Spread of Herbicide Resistance in Row Crops and Thoughts on the Potential for Future Success of Integrated Weed Management Practices

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There is no doubt, there are grand challenges that face U.S. agriculture.

- Food
- Feed
- Fuel
- Fiber

How to Feed Three New Chinas in the Next 40 Years

M. Sutherland 11/4/2010

- Monsanto CEO Hugh Grant spoke at the prestigious 2010 Business Social Responsibility Conference.
- To feed our growing world, farmers will need to adopt modern agricultural practices, such as

"Between the time you got up this morning and the time you'll go to bed, there will be 210,000 new people on the planet," Monsanto CEO Hugh Grant said Wednesday. "By 2050, that's three new Chinas."

Related News

- Monsanto and Illumina Reach Key Milestone in Cotton Genome Sequencing
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- Monsanto Company Recognized as No. 2 Employer by Science Magazine
- Monsanto Makes "Working Mother 100 Best Companies" List
- Recent Vendômois, Séralini GMO article contains no new information

Most Popular

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2. A Sustainable Twist on Growing Tomatoes
3. July 30 St. Louis Federal Court Ruling
4. Hugh Grant Featured Speaker at Influential Aspen Ideas Festival
5. Monsanto's Refuge-in-the-Bag Concept Explained
6. Monsanto Vegetable Seeds: Smart Snacks, Smart Choices
7. Channel Bio Announces New Premier Seed Brand

Media Releases

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14.10.10 Third Quarter 2010 Sales

22.07.10 2010 Half Year Results

More news: Media Releases

Features

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"The mounting water crisis and how agriculture can help provide the solution" - read Syngenta's take on it.

→More

Rice production in Vietnam

During a visit to Vietnam, CEO Mike Mack called for collaborations to increase rice productivity and advance rural economies.

→More

Rural Economies: The basis of food security

Farmers carry the weight of feeding the world. Read how Syngenta supports famers through better solutions tailored to their needs.

→More

Share price (delayed 20 mins)

11/09/2010 17:31 CET

Zurich:	SYNN	286.40	↑
New York:	SYT	58.74	↑

Details

Featured topics

Photo Biodiversity Jobs Awards Vision 2050 Annual Report Water AGM FAQ 2010 Q3 Technology

Not without ADVANCING Integrated Weed Management (IWM)

Why advance IWM?

“U.S. farmers are heading for a crisis”

Dr. Stephen Powles, University of Australia, Crawley.

Science **VOL 341, Page 1329**

20 September 2013

www.sciencemag.org

One of Australia's largest herbicide-resistant weed problem is Rigid ryegrass (*Lolium rigidum*)

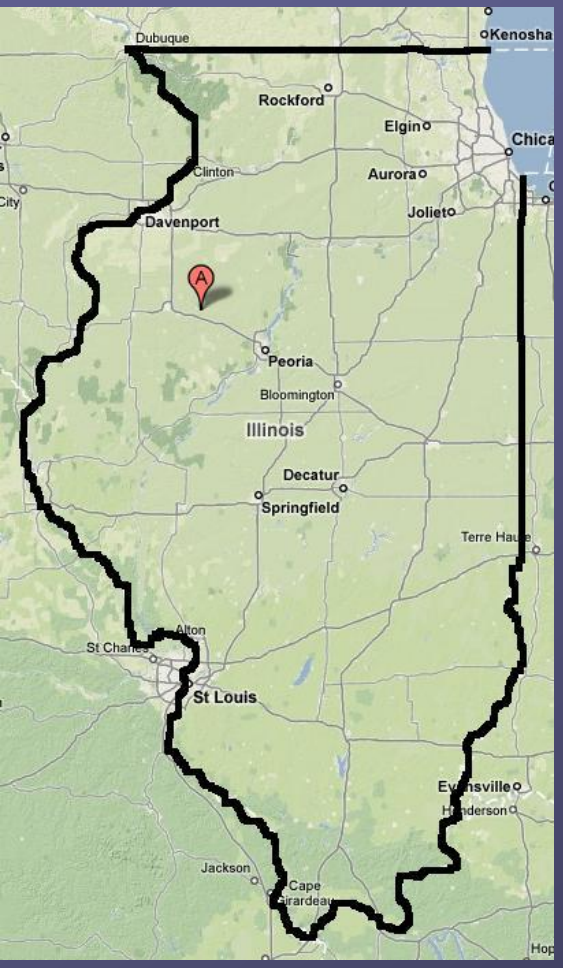
- Italian (annual) ryegrass (*Lolium multiflorum*)
  - 41 unique herbicide resistance cases reported Worldwide across 10 countries (www.weedscience.com)

Southern WI, March 2012

Kate loves the ‘farm’

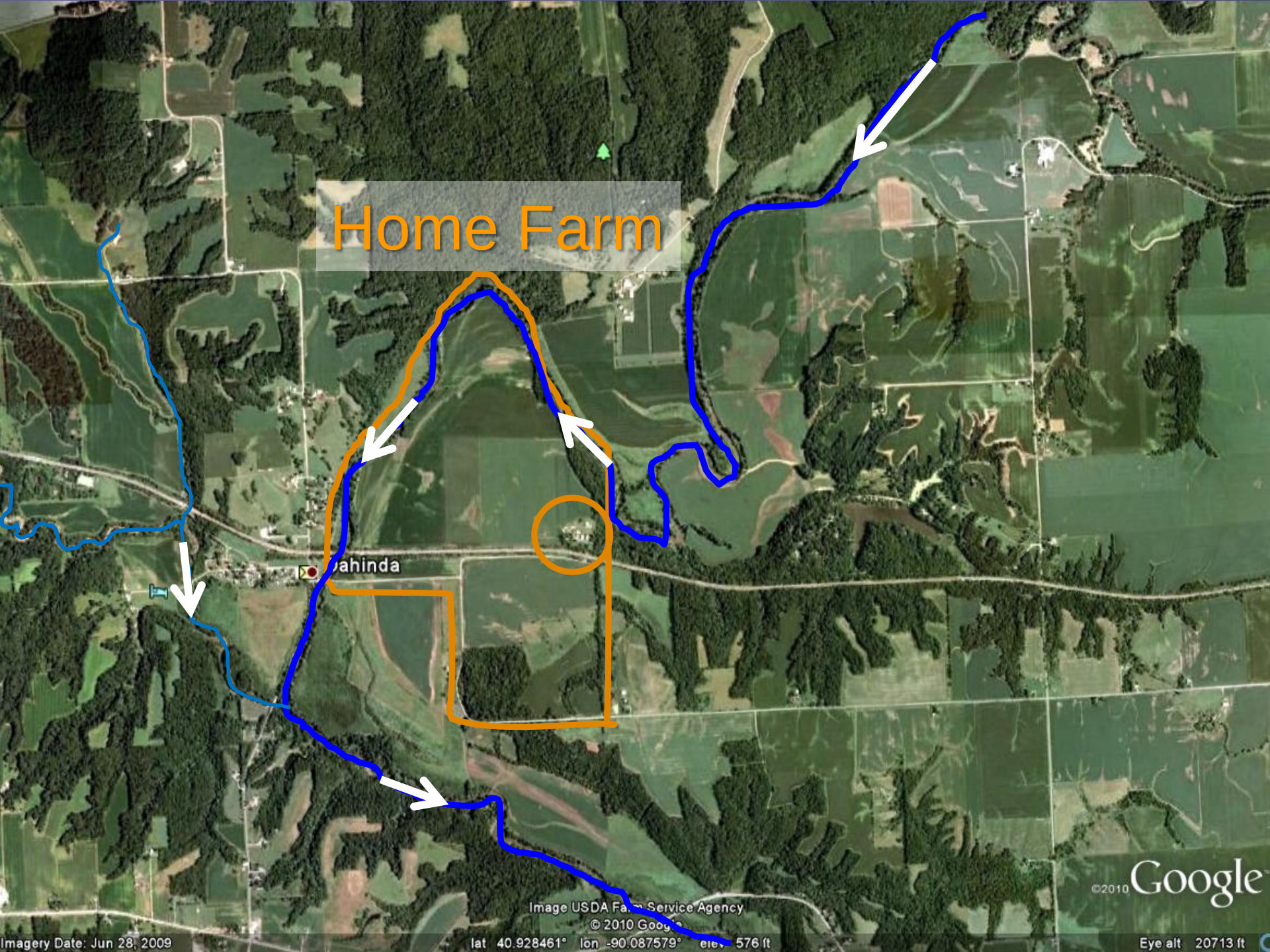
Abby loves Nature

Where I come from…



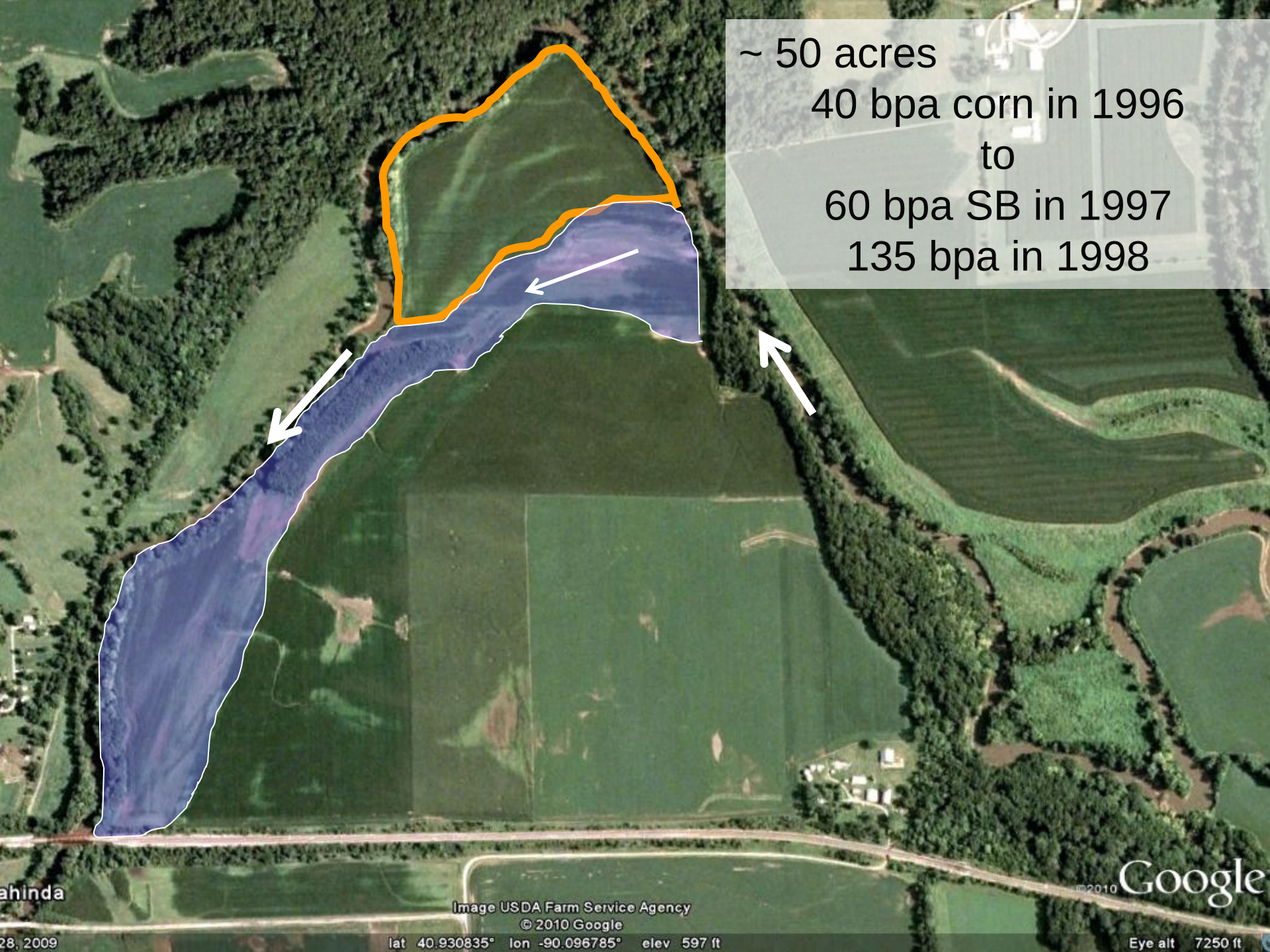
- Grew up on diversified grain and swine farm in Knox Co. IL
- College or Farm? ►College
- Had a summer internship at a research farm following my freshman year ►RR soybeans?

  ►Still searching…..and re-searching….


Home Farm
Image USDA Farm Service Agency
© 2010 Google
Imagery Date: Jun 28, 2009
lat 40.928461° lon -90.087579° elev 576 ft
Eye alt 20713 ft
©2010 Google

Home farm, Knox co. Illinois

We do farm some ‘hills’ in Illinois


~ 50 acres
40 bpa corn in 1996
to
60 bpa SB in 1997
135 bpa in 1998
ahinda
Image USDA Farm Service Agency
© 2010 Google
28, 2009
lat 40.930835° lon -90.096785° elev 597 ft
Eye alt 7250 ft
©2010 Google

No Reason For Residuals In Roundup Ready® Soybeans

Roundup Ready® SOYBEANS

Extensive research has shown that the best weed control and value is achieved when Roundup Ultra™ herbicide is used alone in Roundup Ready® soybeans. Soil residual herbicides add costs, offer no significant weed control benefit, and *create the potential for greater crop injury, delayed canopy closure and carryover.*

Weed Control Comparisons

All across the major soybean growing areas of the Midwest, the consolidated data from 1993 through 1997 confirms the outstanding weed control provided by Roundup Ultra alone in Roundup Ready soybeans.

Narrow Rows (Less than 20")

Weed Species	% Weed Control		% Weed Control	
	Roundup Ultra	Prowl®/Pursuit®	Roundup Ultra	DNA/Roundup Ultra
Giant Foxtail	95	92	96	96
Crabgrass	96	89	95	94
Fall Panicum	93	70	92	92
Velvetleaf	92	89	96	95
Lambsquarters	94	76	91	93
Pigweed	92	86	94	92
Waterhemp	95	77	95	94
Cocklebur	94	90	95	93
Giant Ragweed	87	72	91	89
Morningglory	85	77	83	81
Penn. Smartweed	92	90	93	89

Notes: 1) Clean start with Roundup Ultra at labeled rates – or tillage
2) Rates: Roundup Ultra – 32 oz/A; Commercial Standards – Labeled Rates
3) All tillages combined

1997

Change in Herbicide Diversity Over Time

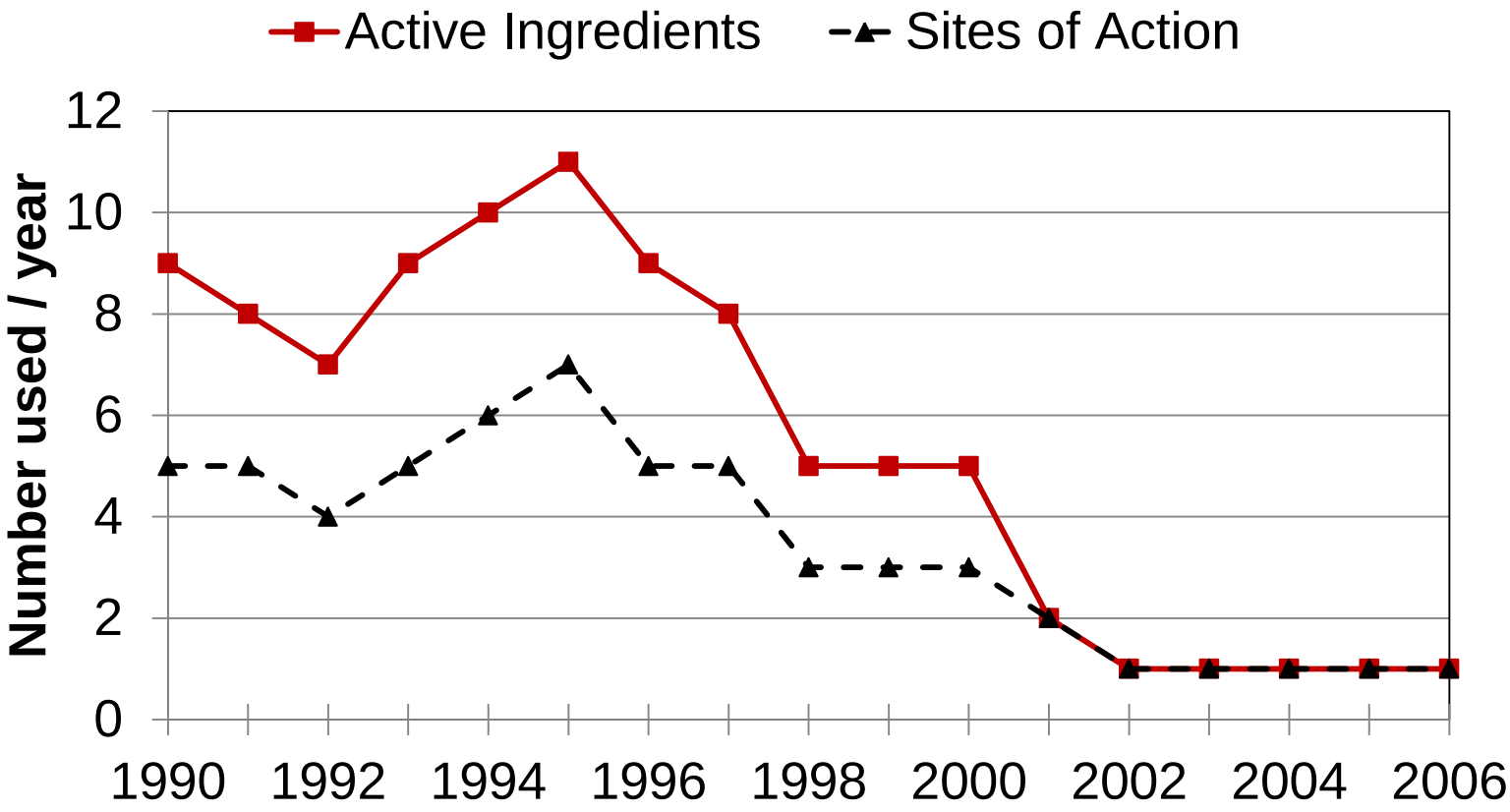
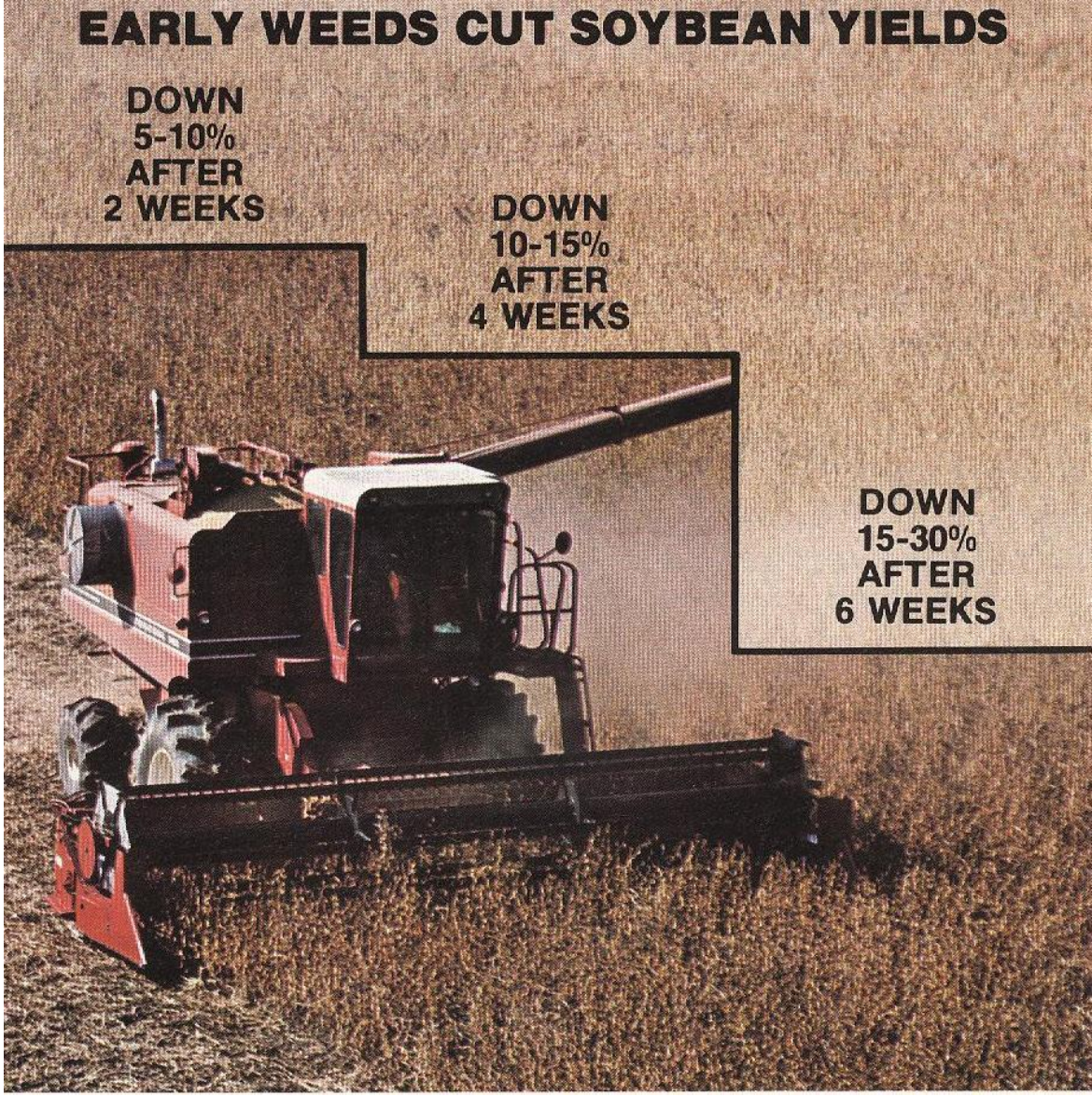


Figure 1. Number of different herbicide active ingredients and herbicide sites of action used on at least 10% of U.S. soybean hectares from 1990 to 2006. Data adapted from USDA-NASS (2008)

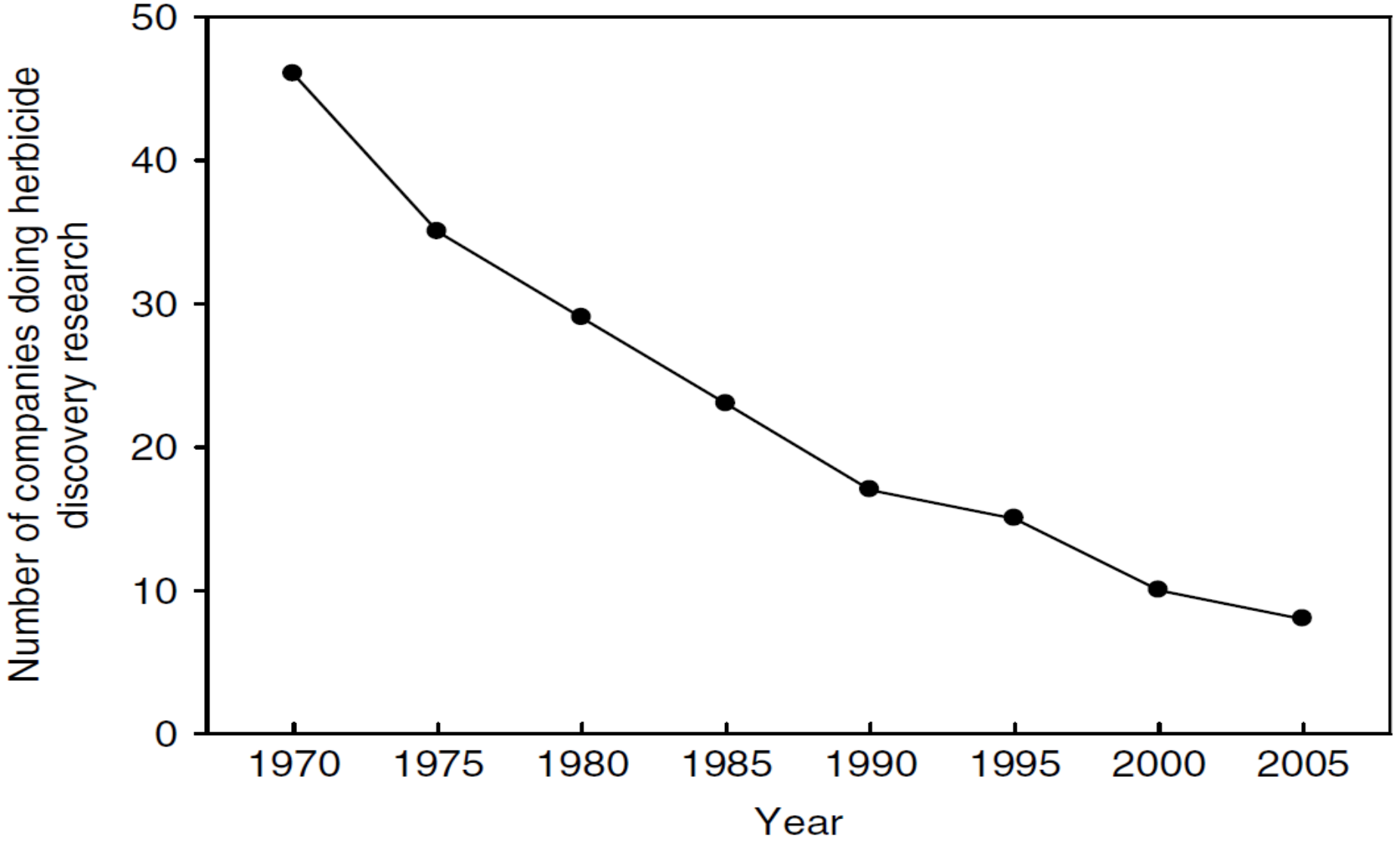
Courtesy of Ryan DeWerff

So what happened?

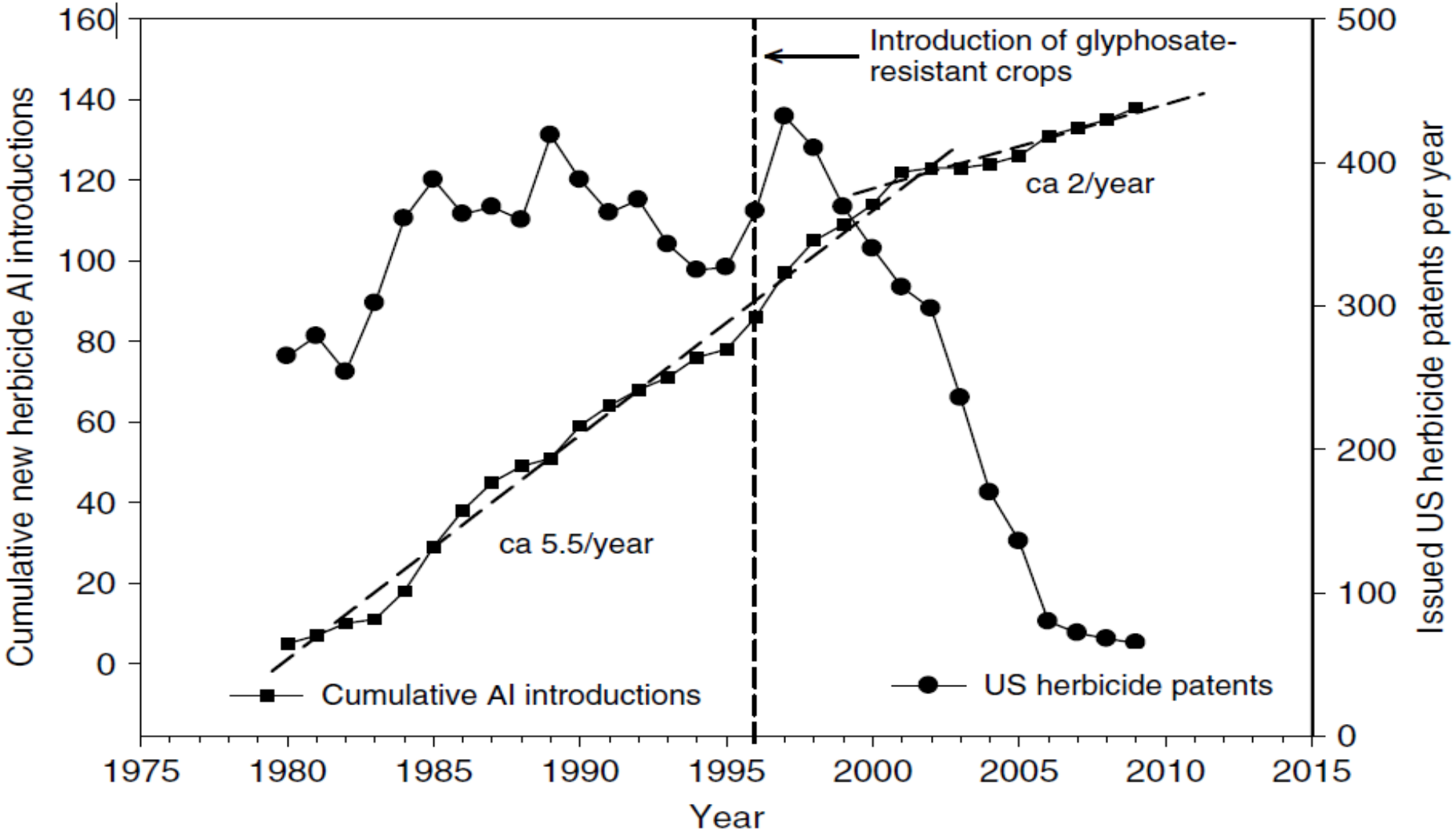
- Reduction in residual herbicide use
- Delayed postemergence herbicide applications
- Glyphosate-resistant weeds…..



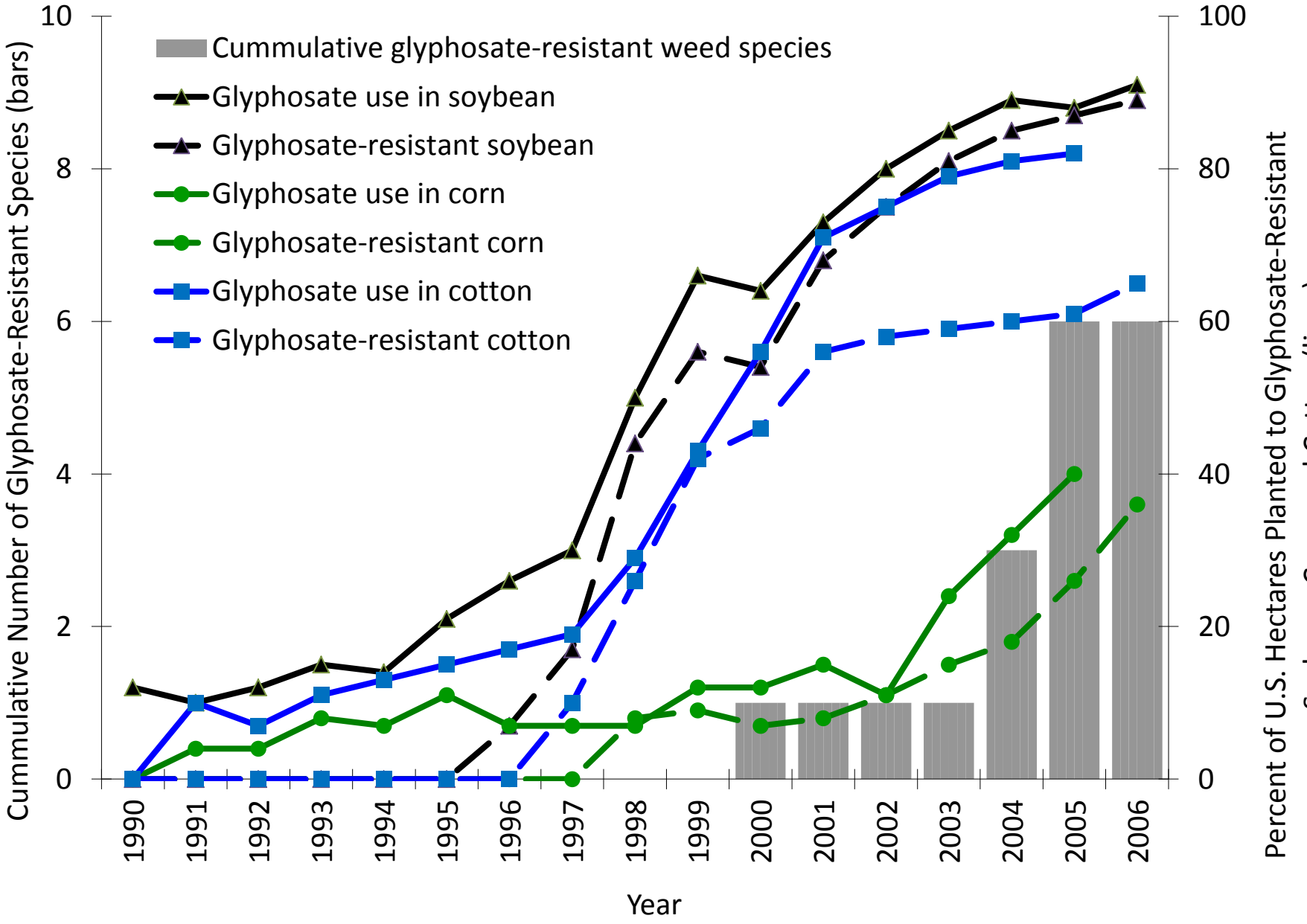
Preplant residual herbicide advertisement in the **1980** (Volume 12) publication of *Weeds Today*



Stephen O Duke; Pest Manag Sci. 2011, DOI 10.1002/ps.2333



Stephen O Duke; Pest Manag Sci. 2011, DOI 10.1002/ps.2333



Johnson et al. 2009. European Journal of Agronomy

and now…2013

ROUNDUP READY PLUS™
WEED MANAGEMENT SOLUTIONS

Roundup Ready® Soybean Recommendations and Incentives

PLAINS, MIDWEST, NORTHEAST

To fight tough weeds, use Roundup® brand agricultural herbicides, the only glyphosate-containing herbicides for use on Monsanto technology acres. Choose from the following eligible brands of herbicides in Genuity® Roundup Ready 2 Yield® Soybeans or Roundup Ready® Soybeans to qualify for incentives.

Roundup Ready PLUS™ Soybean Herbicides | Matching Rates and Incentives Per Acre

WITHOUT GLYPHOSATE-RESISTANT WEEDS or moderate weed pressure

	WARRANT 3.0 pt.	VALOR 2.0 oz. / VALOR XLT 3.0 oz. / GANGSTER 2.4 oz.	COBRA 10.0 oz. / PHOENIX 10.0 oz.	AUTHORITY 5.0 oz. / AUTHORITY 3.2 oz. / AUTHORITY 11 oz. / AUTHORITY XL 4.0 oz.
Roundup PowerMAX	$2.50	$3.00	$3.00	$1.00
Roundup WeatherMAX	$3.00	$3.00	$3.00	$1.50
Matching rates*	22 oz.	22 oz.	22 oz.	22 oz.

- Use 2.0 qt. of INTRRO® along with 22 oz. of Roundup PowerMAX® and receive a $1.00 per acre incentive, or receive a $1.50 per acre incentive when used with 22 oz. of Roundup WeatherMAX®.

Evolving yield robbers….

Davis, V.M.

Horseweed (*Conyza canadensis*)

Davis, V.M.

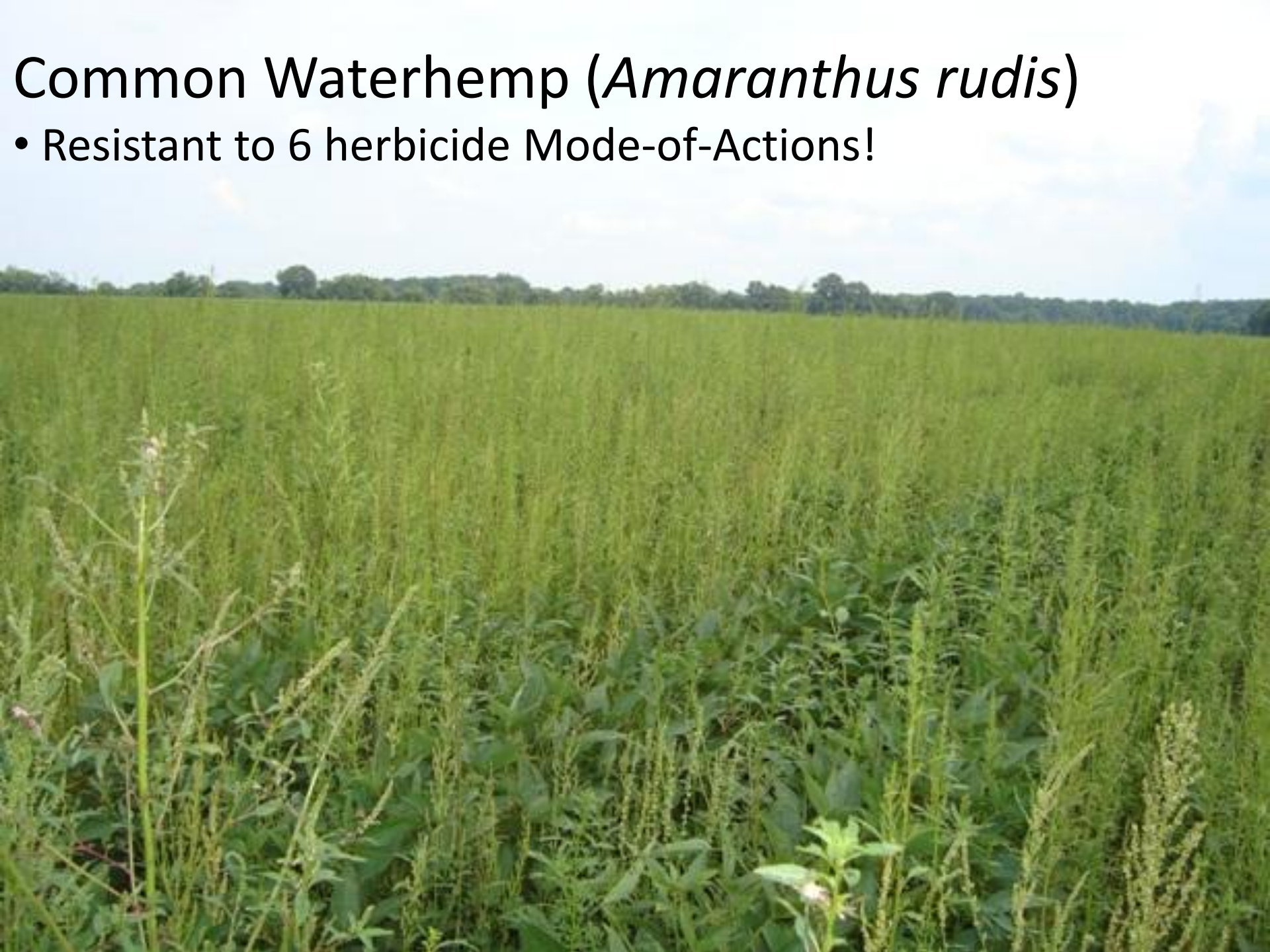

Giant Ragweed
(*Ambrosia trifida*)
Davis, V.M.

Davis, V.M.

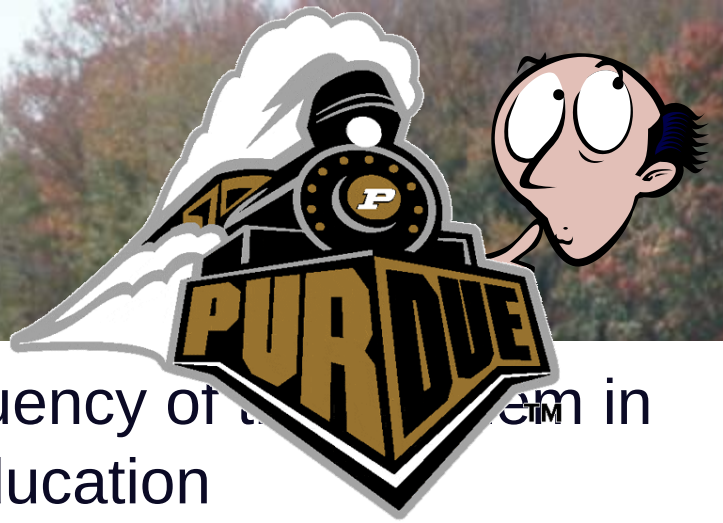

Giant Ragweed
(*Ambrosia trifida*)

Common Waterhemp (*Amaranthus rudis*)

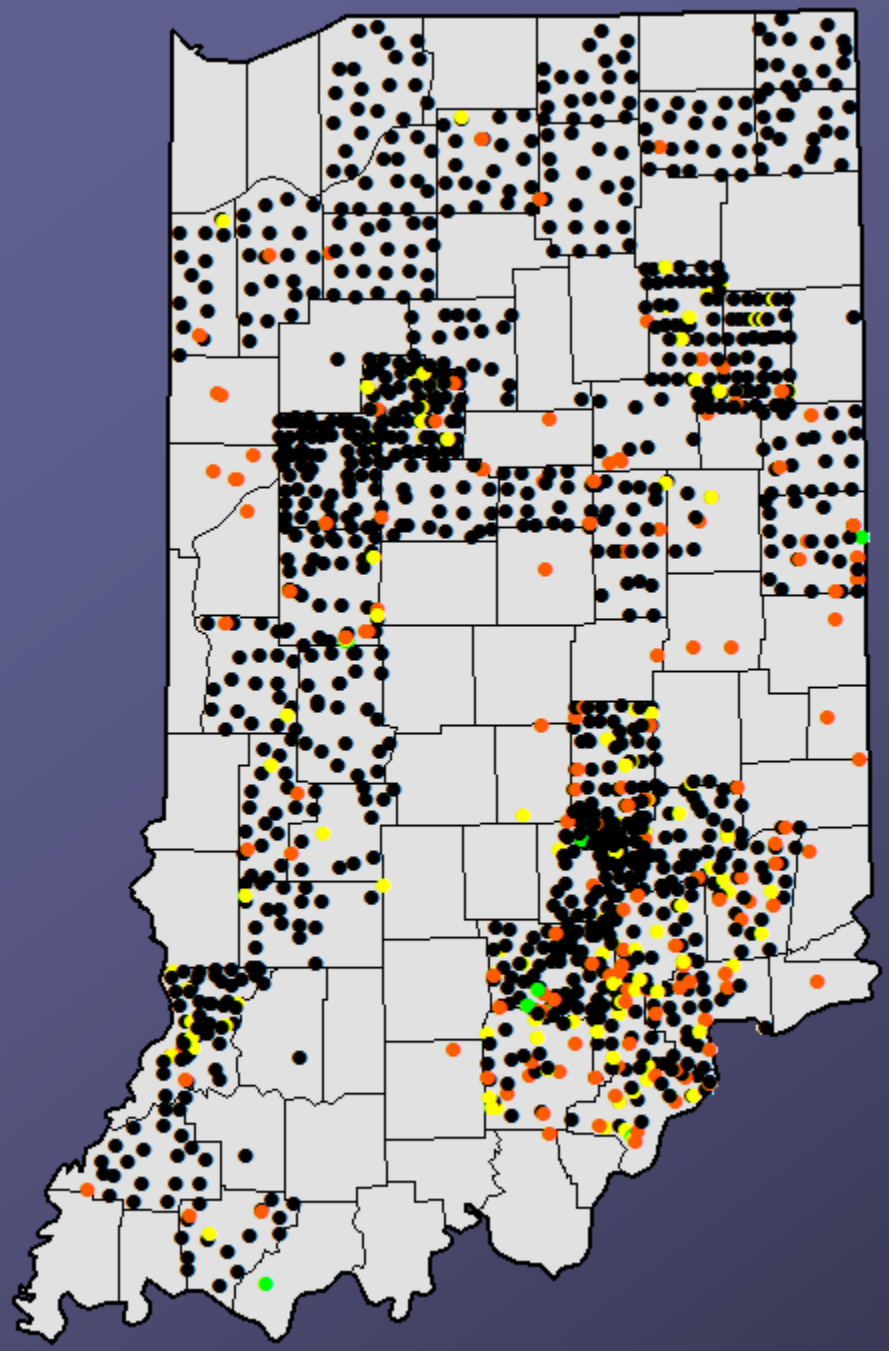
- Resistant to 6 herbicide Mode-of-Actions!



2003, we have a problem



- What is the distribution and frequency of t[illegible]em in Indiana? Provide timely farmer education
- Can resistance be predicted in fields with poor control?
- Are there variable levels of glyphosate resistance?
- What are the growth characteristics and fecundity of this “winter annual weed”?
- How do the population dynamics of glyphosate-resistant horseweed change under various crop management practices?

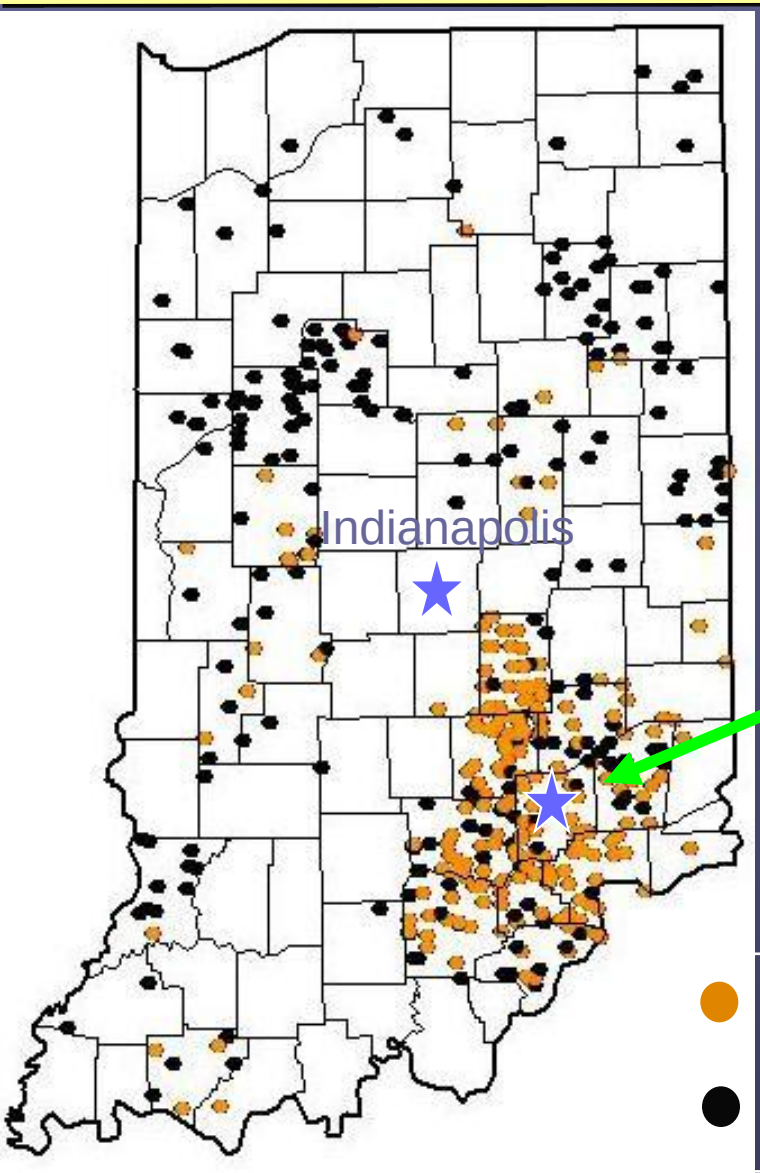


2003 - 2005 Fields Surveyed

Source	%	#
GPS Random	80	1085
High Populations	11	145
Non-cropped area	8	104
Submitted	1	10
Total		1347

Davis et al. 2008. Weed Technol. 22:331-338.

Glyphosate-Resistant (GR) Horseweed



- Found in 29 / 92 counties in Indiana
- In Indiana
  - GR biotypes are most frequently found in the southeastern region
  - Southeastern Purdue Agriculture Center (SEPAC) is centrally located

PURDUE UNIVERSITY

Welcome to the Home of

Horseweed

(*Conyza canadensis*)

www.btny.purdue.edu/weedscience

PURDUE WEED SCIENCE

Funding for our horseweed research and extension efforts has been provided by:
Indiana Soybean Board
Purdue University Ag Research Programs
Monsanto
Syngenta
Dow Agrosciences
BASF
Valent
Dupont
USDA Critical and Emerging Pest Program

Other Publications

Late-Season Weed Escapes in Indiana Soybean Fields - Crop Management Brief

Crop Rotation and Tillage System Influence Late-Season Incidence of - Giant Ragweed and Horseweed in Indiana Soybean - Crop Management Brief

Biology and Management of Horseweed - Extension Publication # 323

Newsletter Articles

Glyphosate - Tolerant/Resistant Marestail

Horseweed (*Conyza canadensis*) is more commonly known as *marestail* to most Indiana farmers. Horseweed is native to the United States, but it has recently become much more problematic to control in Roundup Ready soybean production. Horseweed is well adapted to no-till crop production. It has evolved resistance to several different herbicides including glyphosate products (www.weedscience.com). Horseweed was the first broadleaf weed documented to evolve resistance to glyphosate (Vangessel 2001) in the United States. Since this initial report, glyphosate resistance has been reported in several other states including Indiana.

In Indiana, the first case of glyphosate resistance was confirmed in Jackson County in 2002. With 90% of the soybean acres planted to Roundup Ready varieties and 60% of soybeans grown utilizing no-till practices in Indiana, it is a high priority for Purdue Weed Science Extension to help Indiana soybean producers find the best alternatives to keep horseweed from becoming an even bigger threat to agriculture production and environmental quality.

The objective of this website is to provide information on the distribution, biology, and management of glyphosate-resistant horseweed in Indiana and selected other states. This site contains maps county showing locations of glyphosate-resistant horseweed, and our latest research results on the biology and management of this weed. If you have any questions about this site or if you have information and links you would like added to this site, please contact Vince Davis, Valerie Mock, Bill Johnson, or Glenn Nice.

Distribution of Glyphosate-Resistant Horseweed in Indiana and Ohio

An in-field survey to locate glyphosate-resistant horseweed populations in Indiana was conducted in September and October of 2003, 2004, and 2005. The survey was conducted utilizing GPS and GIS technologies to randomly locate sample fields. Additional information can be accessed through links provided below. To learn even more about this survey please see our recent manuscript in Weed Technology: **Davis, V. M., K. D. Gibson, and W. G. Johnson*. 2008. A Field Survey to Determine Distribution and Frequency of Glyphosate-Resistant Horseweed (*Conyza canadensis*) in Indiana. Weed Technol. 22:331-338.**

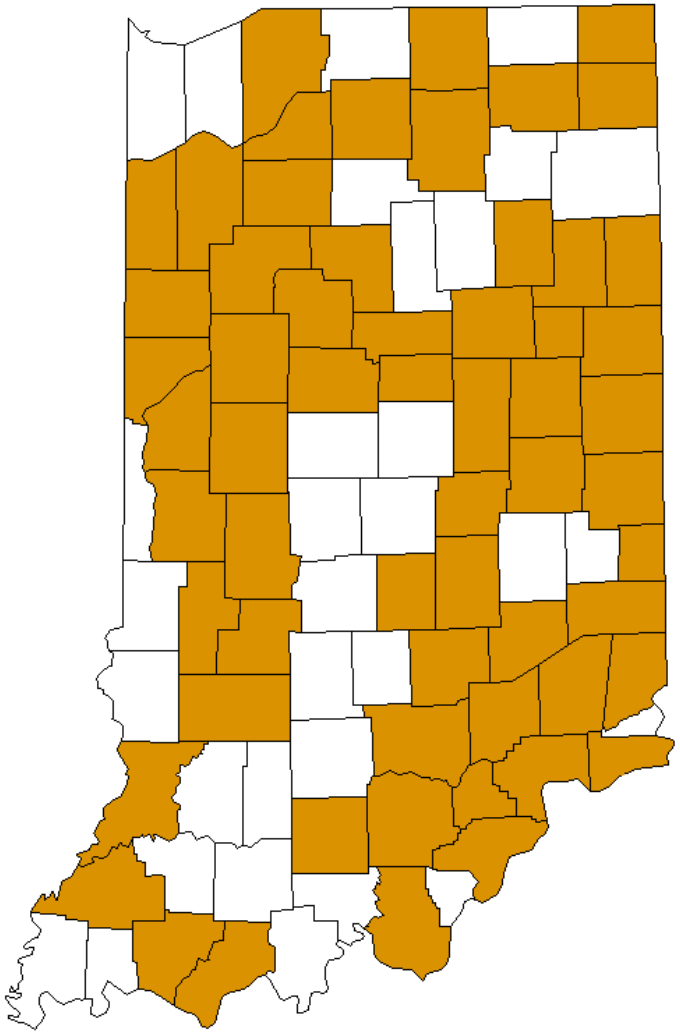
Sites Surveyed - this page displays the intensity and location of Indiana counties that have been surveyed for horseweed escapes in 2003 through 2005.

IN Screening Results - this page is an interactive map of IN that allows users to find detailed information regarding the location of glyphosate resistant samples collected in the fall of 2003 through 2005.

IN and OH Screening Results - this page has a two state map showing counties with confirmed glyphosate resistant horseweed in both IN and OH.

PURDUE WEED SCIENCE

Indiana County Information

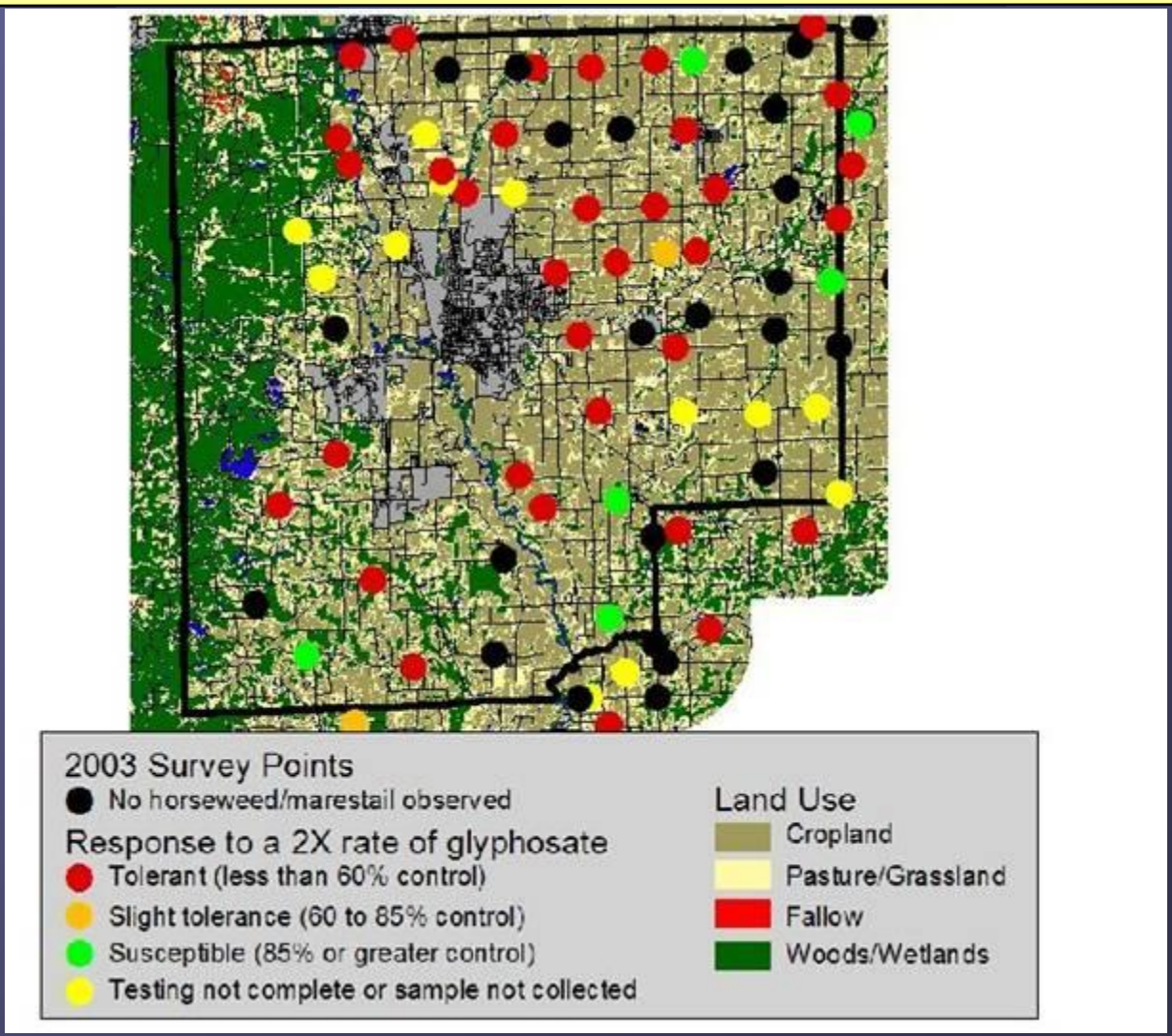


Screening results from 2003 through 2005 horseweed collections are available from counties colored in gold by clicking on the county map or county name.

County Name:

Adams	Lawrence
Allen	Madison
Bartholomew	Marion
Benton	Marshall
Blackford	Martin
Boone	Miami
Brown	Monroe
Carroll	Montgomery
Cass	Morgan
Clark	Newton
Clay	Noble
Clinton	Ohio
Crawford	Orange
Daviess	Owen
Dearborn	Parke
Decatur	Perry
DeKalb	Pike
Delaware	Porter
Dubois	Posey
Elkhart	Pulaski
Fayette	Putnam
Floyd	Randolph
Fountain	Ripley
Franklin	Rush
Fulton	Scott
Gibson	Shelby
Grant	Spencer
Greene	St. Joseph
Hamilton	Starke
Hancock	Steuben
Harrison	Sullivan
Hendricks	Switzerland
Henry	Tippecanoe
Howard	Tipton
Huntington	Union
Jackson	Vanderburgh
Jasper	Vermillion
Jay	Vigo
Jefferson	Wabash
Jennings	Warren
Johnson	Warrick
Knox	Washington

County Resistance Map
Bartholomew County



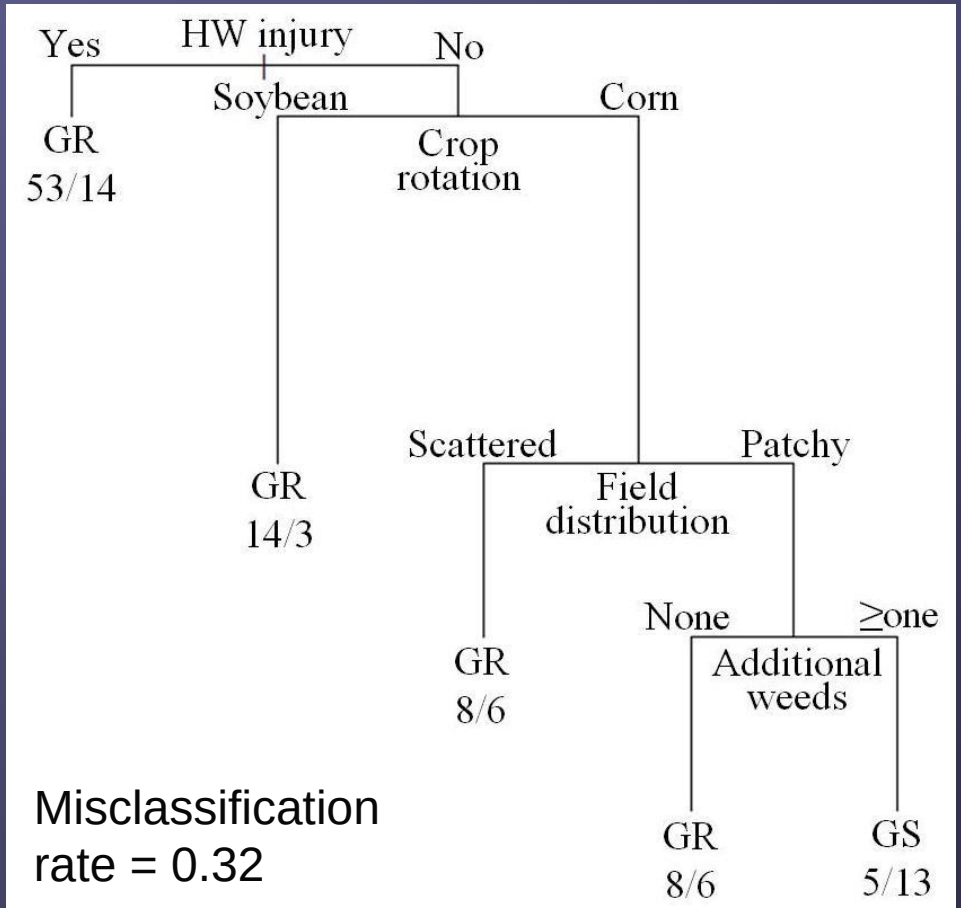
http://www.btny.purdue.edu/weedscience/marestail/counties/Bartholomew03.pdf

Are these resistant?

- Can resistance be predicted in fields with poor control?

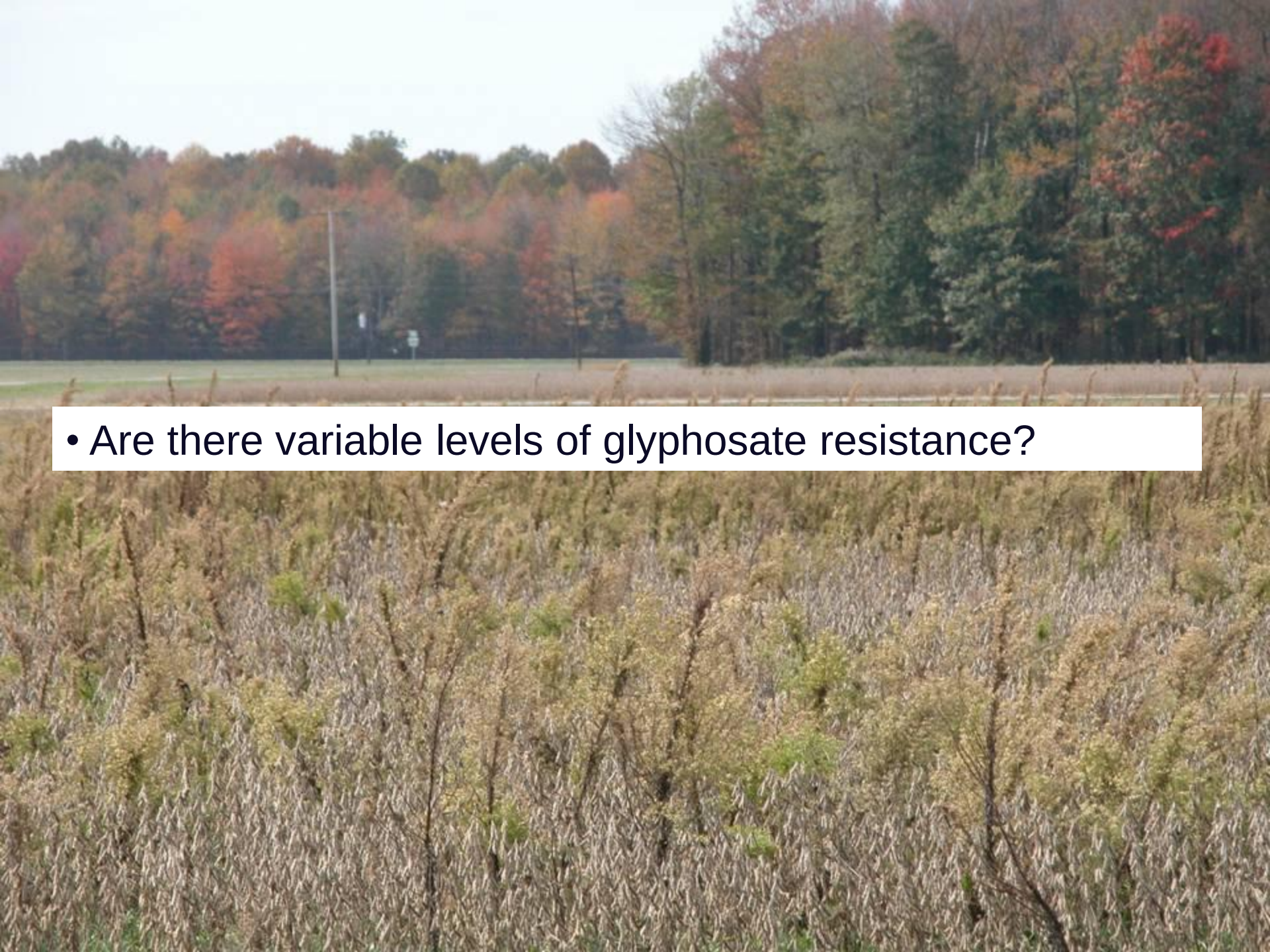
Classification Tree Analysis

- For glyphosate-resistant horseweed, resistance prediction factors



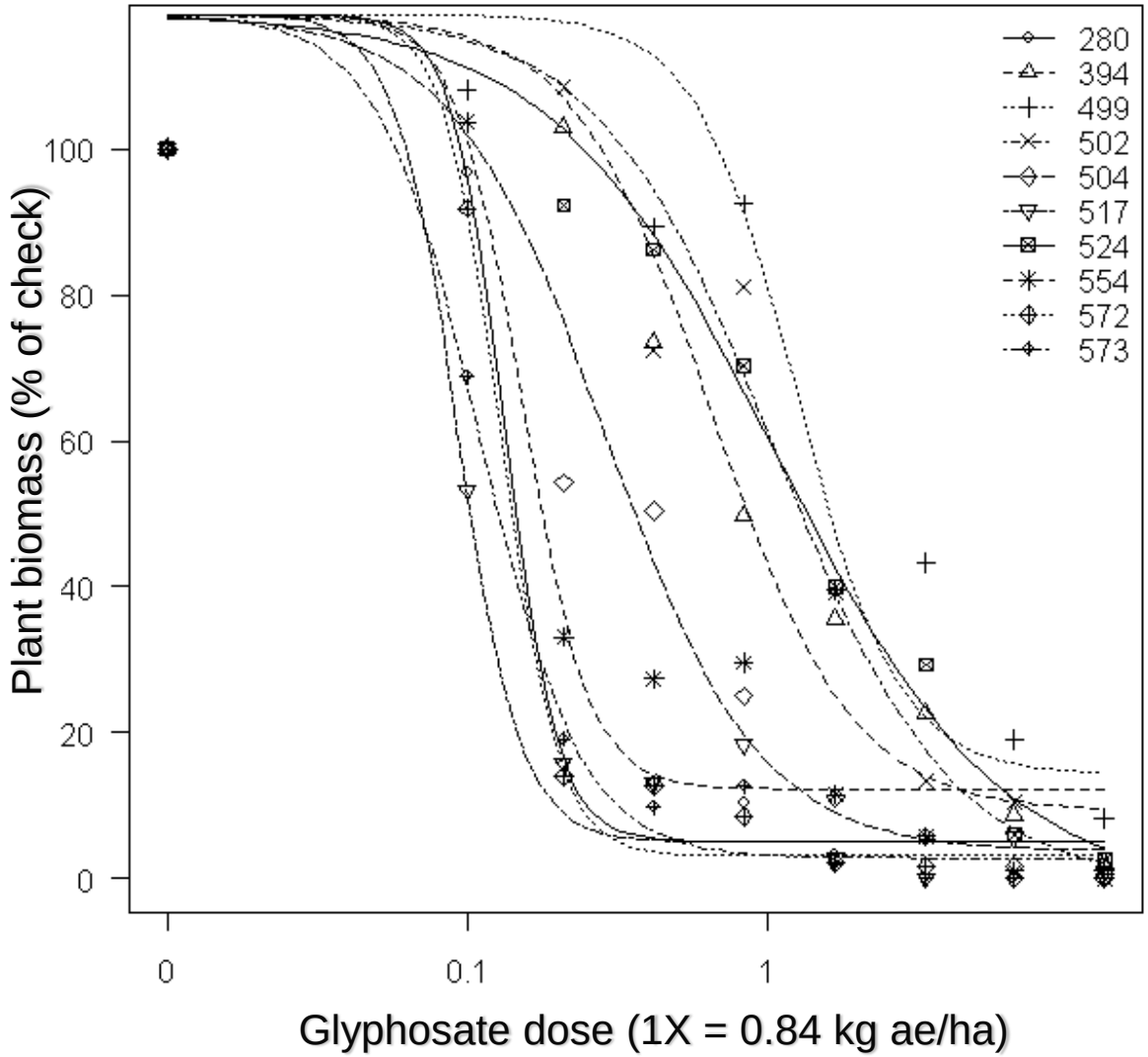
Misclassification rate = 0.32

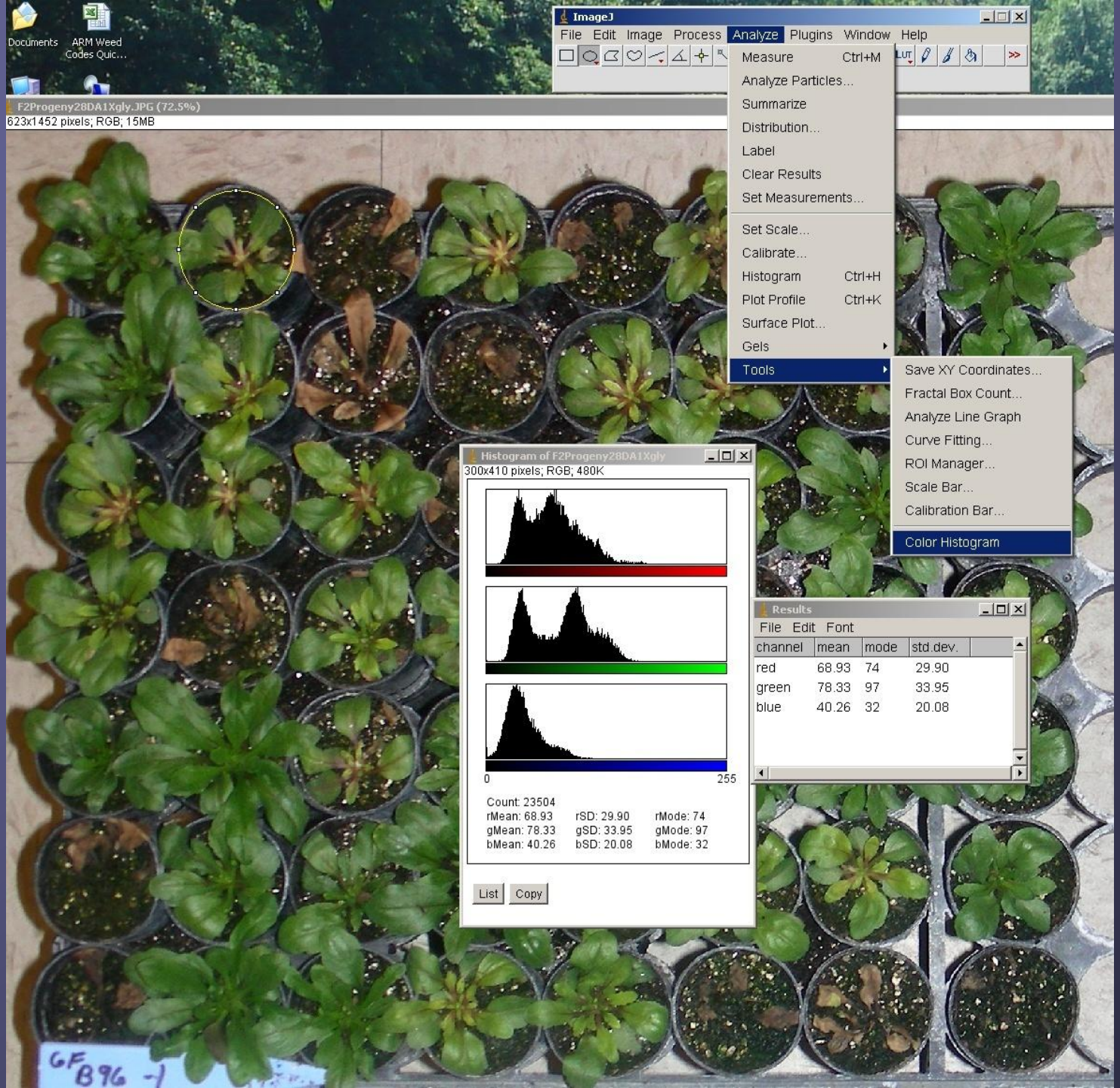
Davis et al. 2009. Weed Sci. 57:281-289.



- Are there variable levels of glyphosate resistance?

Parent Population Glyphosate Dose Response

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Calibrate...
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Plot Profile Ctrl+K
Surface Plot...
Gels
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Fractal Box Count...
Analyze Line Graph
Curve Fitting...
ROI Manager...
Scale Bar...
Calibration Bar...
Color Histogram
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Histogram of F2Progeny28DA1Xgly
300x410 pixels; RGB; 480K
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bMean: 40.26 bSD: 20.08 bMode: 32
List
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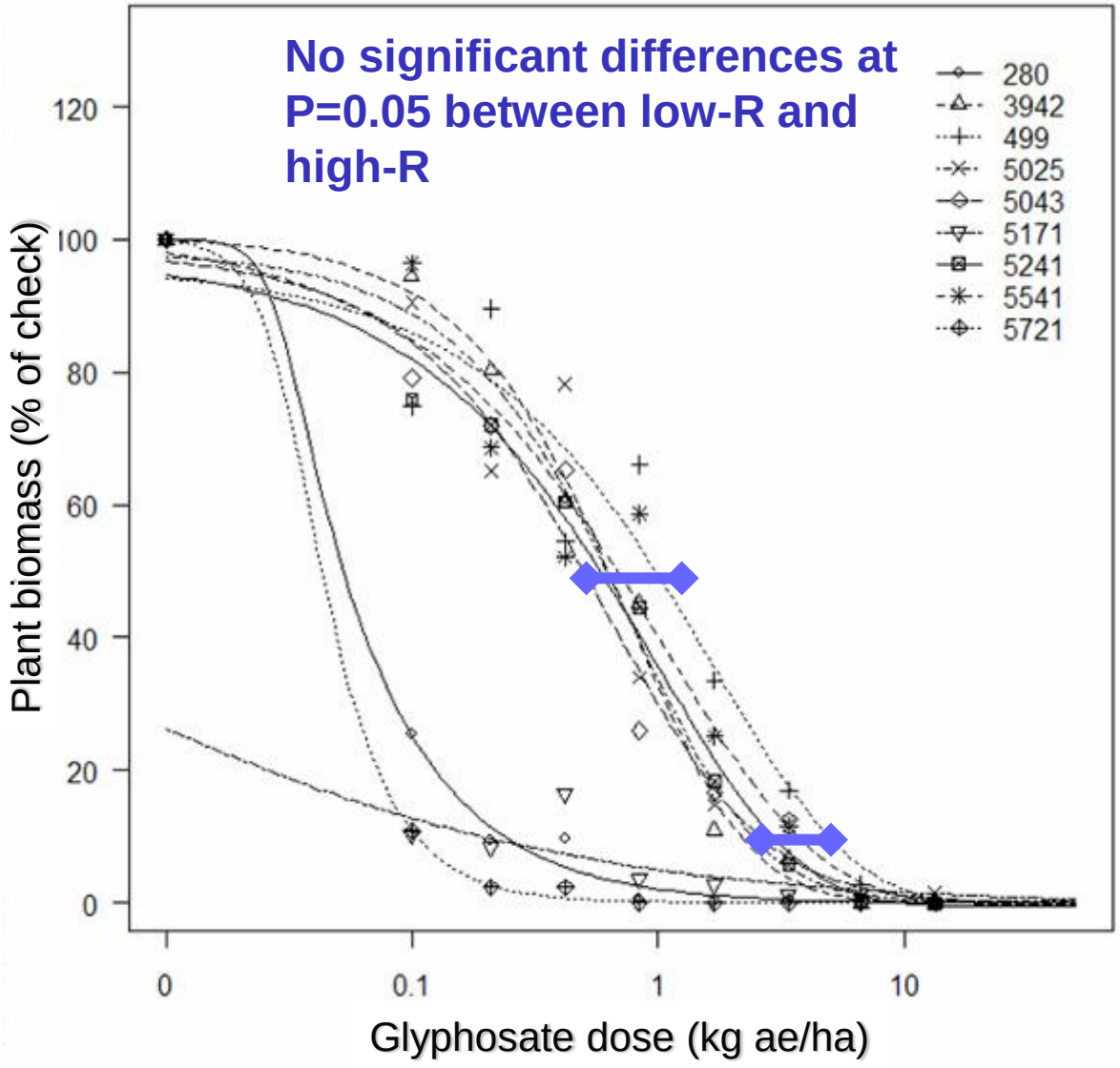
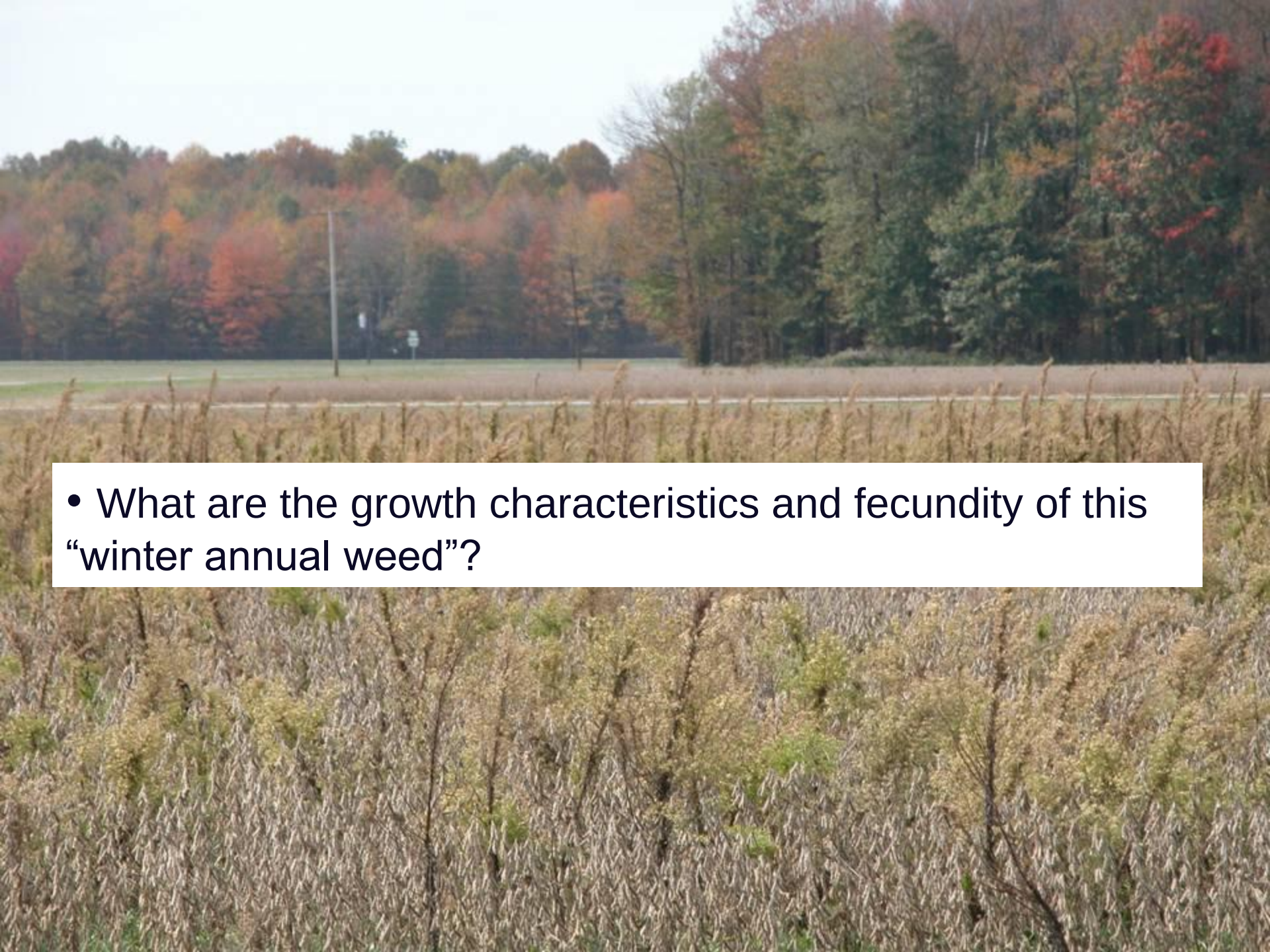
green 78.33 97 33.95
blue 40.26 32 20.08

S1 Progeny Glyphosate Dose Response



Davis et al. 2010. Weed Sci. 58:30-38.



- What are the growth characteristics and fecundity of this “winter annual weed”?

Horseweed Seed Production

- Primarily SRING EMERGING!
- Survivorship is LOW
  - Survival reduced by soybean competition

88 to 98% of seed production comes from plants above the soybean canopy

2 to 12% of seed production comes from plants below the soybean canopy

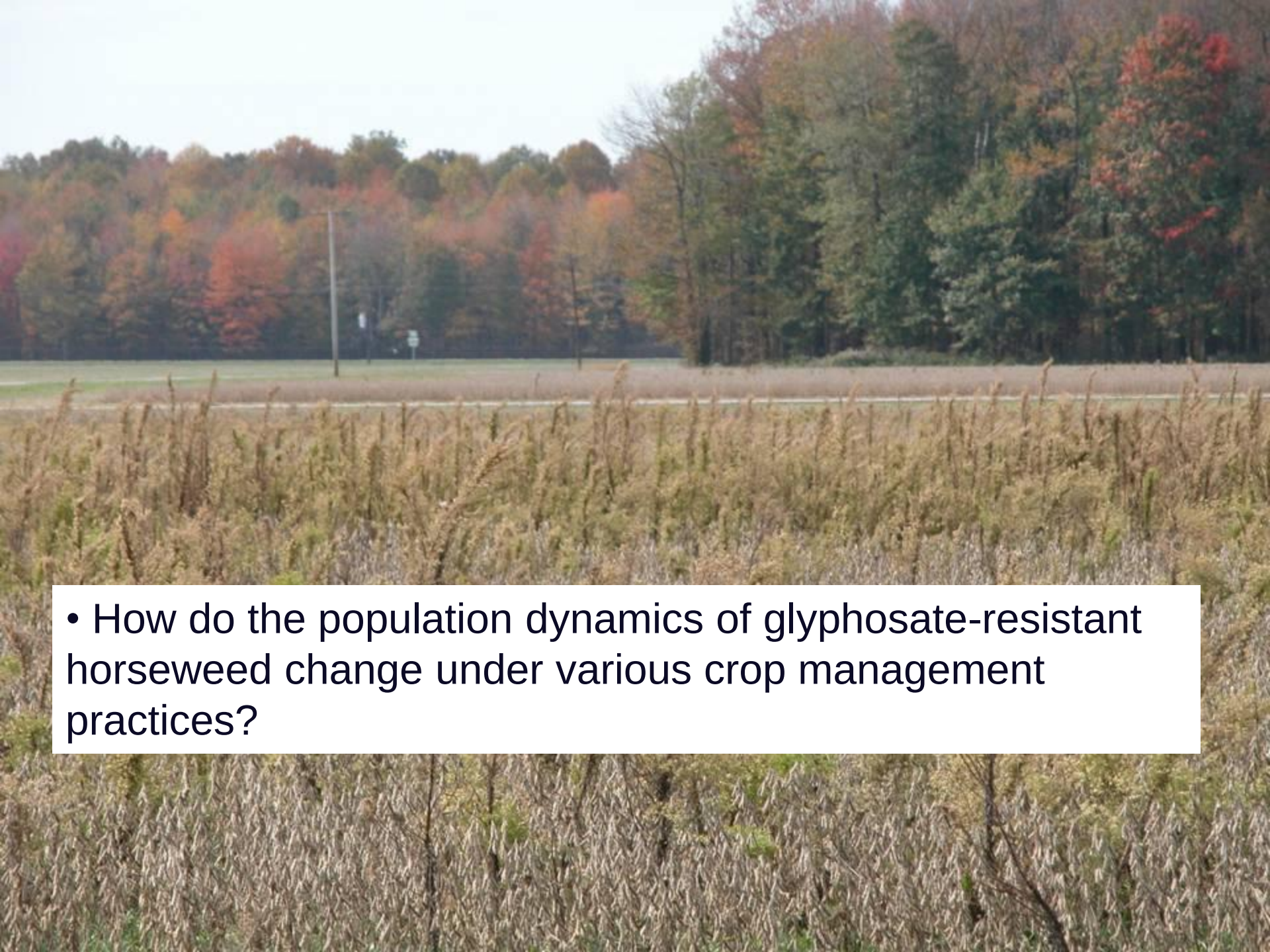
Conclusions

- Davis and Johnson. 2008. Weed Sci. 56:231-236.

How about multiple resistance and fitness following herbicide applications?

• ALS-R + Gly-R (multiple HR) plants can have no fitness penalty producing >280,000 seeds/plt

•Davis et al. 2009. Weed Sci. 57:494-504.



- How do the population dynamics of glyphosate-resistant horseweed change under various crop management practices?

Management Options

- Long-term no-till field experiment
- Established at SEPAC
  - Fall 2003 – Spring 2008
  - Study area was previously in a no-tillage management system
    - contained a moderate infestation glyphosate-resistant horseweed escapes (1 plant m^{-2})

Initial SEPAC S:R Seedbank Ratio

- Screened with 2X glyphosate (1.8 kg ae ha^{-1}) at 5-10 cm rosette size
- sprayed again with 4X at 21DAT

*21 DA 4X glyphosate

1:4

S:R

or

76% resistant

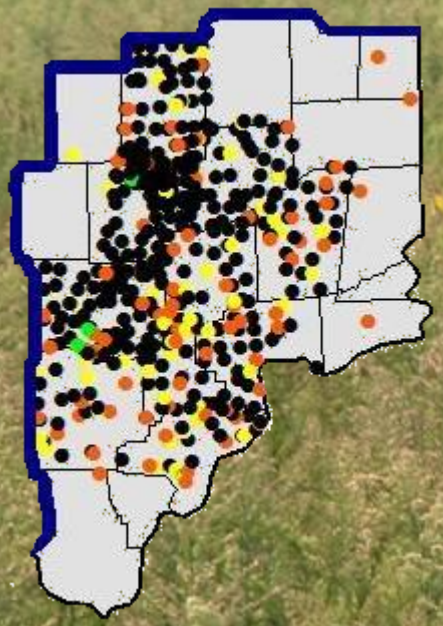
Conclusions 2003-2005

- Viable horseweed seed persistence declines rapidly during the spring and summer months
- To maximize crop yield apply residual herbicide in the spring prior to crop planting
- Davis et al. 2007. Weed Sci. 55:508-516.
- Experiment continued….

Conclusions 2005-2007

- Horseweed densities increased in continuous soybean systems confirmed rotation effects noted in survey
- S:R ratio shifted from 1:4 to 6:1 after four years in systems using residual herbicides and no postemergence glyphosate
- Empirical evidence of resistance shifts influenced by cropping system
- Davis et al. 2009. Weed Sci. 57:417-426.

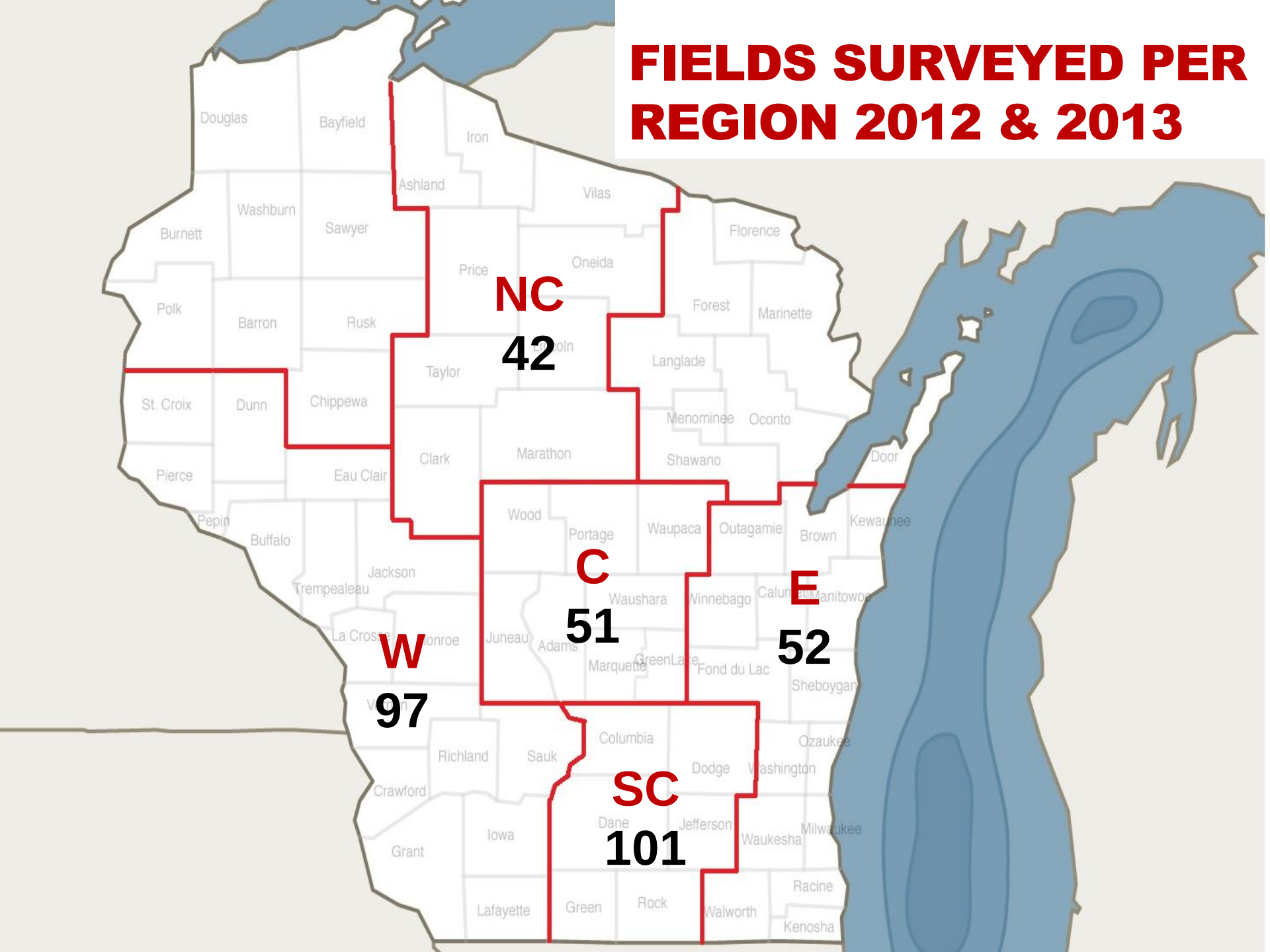
In summary (this was 2009)



- No-till, soybean-soybean rotation
- ~ 20 fold levels of glyphosate resistance
- GR populations can be reasonably predicted
- Primarily spring emerging (summer annual)
- Low fecundity below the soybean canopy
- To manage horseweed,
  - rotate crops, plant soybean crop timely
  - apply herbicides at the right time
  - start with clean field, use residual herbicides, and rotate herbicide MOA's

2013 Glyphosate-resistant horseweed is now in every county of the state”
Dr. William G. Johnson, personal communication

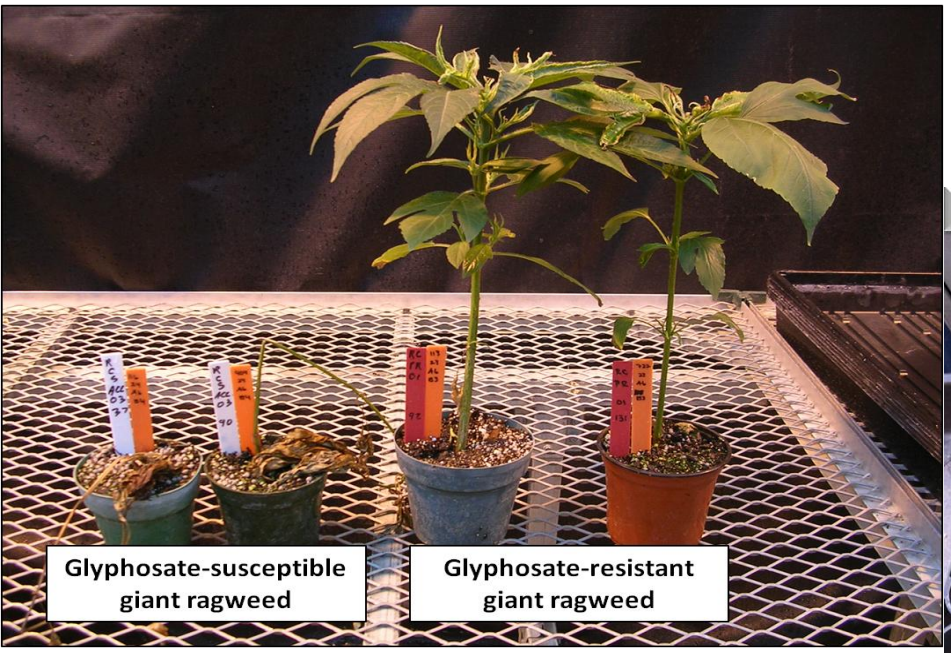
FIELDS SURVEYED PER REGION 2012 & 2013

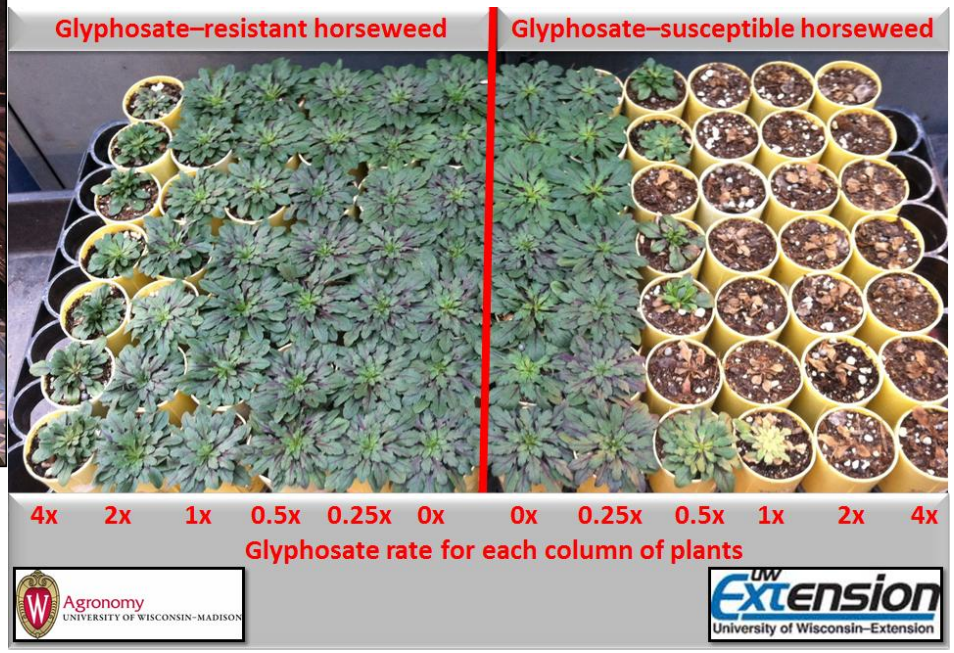


WEED POPULATIONS COLLECTED WITH SUSPICION OF GLYPHOSATE RESISTANCE

	----------Number of Populations Collected----------		
Weed Species	**2012**	**2013**	**Total**
Giant ragweed	5	10	15
Waterhemp	5	9	14
Common lambsquarters	5	1	6
Velvetleaf	4	1	5
Powell amaranth	3	-	3
Common ragweed	2	1	3
Redroot pigweed	2	-	2
Horseweed	1	1	2
Smooth pigweed	1	-	1
Ladysthumb	1	-	1

GLYPHOSATE-REISTANT GIANT RAGWEED - 2012





GLYPHOSATE-RESISTANT HORSEWEED - 2013

What's the big deal?

Thoughts to consider:

- **It's not on my farm,……it's not my problem**

- **If I get it,…….someone (industry) will give me new tools to fix it**

Take ACTION
HERBICIDE-RESISTANCE MANAGEMENT

WEED OUT RESISTANCE

- Know Your Weeds
- Know Weed Growth
- Know Weed Seed Characteristics
- Know Herbicide Resistance

IN THE FIELD

- Crop Rotation
- Multiple Herbicide Modes of Action
- Mechanical Practices
- Know Herbicide Tolerant Traits

SPRAY ATTENTION

- Herbicide Mode of Action and Properties
- Drift Management
- Know Environmental Conditions
- Know Your Neighbors

THE BOTTOM LINE

- Risk Management
- Cost-Benefit of Practices
- Know the Cost of Poor Weed Control

More Herbicide, More Tillage, or Better Agronomic Practices needed to mitigate herbicide resistance?

Mortensen, D.A., J.F. Egan, B.D. Maxwell, M.R. Ryan, and R.G. Smith. 2012. Navigating a Critical Juncture for Sustainable Weed Management. BioScience 62: 75-84.

UW Extension Cooperative Extension

The University of Wisconsin Madison

CAST® Issue Paper
Number 49
February 2012

Herbicide-resistant Weeds Threaten Soil Conservation Gains: Finding a Balance for Soil and Farm Sustainability

The balance between conservation tillage and herbicide-resistant weed management is the central issue addressed in this paper. (Left photo from ARS; middle photo from Howard F. Schwartz, Colorado State University, Bugwood.org; right photo from Shutterstock.)

Abstract

Tillage has been an integral part of crop production since crops were first cultivated. Growers and scientists have long recognized both

Glyphosate-resistant crops are planted on the majority of canola, corn, cotton, soybean, and sugarbeet acres in the United States and many other nations as a result of efficacy and economics. When any single her-

where the farmer does not need to modify or abandon his current conservation tillage practices in order to manage a resistant weed population. Best management practices (BMPs) that have been established for both

June 2013

Using a roller-crimper for no-till organic soybeans

College of Agricultural & Life Sciences
UNIVERSITY OF WISCONSIN-MADISON

UW Extension
University of Wisconsin-Extension


November 2013
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Controlling weeds with Herbicides

What is the number one most important aspect for IWM in the future to include?

What is the number one most useful aspect of herbicides?

- **SELECTIVITY!**
  - Selecting different herbicides, and different herbicide application methods, give the ability to control a weed WITHOUT significant (or any) detrimental effects to vegetation of interest
- **Followed by: Residual control!**

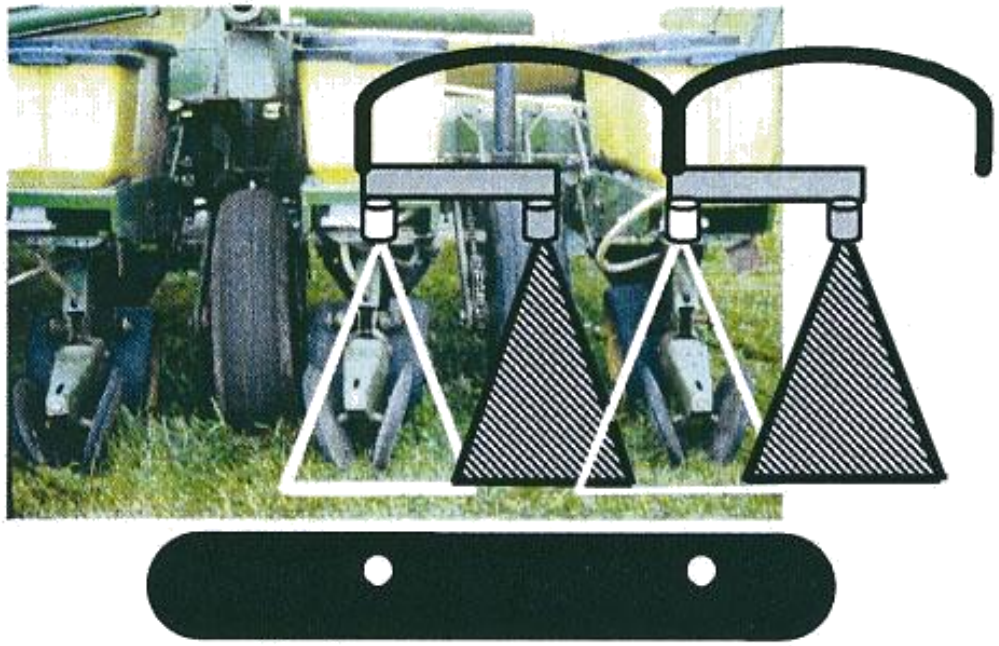
Mechanical Weed Management

Row Cultivation

Zone Herbicide Application

Different herbicide rates applied between-row and in-row

Can we return to this?



Flame Weeding

Flame Weeding

Flame Weeding

Mechanical Weed Management

- Challenges to mechanical weed management:
  - Weather
  - Timing and labor
  - Equipment cost
  - A lost “art”
  - Root pruning
  - No-till
  - Energy usage
  - No residual control
  - Lack of control in close proximity to crop plants


Lynn Betts, USDA-NRCS

In conclusion

- The issue is not simple, and neither will be the solution
- We can't 'return' to IWM practices of yesteryear, they weren't robust then, why would they be now.
- We need new 'novel' integrated approaches to address this issue
- They will have to integrate new technologies (biological, computer, and equipment)


Thanks for your attention!
Vince M. Davis vmdavis@wisc.edu