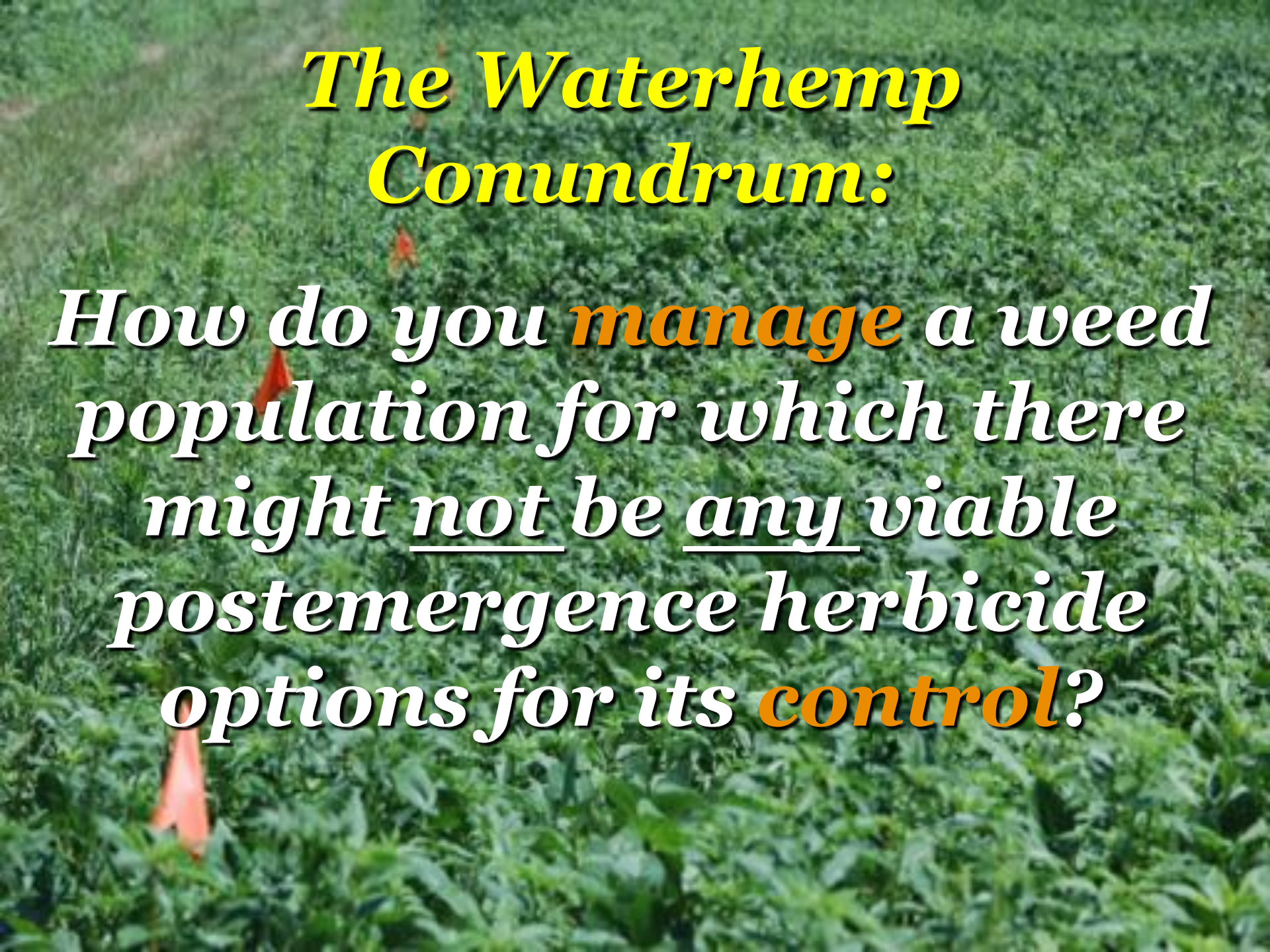
Palmer amaranth
Glyphosate, ALS

Shattercane
ALS inhibitors

Foxtail
ALS inhibitors
ACCase inhibitors


Champaign County 2015


Iroquois County 2015


The Waterhemp Conundrum:
How do you manage a weed population for which there might not be any viable postemergence herbicide options for its control?

Herbicide Resistance in *A. tuberculatus*

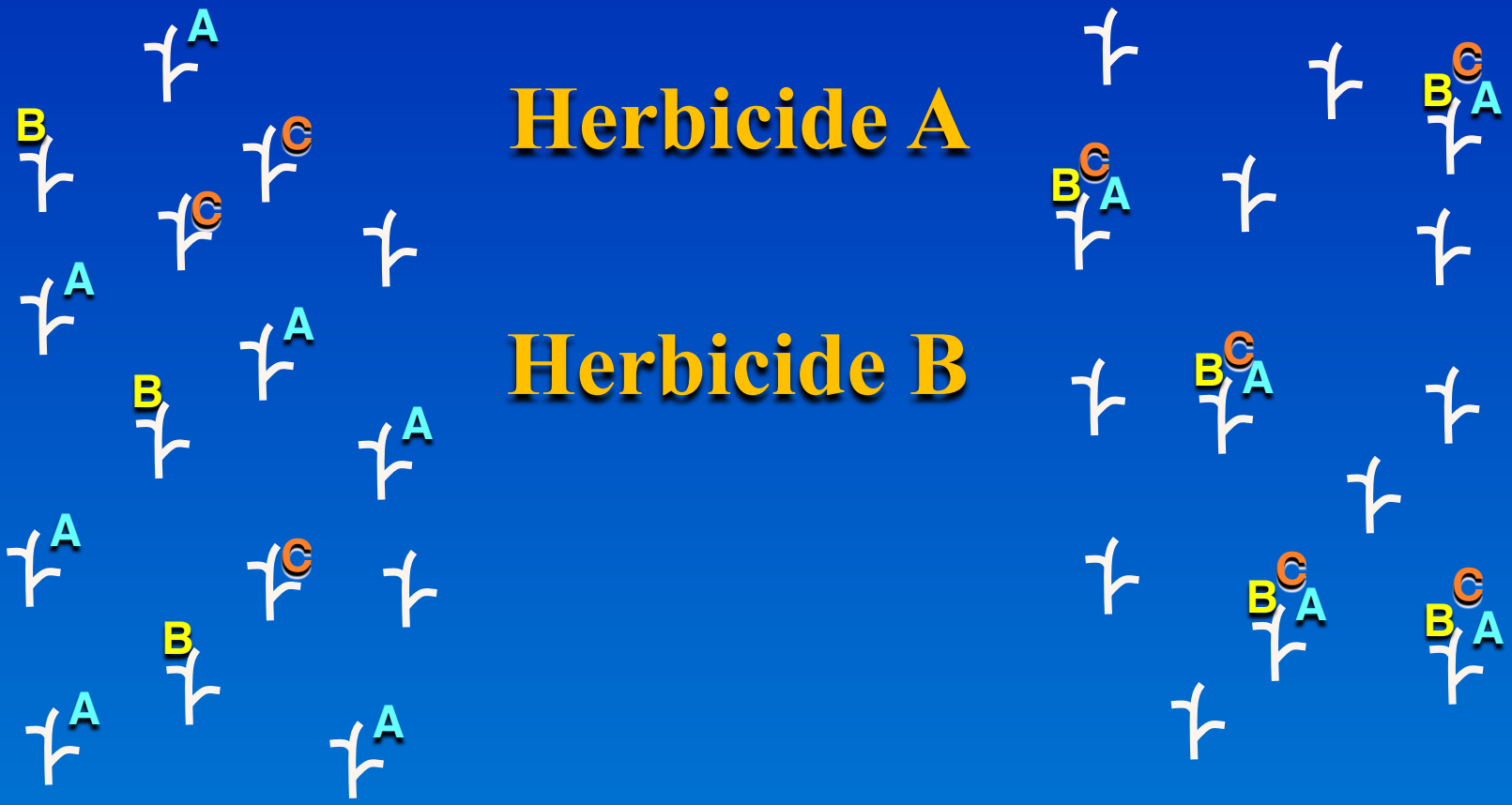
- Several biological characteristics of *A. tuberculatus* help facilitate selection of herbicide resistant biotypes
  - dioecious species, so cross pollination must occur to make seed
  - female plants capable of producing large amounts of seed

- Resistance in the Illinois *A. tuberculatus* has been documented to five (soon, six) herbicide classes
  - ALS inhibitors, triazines, PPO inhibitors, glyphosate and HPPD inhibitors
    - resistance to auxinic herbicides in Nebraska and Illinois

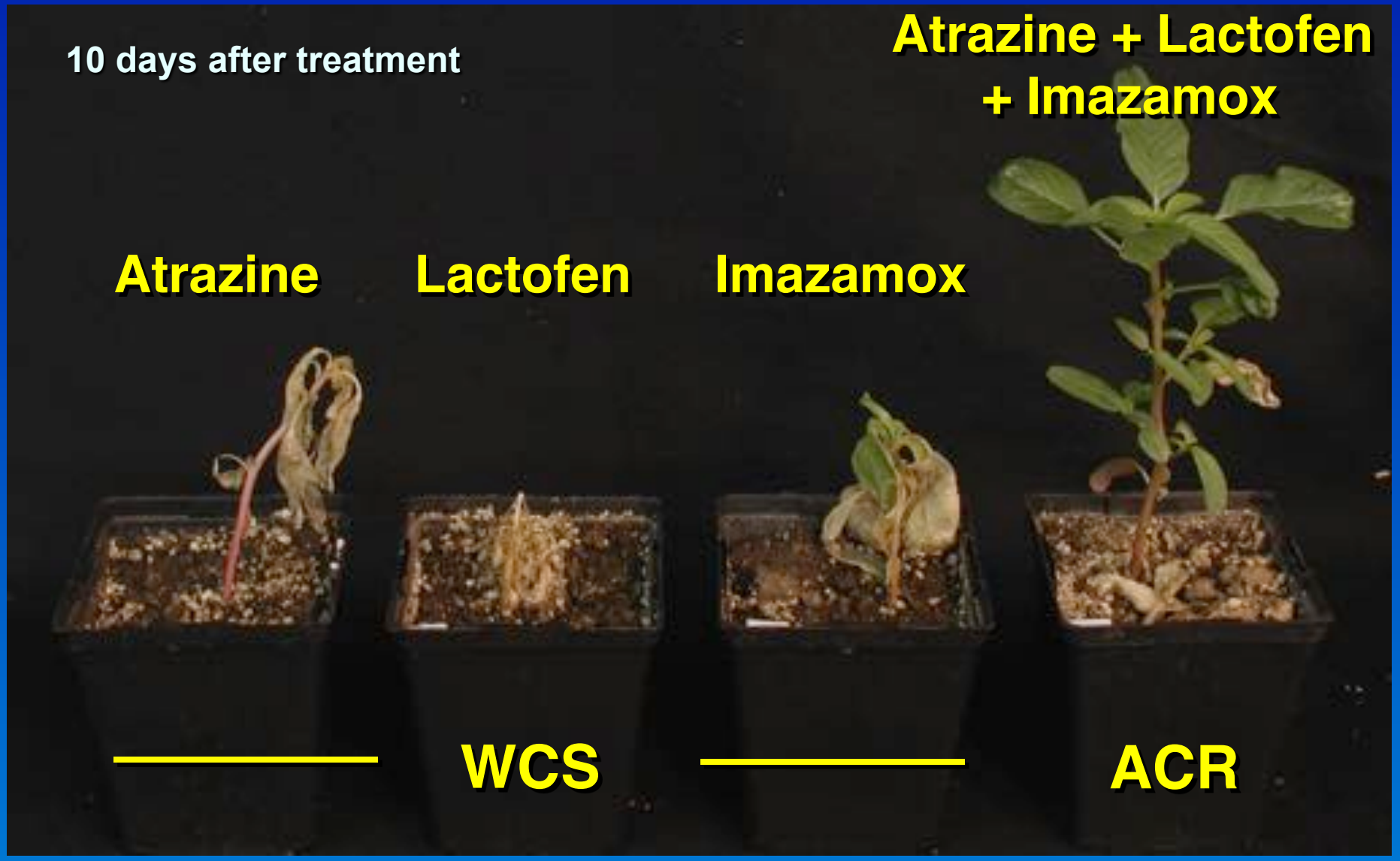
Waterhemp has now evolved resistance to 6 herbicide families, but even more challenging than this is……..

Multiple herbicide resistance in waterhemp

Multi-resistance at population vs. individual level



Multiple resistant waterhemp in Illinois

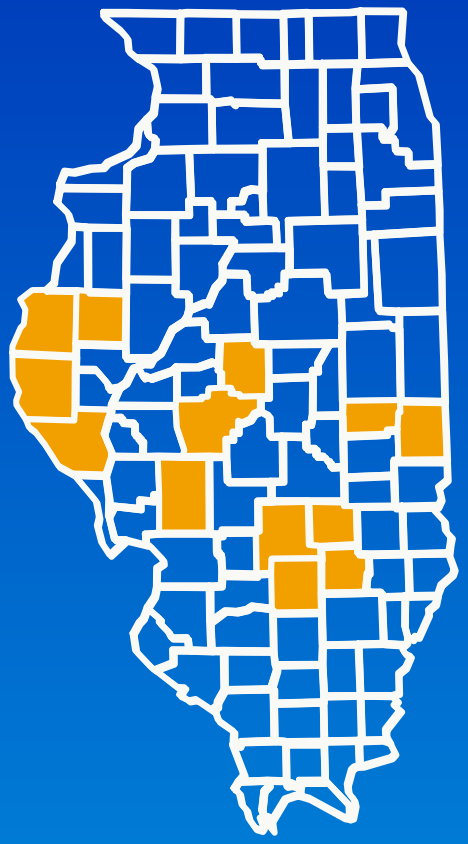



Resistance has evolved to:
Group 2 (ALS)
Group 14 (PPO)
Group 27 (HPPD)
Group 5 (PS II)
Group 4 (2,4-D)
Population or individual?

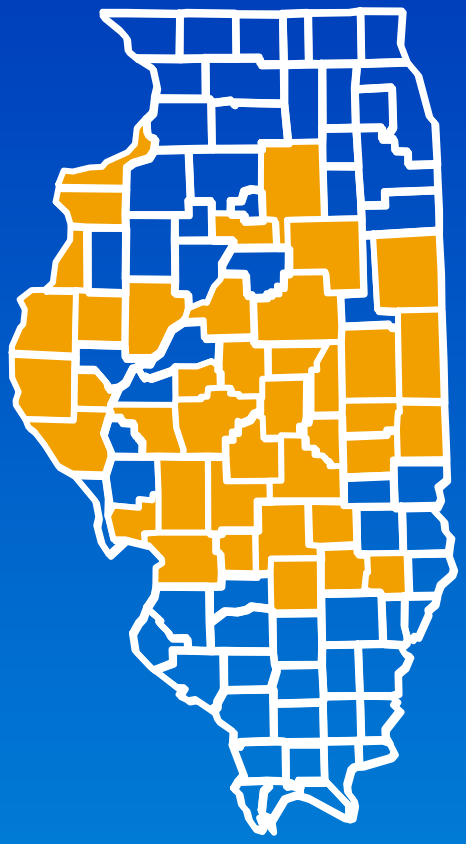
Range expansion of glyphosate-resistant waterhemp

Counties confirmed with GR waterhemp, based on grower submissions

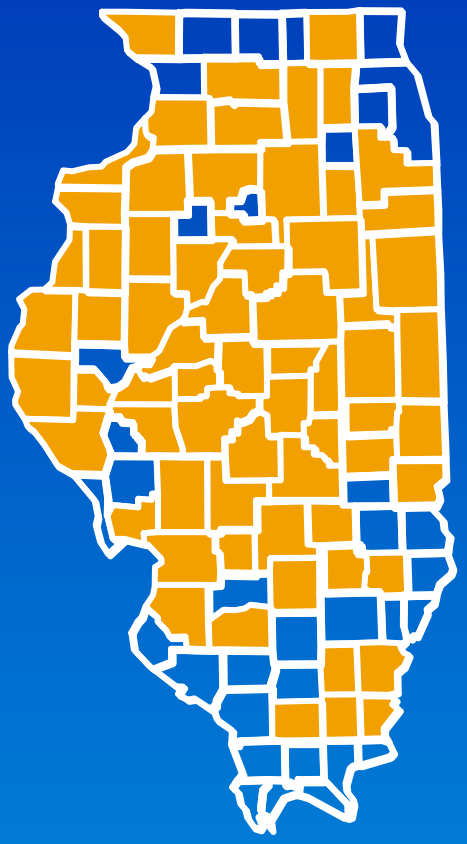
2010



2012

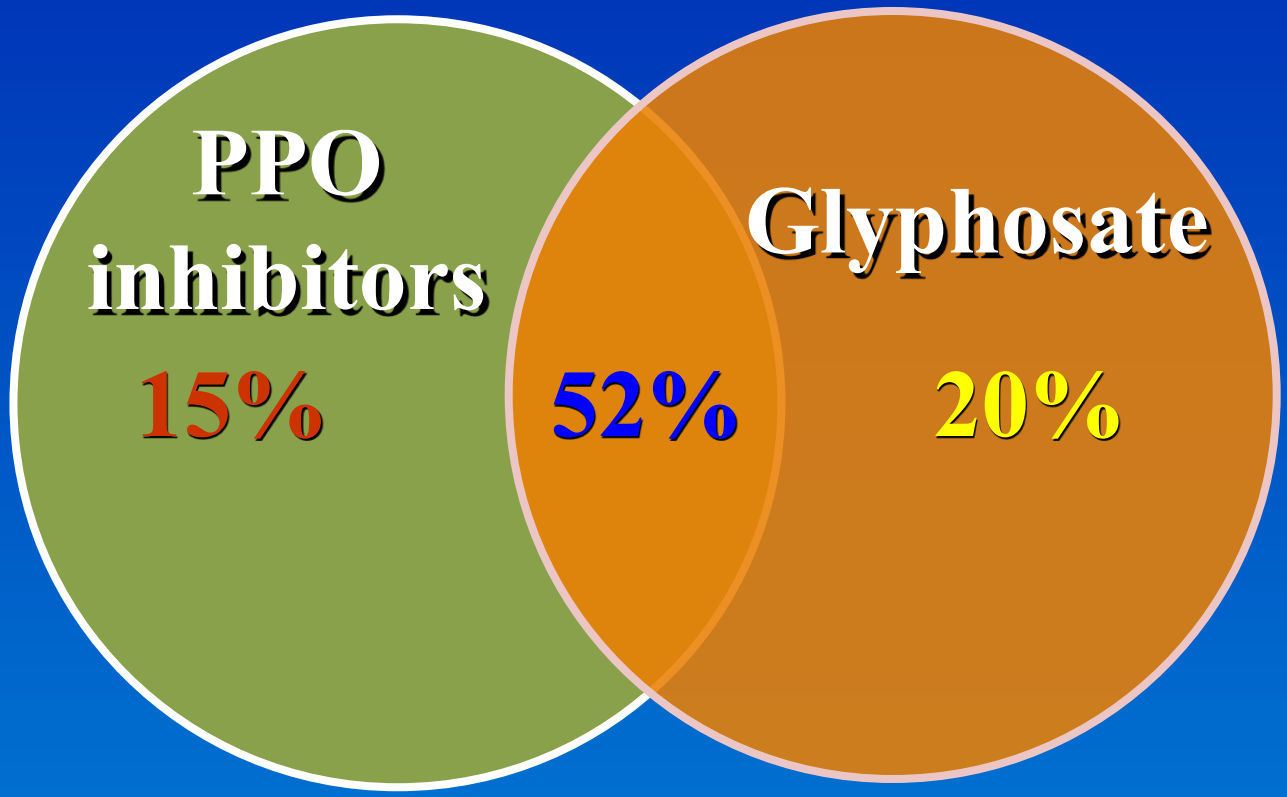


2014



2014 Multiple-Resistant Waterhemp Summary

295 Fields

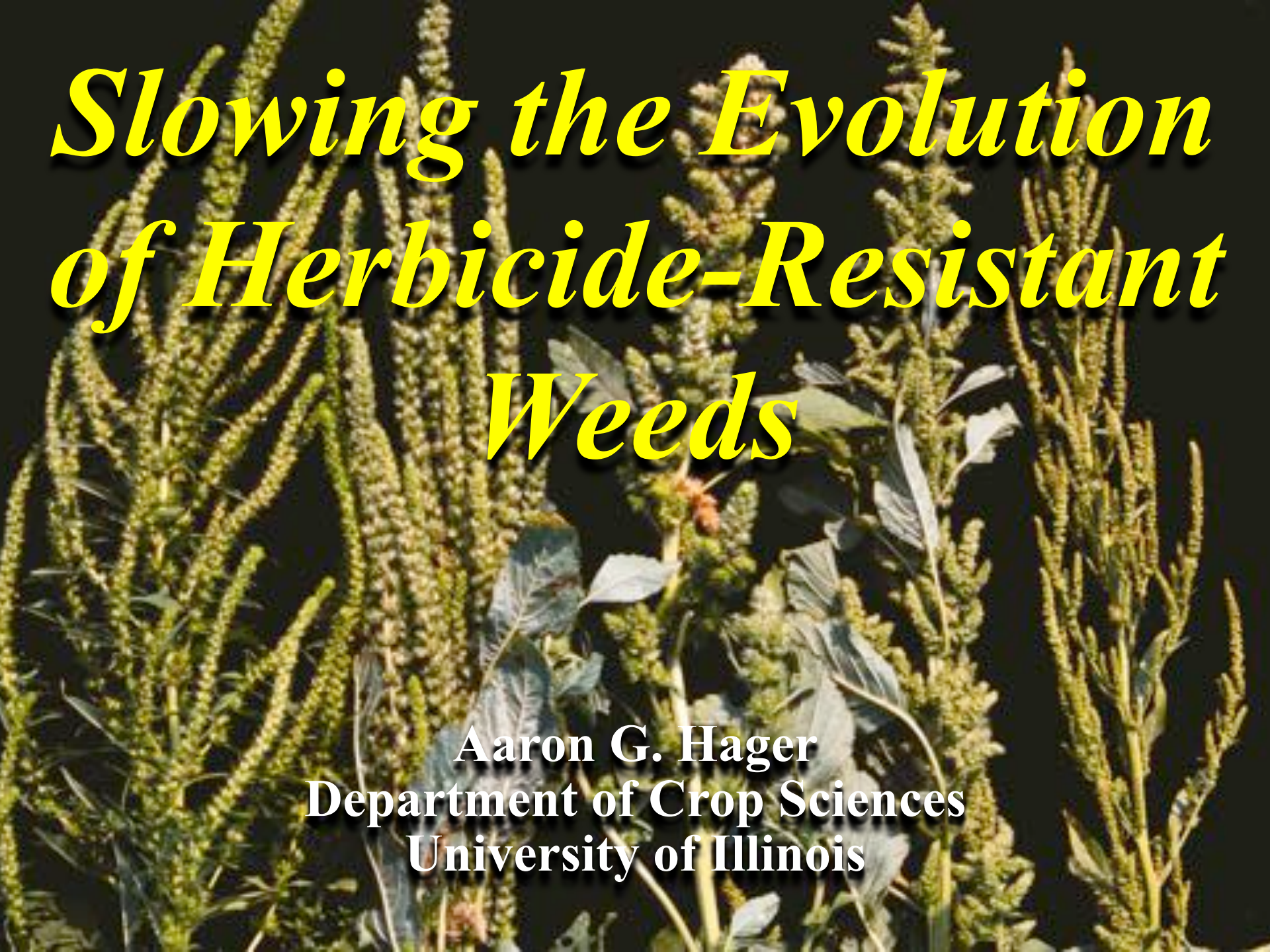


Illinois waterhemp has evolved resistance to herbicides from five (six) sites of action:

1) **ALS: target site and non-target site**
2) **PSII: target site and non-target site**
3) **PPO: target site (unique codon deletion)**
4) **EPSPS: target site and non-target site**
5) **HPPD: non-target site (metabolism)**

Our greatest challenge will be populations/plants with resistance to herbicides from multiple site-of-action groups

Questions?



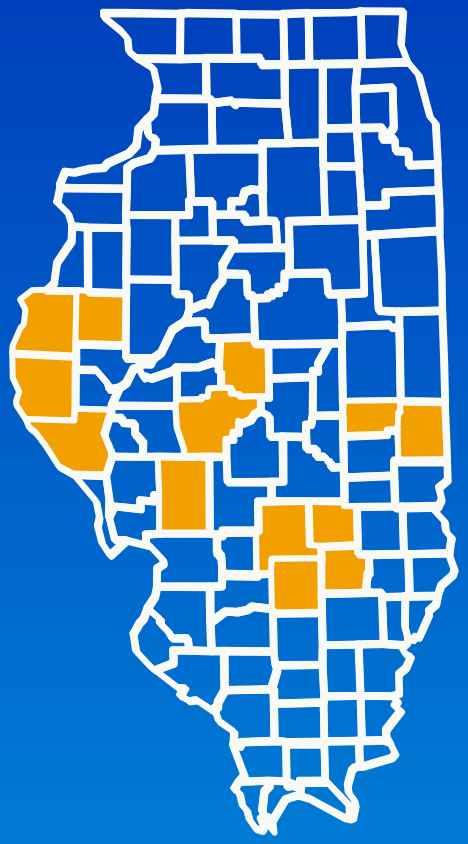
Slowing the Evolution of Herbicide-Resistant Weeds

Aaron G. Hager
Department of Crop Sciences
University of Illinois

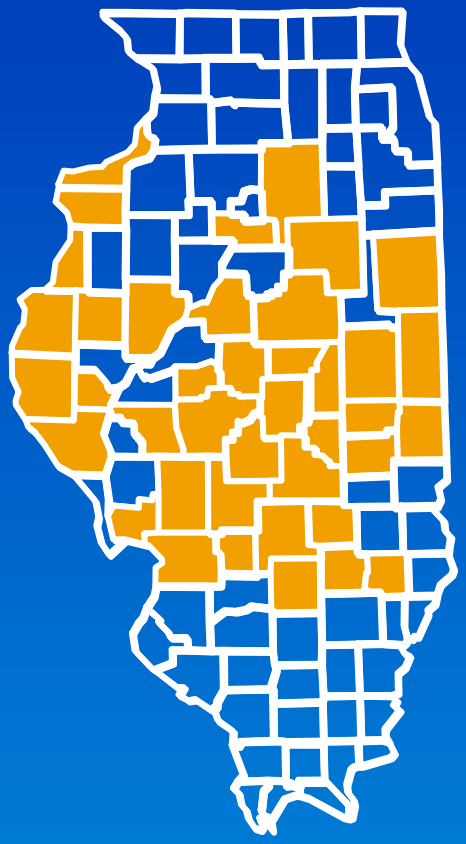
Range expansion of glyphosate-resistant waterhemp

Counties confirmed with GR waterhemp, based on grower submissions

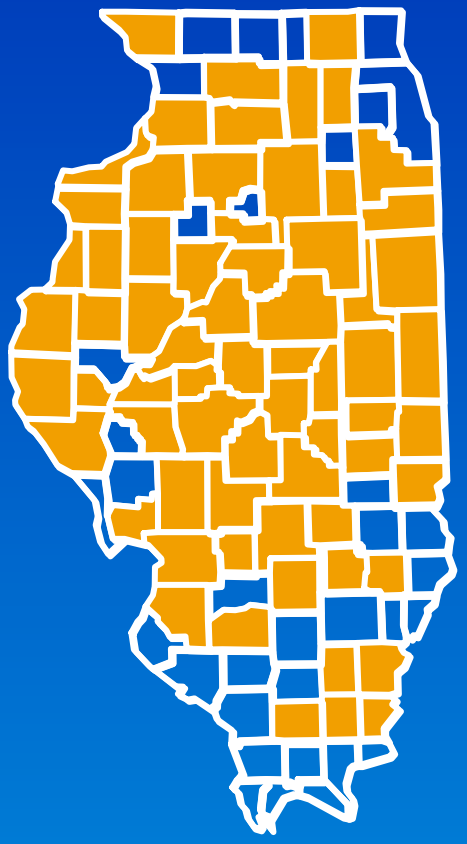
2010



2012



2014



Characterization of a novel five-way resistant population of waterhemp (*Amaranthus tuberculatus*)

Cody Evans, Patrick Tranel, Dean Riechers, Adam Davis, Doug Maxwell, Lisa Gonzini, and Aaron Hager

Department of Crop Sciences
University of Illinois

Population and Field History

- In 2012 a grower reported poor control of waterhemp following a foliar application of topramezone (Laudis, and HPPD inhibitor) in corn
- Annual rotation of conventional corn and soybean
- Herbicide use history included HPPD, PPO, ALS, and synthetic auxins
- Initial screenings of seedlings grown from field-collected seed suggested resistance to herbicides from five SOA might be present within population

Research Objective

Characterize the response of the waterhemp population (designated M6) to herbicides from five site-of-action groups

1. **Quantify response of population to foliar applications of mesotrione, atrazine, and 2,4-D in greenhouse dose-response experiments**

   confirmation of target-site based resistance to PPO and ALS inhibitors via molecular assays

2. **Characterize population's response to foliar-applied treatments under field conditions**

   experiments included herbicides from 7 SOA

Investigating Herbicide Resistance

- **Dose-response experiments**
  - Apply multiple rates (8–10) of candidate herbicide(s) to putative resistant population (10 or more replicates of each rate) and compare response to that of a known sensitive population(s)
    - confirms resistance
    - determines the magnitude of resistance
    - provides insight into the mechanism or resistance
      - high magnitude often related to modified site of action
      - low magnitude often related to enhanced metabolism

Investigating Herbicide Resistance

- **Dose-response experiments**
  - Generate response curves from which you can calculate the dose required to produce the same level of response in each population
    - often the dose required to reduce plant biomass by 50%
    - other parameters often reported include differences in plant emergence, enzyme activity
    - apply statistical tests to determine if differences are significant
      - resistance ratio describes the degree of resistance
      - GR_{50} resistant / GR_{50} susceptible = resistance ratio

Idealized Dose-Response Curves

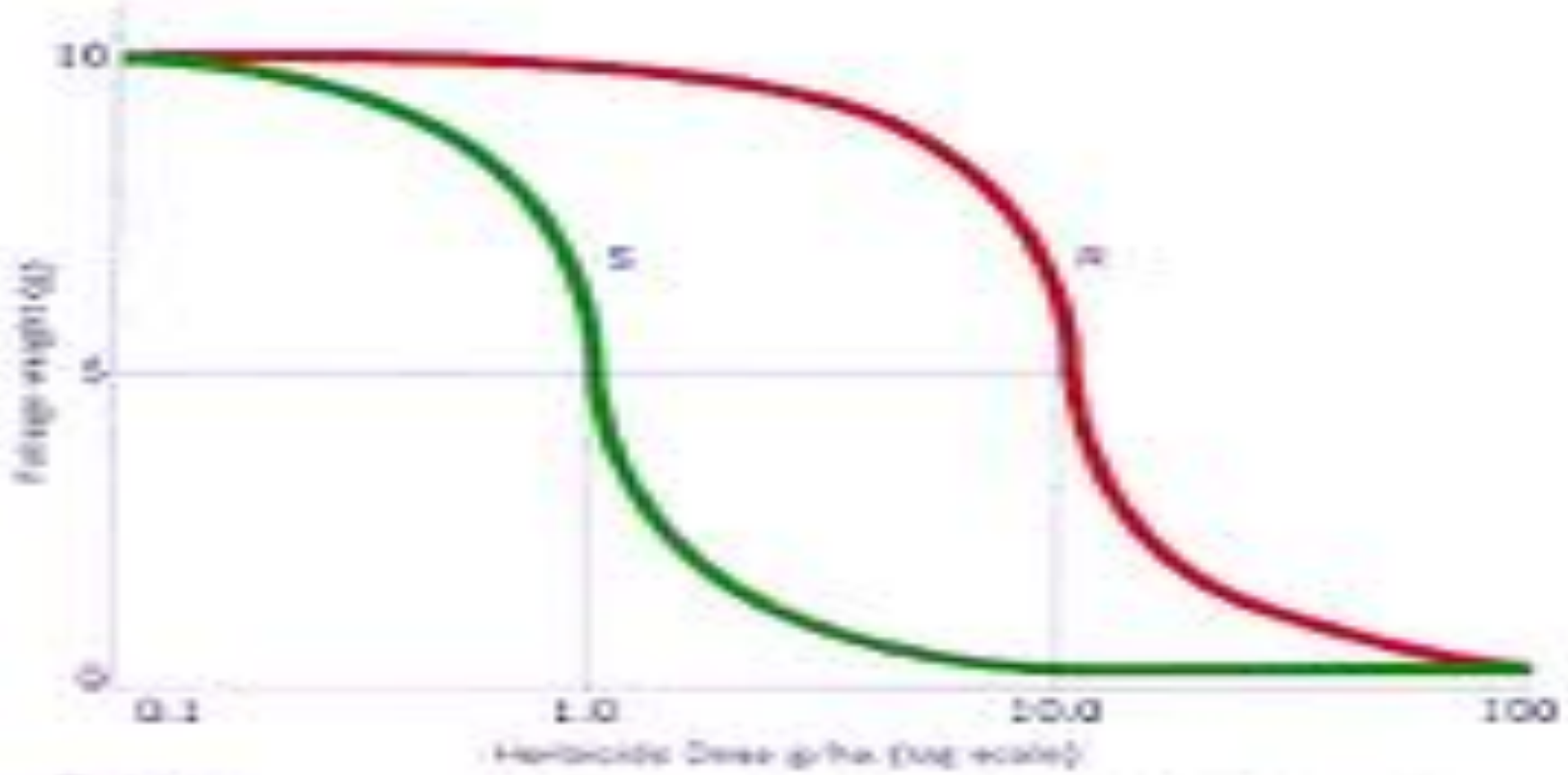


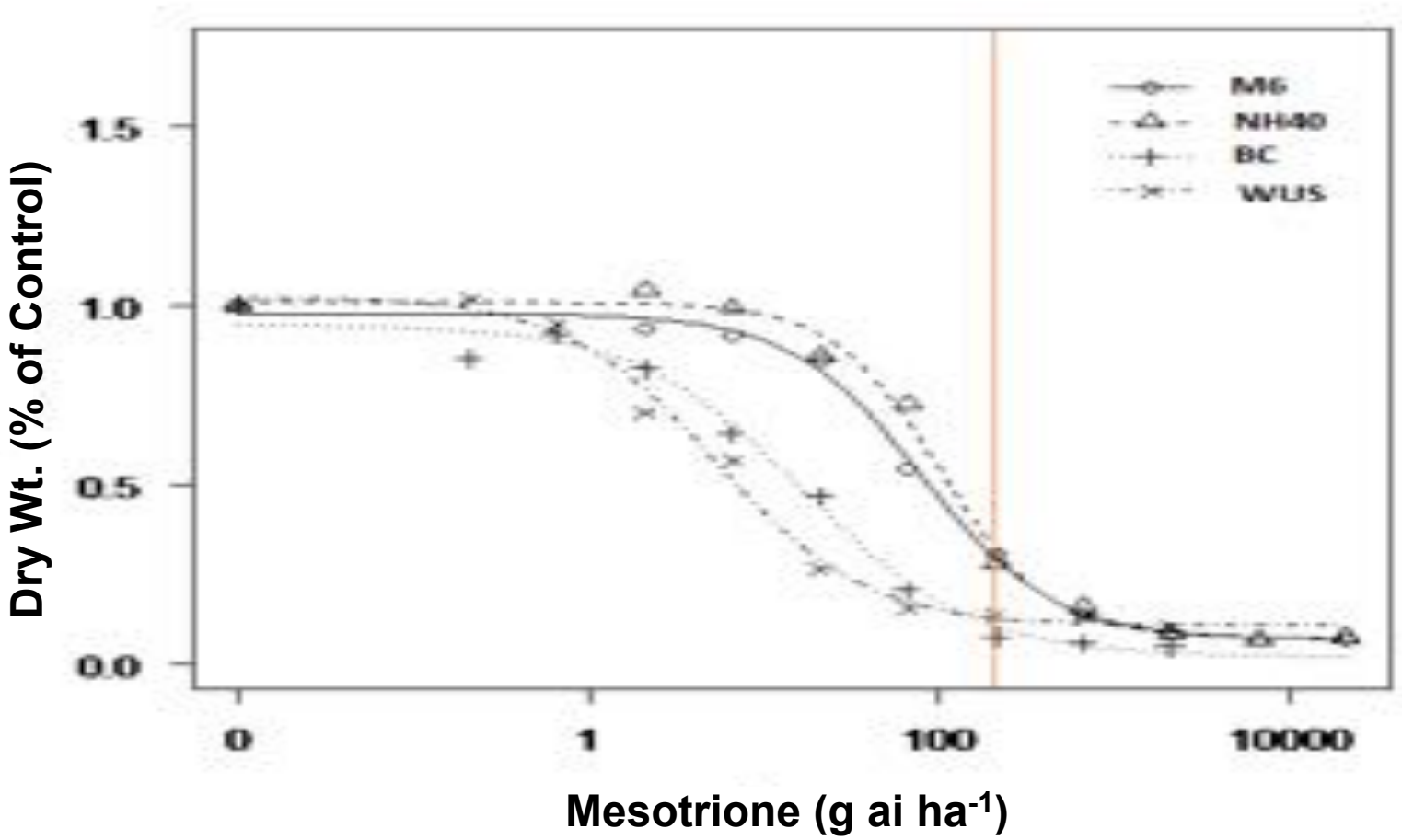
Figure 2.
Dose response curves for a Susceptible (S) and a Resistant (R) population

ED_{50} (susceptible) = 1.0 ED_{50} (resistant) = 10.0

Resistance Index = $\frac{ED_{50}\text{ (resistant)}}{ED_{50}\text{ (susceptible)}} = \frac{10}{1} = 10$

Source: HRAC 2014

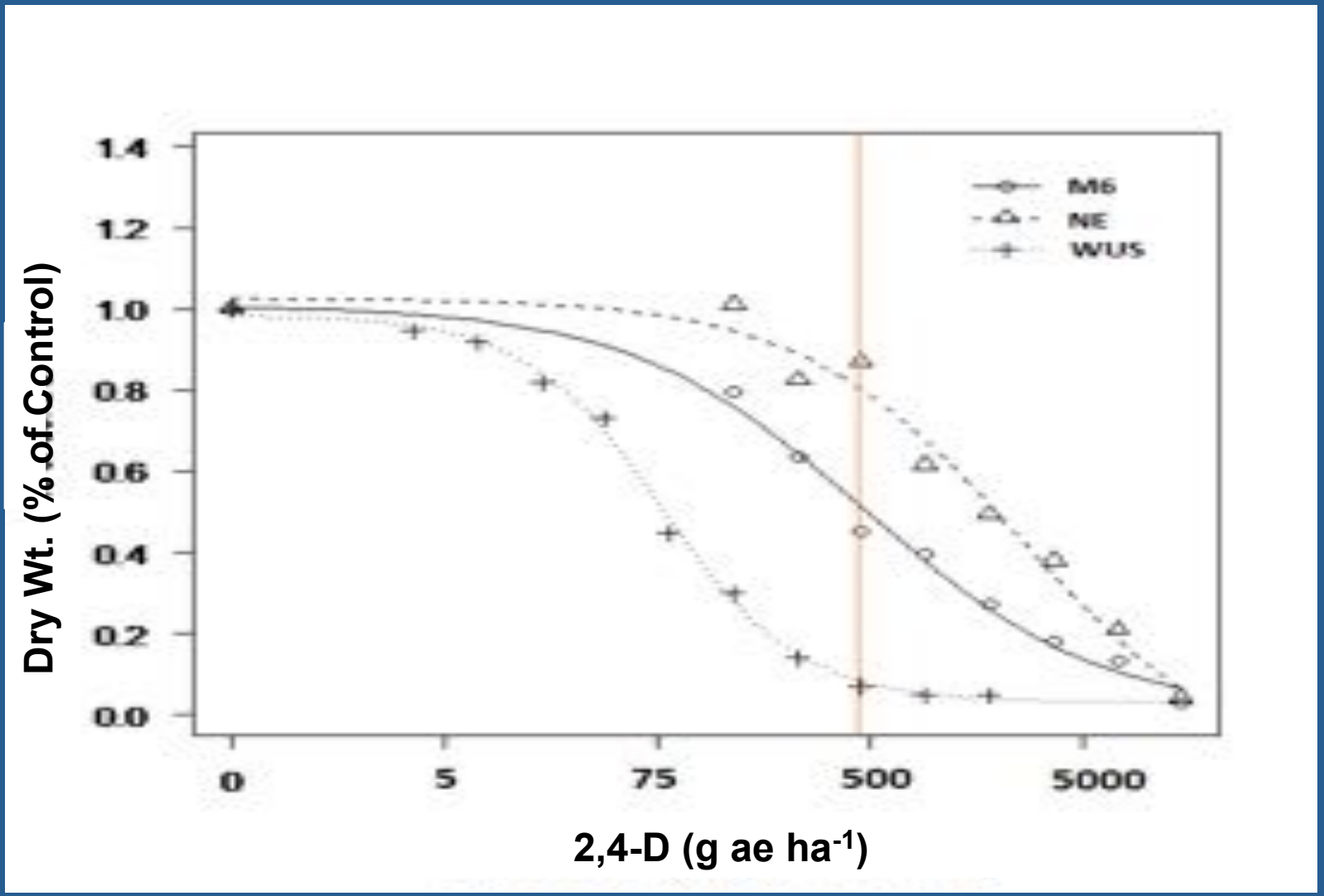
Results: HPPD Dose-Response



Conclusions: HPPD

- M6: 16-fold more resistant to mesotrione than the sensitive WUS
- M6: 5-fold more resistant to mesotrione than BC
- NH40: displays a slightly higher resistance to mesotrione (1.25-fold) than M6

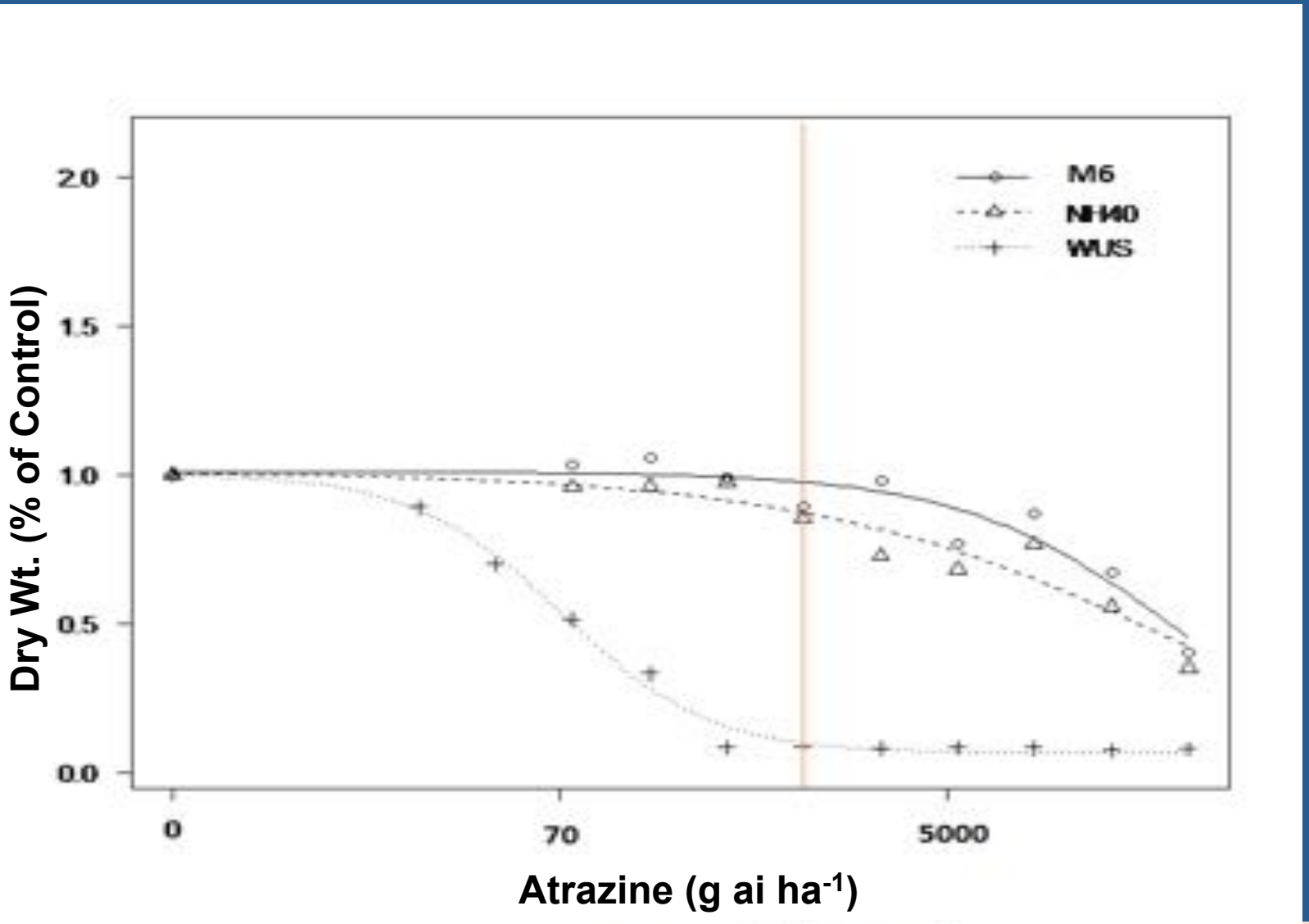
Results: PGR Dose-Response



Conclusions: PGR (2,4-D)

- M6: 30-fold more resistant to 2,4-D than the sensitive WUS
- NE: 4-fold more resistant than M6
- NE: longer history of exposure to PGR herbicides than M6?

Results: PSII Dose-Response



Conclusions: PSII (atrazine)

- M6: 253-fold more resistant to atrazine than the sensitive WUS
- M6: very high level of resistance to atrazine
  - suggests target site-based resistance?

Molecular Confirmation of Resistance: ALS and PPO inhibitors

Marker analysis revealed resistance to ALS- and PPO- inhibiting herbicides via well-characterized target site mutations (Riggins 2015)

Changes in amino acid position 574 of ALS (Bell et al. 2013)

Codon deletion (ΔG210) of PPX2L for PPO (Patzoldt et al. 2006)

High-level resistance to atrazine:

- Target site or non-target site based resistance?

Sequence of gene encoding PSII target protein indicated atrazine resistance is not via a target site mutation

Summary

- In greenhouse dose-response experiments compared with sensitive populations, M6 (CHR x CHR) displayed:
  - 16-fold resistance to mesotrione (HPPD)
  - 30-fold resistance to 2,4-D (PGR)
  - 253-fold resistance to atrazine (PSII)
- Resistance to ALS- and PPO-inhibiting herbicides confirmed by molecular markers
  - target-site resistance


Resistance has evolved to:
Group 2 (ALS)
Group 14 (PPO)
Group 27 (HPPD)
Group 5 (PS II)
Group 4 (2,4-D)
What are the best recommendations?

Best Management Practices for Herbicide Resistance

(Abridged from Norsworthy et al. 2012)

1) Understand biology of weeds present
2) Use diversified approach
3) Start/stay weed free
4) Plant weed free seed
5) Scout fields
6) Use multiple, effective MOAs
7) Apply label rate at recommended weed sizes
8) Use cultural practices to keep crop competitive
9) Use mechanical and biological practices
10) Prevent seed/propagule movement
11) Manage weed seed at/after harvest
12) Manage field borders

A landscape-scale approach to understand glyphosate-resistant waterhemp

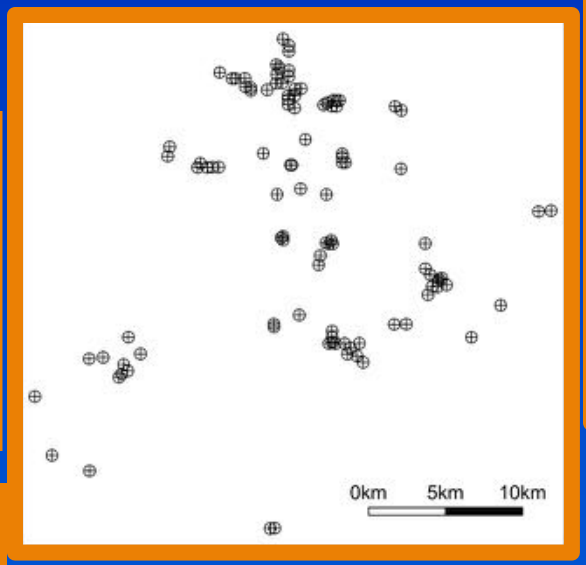
Jeff Evans
Patrick Tranel
Aaron Hager
Adam Davis

Managing the Evolution of Herbicide Resistance

JA Evans, PJ Tranel, AG Hager, B Schutte, C Wu, LA Chatham, AS Davis
University of Illinois and USDA-ARS

What factors contribute to the occurrence of herbicide-resistant weeds?

Address using an epidemiological approach.



- **Management**
  - Mean(MOA/yr)
  - Max(MOA/yr)
  - % years PRE used
  - % years Gly used
  - Mean(Gly apps./yr)
  - Herbicide turnover index
  - % corn years
  - Manure
- **Soil**
  - Concentrations of each of 12 nutrients
  - pH
  - C:N ratio
  - OM
  - Inorganic N
  - Bulk density
  - Sand %
  - Silt %
  - Clay %
  - Texture
  - Water holding capacity
- **Weeds**
  - Waterhemp seed bank density
  - 3 descriptions of waterhemp density/distribution in field
  - Presence of other *Amaranthus* weeds
  - Presence of grass weeds and each of 8 other broadleaf weeds
- **Landscape**
  - Elevation
  - Max slope
  - Dist. to forest
  - Dist. to stream
  - No. and area of bare patches
  - Presence and length of grass waterways
  - Field area
  - Presence of watercourse on margin
  - Perimeter length
  - Edge:interior ratio
  - Dist. to resistant pop.
  - % field border with trees

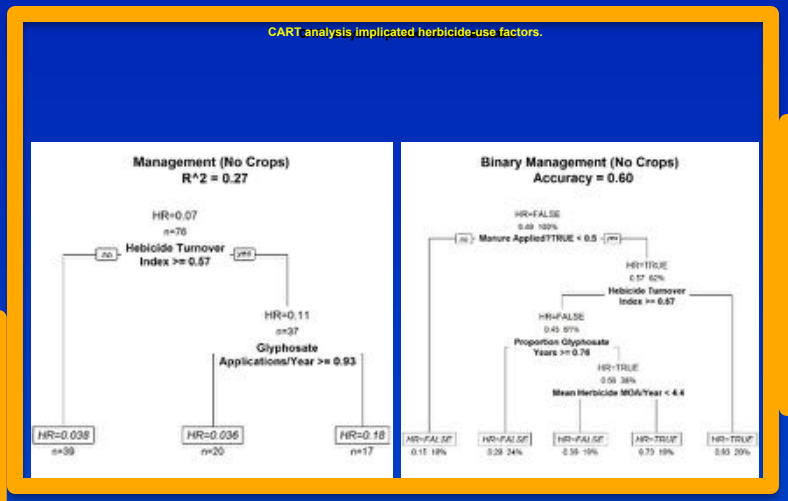
Test association of factors with occurrence of glyphosate-resistant *A. tuberculatus*.

Managing the Evolution of Herbicide Resistance

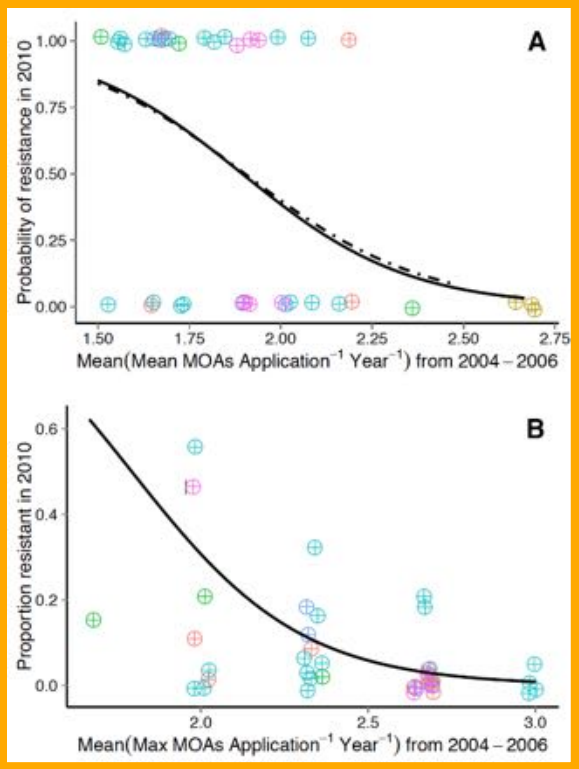
Major Findings

Dependent var.	Model	R^2
% Resistance	Management	0.27
	Soil	0.18
	Landscape	0.18
	Weeds	0.09
	M + S + L + W	0.26
	S + L + W	0.18
Presence/absence of resistance	Management	0.53
	Soil	0.29
	Landscape	0.44
	Weeds	0.38
	M + S + L + W	0.41
	S + L + W	0.29

1) Management factors are most important.



But… did management influence resistance, or did resistance influence management?



2) Herbicide mixing, and not herbicide rotation, mitigates resistance.

3) Proximity to neighbor's GR waterhemp was not a good predictor.

Funding: USDA AFRI, Monsanto Co., ISA

Tillage, Cropping System, and Soil Depth Effects on Common Waterhemp (*Amaranthus rudis*) Seed-Bank Persistence

Lawrence E. Steckel, Christy L. Sprague, Edward W. Stoller, Loyd M. Wax, and F. William Simmons

Weed Science 55(3):235-239. 2007

A field experiment was conducted in Urbana, IL, from 1997 to 2000 to evaluate the effect that crop tillage, and soil depth have on common waterhemp seed-bank persistence. A heavy field infestation of common waterhemp (approximately 410 plants m^{-2}) was allowed to set seed in 1996 and was not allowed to go to seed after 1996. In 1997, 1998, 1999, and 2000, the percentage of the original common waterhemp seed bank that remained was 39, 28, 10, and 0.004%, respectively, averaged over tillage treatments. Initially, germination and emergence of common waterhemp was greater in no-till systems. Consequently, the number of remaining seeds was greater in the till treatments compared with no-till in the top 0 to 6 cm of the soil profile. This reduction was in part explained by the higher germination and emergence of common waterhemp in the no-tillage treatments. Tillage increased the seed-bank persistence of common waterhemp in the top 0 to 2 cm of the soil profile in 1997 and the top 0 to 6 cm in 1998. Crop had no effect on common waterhemp emergence or seed-bank persistence

Summary

- Herbicide resistance is a very real challenge that will continue to expand across Illinois
  - multiple resistance will become the norm
- The days of "simplified" weed control are over
  - change from weed control to weed management
- Those who understand weed biology, herbicide physiology, etc. will be increasingly valuable to their customers
  - SOA, MOA, soil factors, environmental factors, etc.


Best wishes for a safe and
prosperous 2016