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**Driven to Discover**<sup>SM</sup>

# **Institute of Ag Professionals**

Proceedings of the

## **2015 Crop Pest Management Shortcourse &**

### **Minnesota Crop Production Retailers Association Trade Show**

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# Herbicide Resistant Weeds – Reliance on Herbicide Technologies alone won't manage the problem



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**Special Thanks to:**  
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**Rochester, MN**  
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**&**  
**Bob Hartzler**  
**Weed Science**  
**Iowa State University**

# Herbicide resistance

- Weeds have evolved resistance to 21 of the 25 known herbicide sites of action
  - Consists of 148 different herbicides
- At least 24 species resistant to glyphosate worldwide
- Threatens the continued utility of herbicides for weed control
  - Including herbicide resistant traits (both current and future)

(Heap, 2013)



# Herbicide resistance

- This is not a new problem and predates herbicide resistant crops by several decades
- Recently, evolved resistance to glyphosate has become synonymous with herbicide resistance
- It is a much greater and far-reaching problem than glyphosate resistance



# Important glyphosate-resistant weeds associated with glyphosate-resistant crops in the USA



*Amaranthus tuberculatus*



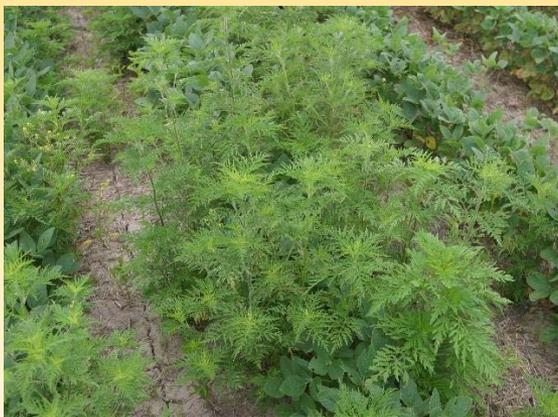
*Conyza canadensis*



*Amaranthus palmeri*



*Ambrosia trifida*



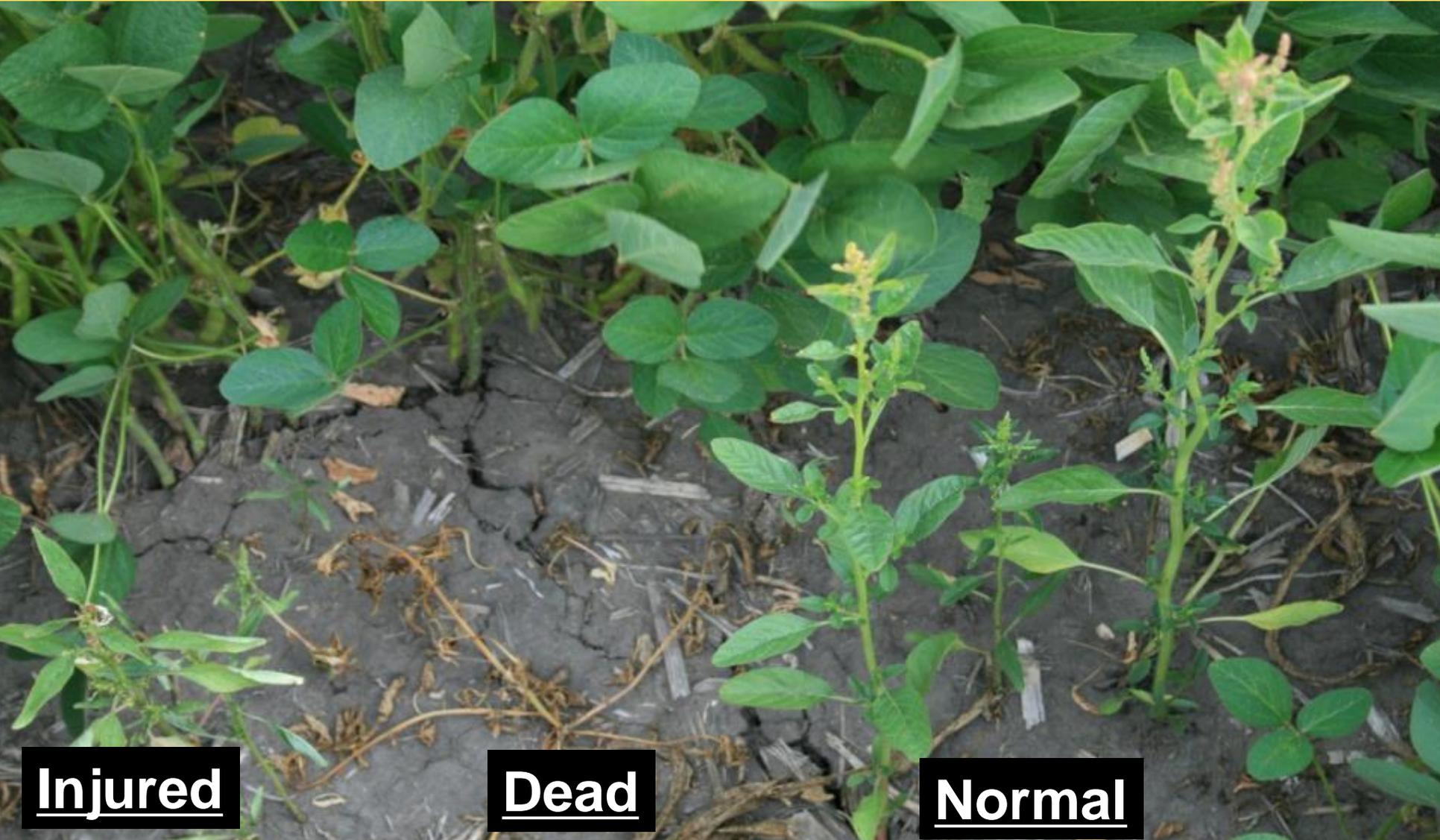
*Ambrosia artemisiifolia*



... and many biotypes are also resistant to ALS inhibitor and other herbicides!



# What Does Herbicide Resistance Look Like?



Injured

Dead

Normal

# Another sign of herbicide resistance



# Left untended herbicide resistance can sneak up on you!

## Don't delay addressing the problem

Watehemp 2013

Same Field in 2015



**Addressing the problem at this point  
increases input costs because you  
must now target the weed seed bank**





## **Is this a sign of Herbicide Resistance? Are These Giant Ragweed Going to Die?**

**These plants needed to be  
sprayed at 2-3 inches.**



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# Percent of growers at a PPAT location in 2013 & 2014 reporting glyphosate *has not been* performing as well as when they first used it.

Which weed is becoming the most problematic?

Waterhemp ...and it is moving east.

Add layer Share

2013-glyphosate-map.xlsx

Styled by % Producers

70-79 (9)

60-69 (6)

80-89 (6)

50-59 (4)

90-100 (4)

2014-glyphosate map.xlsx

Styled by % Producers

90-100 (8)

80-89 (6)

70-79 (3)

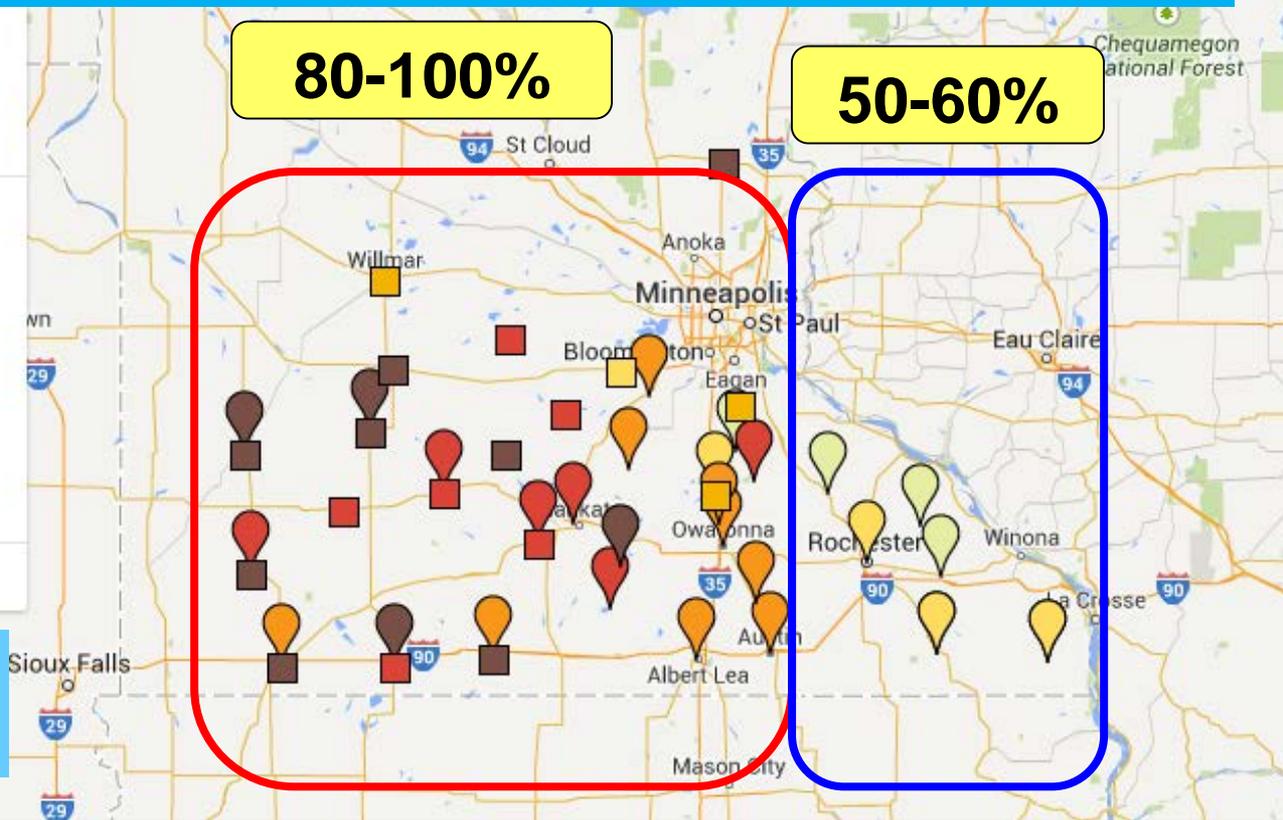
60-69 (1)

Base map

Or Giant Ragweed  
...and it is moving west

80-100%

50-60%



# But wait, there is worse news: Multiple resistance

SOA#'s  
2,4,5,9,14,27

SOA#'s  
2,9

SOA#'s  
2,5,9,14

SOA#'s  
2,4,5,9

COMMON WATERHEMP

*Amaranthus rudis*

SHOWN RESISTANCE TO:

2 4 5 9 14 27

GIANT RAGWEED

*Ambrosia trifida*

SHOWN RESISTANCE TO:

2 9

COMMON RAGWEED

*Ambrosia artemisiifolia*

SHOWN RESISTANCE TO:

2 5 9 14

KOCHIA

*Kochia scoparia*

SHOWN RESISTANCE TO:

2 4 5 9

2 = Pursuit, FirstRate

9 = Glyphosate

14 = Valor, Flexstar, Cobra

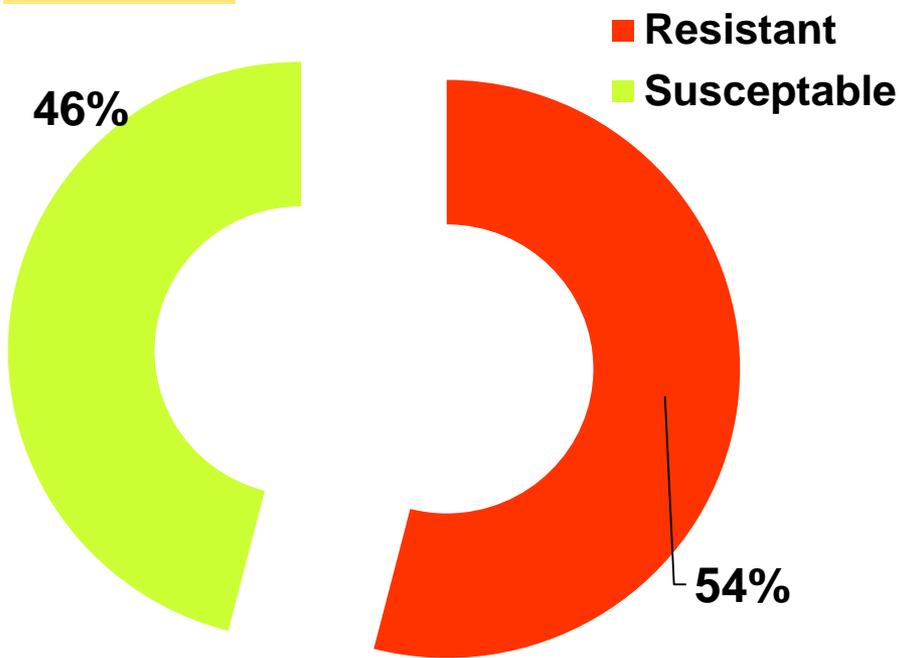


# ISU Reports waterhemp responses to labeled herbicide rates indicate: 700 fields

## Glyphosate

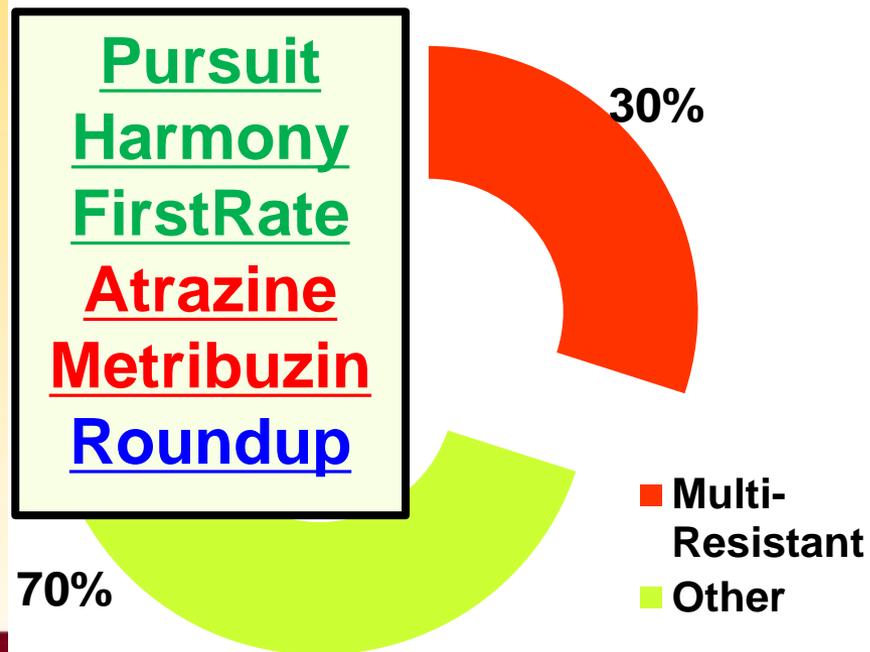
Roundup

SOA 9 EPSP



## Multiple Resistance

SOA 2, 5, & 9 (ALS, triazines, ESPS)



# Multiple resistant waterhemp in Illinois

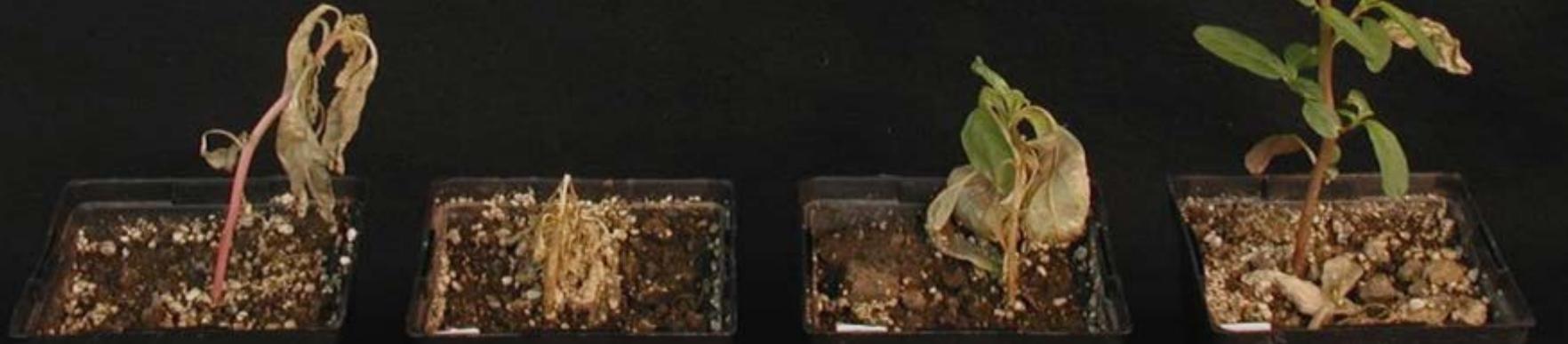
10 days after treatment

**#5 + #14 + #2**

**SOA #5**

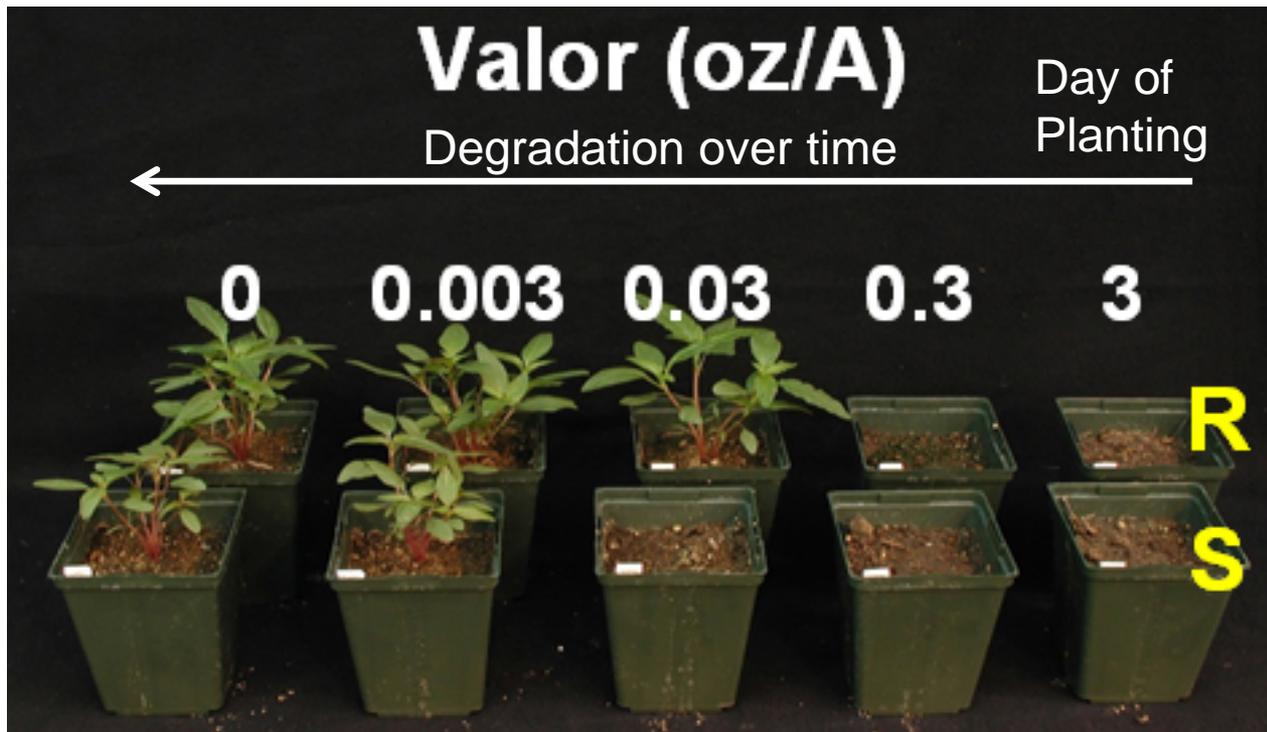
**SOA #14**

**SOA #2**



# Selection for resistance can also come from PRE herbicides

## PPO (SOA#14) -Resistance



Credit to Aaron Hager,  
Univ. of Illinois

# Mechanisms of Herbicide Resistance

- Altered Target Site (e.g. SOA #2)
  - Conformational change to target protein
  - Prevents herbicide from binding
  - Waterhemp, ragweeds, kochia
- Amplified expression of an enzyme (e.g. SOA #9)
  - More proteins than there are herbicide molecules
  - Unaffected proteins continue to function
  - Waterhemp
- Compartmentalization or sequestration (e.g. SOA #9)
  - Plants sequester herbicide in vacuoles
  - Prevent herbicide from reaching site of action
  - Giant ragweed
- Enhanced metabolism (e.g. SOA # 4, 27)
  - Plant is able to rapidly break down herbicide / make it inactive



# Mechanisms of Herbicide Resistance

Resistance mechanism	SOA 1	SOA 2	SOA 3	SOA 4	SOA 5	SOA 9	SOA 14	SOA 27
Herbicide class	ACC'ase	ALS	DNA	PGR	Triazine	Gly	PPO	HPPD
Target site	+	+	+	+ <sup>?</sup>	+ <sup>1</sup>	+	+	
Metabolism <sup>2</sup>	+	+			+			+
Sequestration						+		
Gene amplification						+		

- Decreased absorption and/or translocation is also a possible resistance mechanism
- <sup>?</sup> Likely but not conclusively confirmed
- <sup>1</sup> This mutation makes weeds less fit than susceptible wild types
- <sup>2</sup> Can confirm cross-resistance to herbicides from multiple SOA's (2,4-D & "fops")  
Can provide resistance to herbicides that have yet to be discovered
- Crop resistance is metabolism-based for: 2,4-D (Enlist) ; glufosinate (Liberty Link) ; dicamba (Xtend)
- Crop resistance is target site-based for; Roundup Ready corn and soybean

# Mechanisms of Herbicide Resistance

- Herbicide resistance is complex
- Herbicides are tremendous selection agents
- Frequency of resistance traits varies among herbicide SOA groups
  - e.g. SOA 2 > SOA 9
- Weeds that out-cross and are genetically diverse are a higher risk
- The numerous mechanisms of resistance indicates the need for using multiple SOA groups and non-herbicide control measures



# Mechanisms of Herbicide Resistance

- Altered Target Site (e.g. SOA #2)
  - Conformational change to target protein

**Unless the resistant trait  
reduces a plants ability to  
reproduce, the trait does  
NOT leave the population**

- Giant ragweed
- Enhanced metabolism (e.g SOA # 27)
  - Plant is able to break down herbicide / make it inactive



# The Main Drivers of Herbicide Resistance

- Selection intensity – using the same weed management tactic again and again
  - Need for diversification of weed management tactics
- Allowing weed population size to increase in the seed bank
  - Increases probability of a R-trait
  - Need to prevent pollen and seed production
  - **This calls for weed seed bank management**





Specially formulated for Roundup Ready crops

GROUP 9 HERBICIDE

BASF The Chemical Company

GROUP 14 HERBICIDE

SPECIMEN

Sharpen

GROUP 14 2 HERBICIDE



...tribution of this product in Nassau and ...n the State of New York is prohibited.

GROUP 5 15 27 HERBICIDES

Dow Dow AgroSciences



Herbicide WITH COLEX-D TECHNOLOGY

©™ Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow

For control of annual and perennial weeds and use on Enlist™ corn and soybeans; use as a non-selective burndown; chemical fallow; and use as a preplant or preemergence or postemergence herbicide on listed crops, for control of emerged weeds only.

2,4-D products that do not contain COLEX-D™ Technology are not authorized for use in conjunction with Enlist corn and soybeans.

Do not allow contact of herbicide with foliage, green stems, exposed root systems or fruit of crops, desirable plants and trees because severe injury or destruction may result.

GROUP 4 9 HERBICIDE



Acuron Herbicide

GROUPS 14 15 HERBICIDE



GROUP 14 HERBICIDE



# Available Sites of Action by Crop

Sequential Reliance on a single SOA

Induces multiple resistance

Site of Action (SOA #)			
Corn		Soybean	
Corn PRE	POST	Soybean PRE	POST
2	2	2	2
④	④	3	[9]
5	5	5	[10]
15 (Epost)	[9]	15 (Epost)	⑭
⑳	[10]	⑭	
	14		
	⑳		



# How to Manage Herbicide-Resistant Weeds

- Know how to identify resistance
  - 4 known species (GIRW;CORW;COWH;Kochia)
  - Frequency of resistant plants in the field
  - Response of individual plants
- Admit there is a problem and realize that Herbicide Technology alone cannot adequately address the problem
- Change management strategies quickly to more diverse weed management practices
  - Preemergence herbicides
  - Use other effective POST herbicides
  - Include effective tank-mix partners
  - Consider Liberty Link Crops
  - Integrate Cultural Weed Management Practices



# Use PRE's & at Maximum Rates



# Advantages PRE Herbicides Bring to Weed Management

- Reduces weed density
  - Increases yield potential
- Reduces weed species mixtures
  - Improves herbicide and adjuvant compatibility
- Results in a narrower distribution of weed sizes
  - Improves consistency of weed control
- Results in added value
  - Increased nitrogen efficiency in corn
  - Early-season canopy in soybean



# Let's see what a PRE can do

Weed Code Rating Date				Giant Ragweed		
				June 5	June 10	
Trt	Treatment	Rate	Appl	% CONTROL		
Boundary	(5,15)	1.5	pt/a	A / B	20	99
Boundary	(5,15)	1.5	pt/a	A / D	20	31
BroadAxe	XC (14,15)	25	oz/a	A / D	23	23
Verdict		5	oz/a	A / C	60	98

A = PRE = 5/13

B = POST I = 6/5

C = POST II = 6/8

D = POST III = 6/10

**Common Lambsquarters Control = ~99%**  
**Common Waterhemp Control = ~99%**



# Let's see what a PRE can do

Weed Code				Giant Ragweed		INJURY
Rating Date				June 5	June 10	June 5
Trt	Treatment	Rate	Appl	% CONTROL		(%)
<b>Fierce (14,15)</b>	3	oz/a	A / E	71	72	<b>24</b>
<b>Sencor (5)</b>	4	oz/a	A / E			
Verdict (14,15)	5	oz/a	A / E	70	71	<b>4</b>
Outlook (15)	10	oz/a	A / E			
<b>Rowel (14)</b>	3	oz/a	A / C	72	82	<b>26</b>
Zidua (15)	2	oz/a	A / E	73	71	<b>3</b>
Verdict (14,15)	5	oz/a	A / E			
Authority Assist (2,14)	12	oz/a	A / E	75	79	<b>0</b>
<b>Enlite 2.8 oz/A (2,14)</b>				76	70	<b>23</b>
- chlorimuron	0.33	oz/a	A / E			
- thifensulfuron	0.5	oz/a	A / E			
- flumioxazin	2	oz/a	A / E			
Zidua PRO				77	80	<b>0</b>
- Optill (2,14)	2	oz/a	A / E			
- Zidua (15)	2	oz/a	A / E			
Sonic	4.5	oz/a	A / E	79	81	<b>0</b>

Common Lambsquarters Control = ~99%  
 Common Waterhemp Control = ~99%

A = PRE = 5/13  
 C = POST II = 6/8  
 E = POST IV = 6/16

# Let's see what a PRE can do

Weed Code Rating Date				Giant Ragweed			INJURY	
				June 5	June 10	June 19	June 5	
Trt	Treatment	Rate	Appl	% CONTROL			(%)	
	Sonic (2,14)	6	oz/a	A / E	86	87	96	0
	Authority First (2, 14)	6	oz/a	A / C	86	89	98	0
	Fierce (14,15)	3	oz/a	A / E	86	88	95	25
	FirstRate (2)	0.3	oz/a	A / E				
	Authority First (2,14)	6.4	oz/a	A / F	86	88	84	0
	Surveil (2,14)	2.8	oz/a	A / F	88	91	87	23

A = PRE = 5/13

C = POST II = 6/8

E = POST IV = 6/16

F = POST V = 6/25

Common Lambsquarters Control = ~99%

Common Waterhemp Control = ~99%





08/03/2015

# WHAT ABOUT WATERHEMP?



## OPTILL PRO

OPTILL 2 oz/a + OUTLOOK 10 fl oz/a PREPRE applied: 5/5/15

LIBERTY 280 29 fl oz/a + AMS 8.5 lb/100 gal

MIDPOWE: Applied on: 6/23/2015



June 22, 2015



July 8, 2015

**60 Bu/A**



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## OPTILL PRO

OPTILL 2 oz/a + OUTLOOK 10 fl oz/a PREPRE applied: 5/5/15

LIBERTY 280 29 fl oz/a + AMS 8.5 lb/100 gal

MIDPOWE Applied on: 6/23/2015



**60 Bu/A**

**August 27, 2015**

**BOUNDARY 1.95 pt/a PREPRE applied: 5/5/15  
CULTIVATION EAPOWE: 6/24/2015**



**June 22, 2015**



**June 29, 2015**

**57 Bu/A**



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**BOUNDARY 1.95 pt/a PREPRE applied: 5/5/15**  
**CULTIVATION EAPOWE: 6/24/2015**



**57 Bu/A**

**August 27, 2015**

**VERDICT 5 fl oz/a PREPRE applied: 5/5/15**  
**COBRA 10 fl oz/a + SELECT MAX 15 fl oz/a + COC 1.5 pt/a + AMS 17 lb/100 gal**  
**MIDPOWE : Applied on: 6/16/2015**



Consider the impact of an open crop canopy on late-emerging weeds  
A closed crop canopy is FREE weed control

Sound agronomics contributes to early canopy closure



**June 22, 2015**

**July 8, 2015**

**40 Bu/A**



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**VERDICT 5 fl oz/a PREPRE applied: 5/5/15**  
**COBRA 10 fl oz/a + SELECT MAX 15 fl oz/a + COC 1.5 pt/a + AMS 17 lb/100 gal**  
**MIDPOWE : Applied on: 6/16/2015**



**40 Bu/A**

**August 27, 2015- Poor lambsquarter control**

# Consider Layering Herbicides. WHY?

## Extend the control season.

- One **strategy** for dealing with glyphosate resistant waterhemp is to **layer** soil residual herbicides.
- Three herbicides were evaluated in this study,
  - 1) **Dual II Magnum** (s-metolachlor) at 1.5 pts/A **PRE only**
    - or 1.5 pts/A **PRE** followed by 1.0 pt/A **POST**
  - 2) **Outlook** (dimethenamid-P) at 18 fl oz/A **PRE only**
    - or 14 fl oz/A **PRE** followed by 10 fl oz/A **POST**
  - 3) **Warrant** (acetochlor) at 1.6 pt/A **PRE only**
    - or 1.6 pt/A **PRE** followed by 1.6 pt **POST**
    - 
    - *Rates used were based on soil type and seasonal limits.*
- Selected because of their **known effectiveness** for controlling waterhemp and their **flexibility of application timing**.



**Comparison of weed control in soybean with a single preemergence application of Outlook (left) and layered applications of Outlook May 5 and June 8 (right).**

Photos taken July 14, 2015.



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**Comparison of weed control in soybean with a single preemergence application of Outlook (left) and layered applications of Outlook May 5 and June 8 (right).**

Photos taken August 27, 2015.



Pest Code				<u>Waterhemp</u>										YIELD	
Rating Date				5-27-15		6-10-15		6-26-15		7-8-15		9-29-15		BU/A	
T <sub>rt</sub>	Treatment	Rate	Appl												
	DUAL II MAGNUM	1.5 pt/a	A	99	a	96	b	91	b	85	b	81	b	43	cd
	Pursuit	4 fl oz/a	A												
	DUAL II MAGNUM	1.5 pt/a	A	99	a	98	a	96	a	97	a	95	a	49	ab
	Pursuit	4 fl oz/a	A												
	DUAL II MAGNUM	1.0 pt/a	B												
	OUTLOOK	18 fl oz/a	A	99	a	96	b	85	c	73	c	71	c	40	d
	Pursuit	4 fl oz/a	A												
	OUTLOOK	14 fl oz/a	A	99	a	98	a	97	a	97	a	94	a	51	a
	Pursuit	4 fl oz/a	A												
	OUTLOOK	10 fl oz/a	B												
	WARRANT	1.6 qt/a	A	99	a	91	c	82	c	69	c	62	d	32	e
	Pursuit	4 fl oz/a	A												
	WARRANT	1.6 qt/a	A	98	b	95	b	95	a	94	a	90	a	46	bc
	Pursuit	4 fl oz/a	A												
	WARRANT	1.6 qt/a	B												

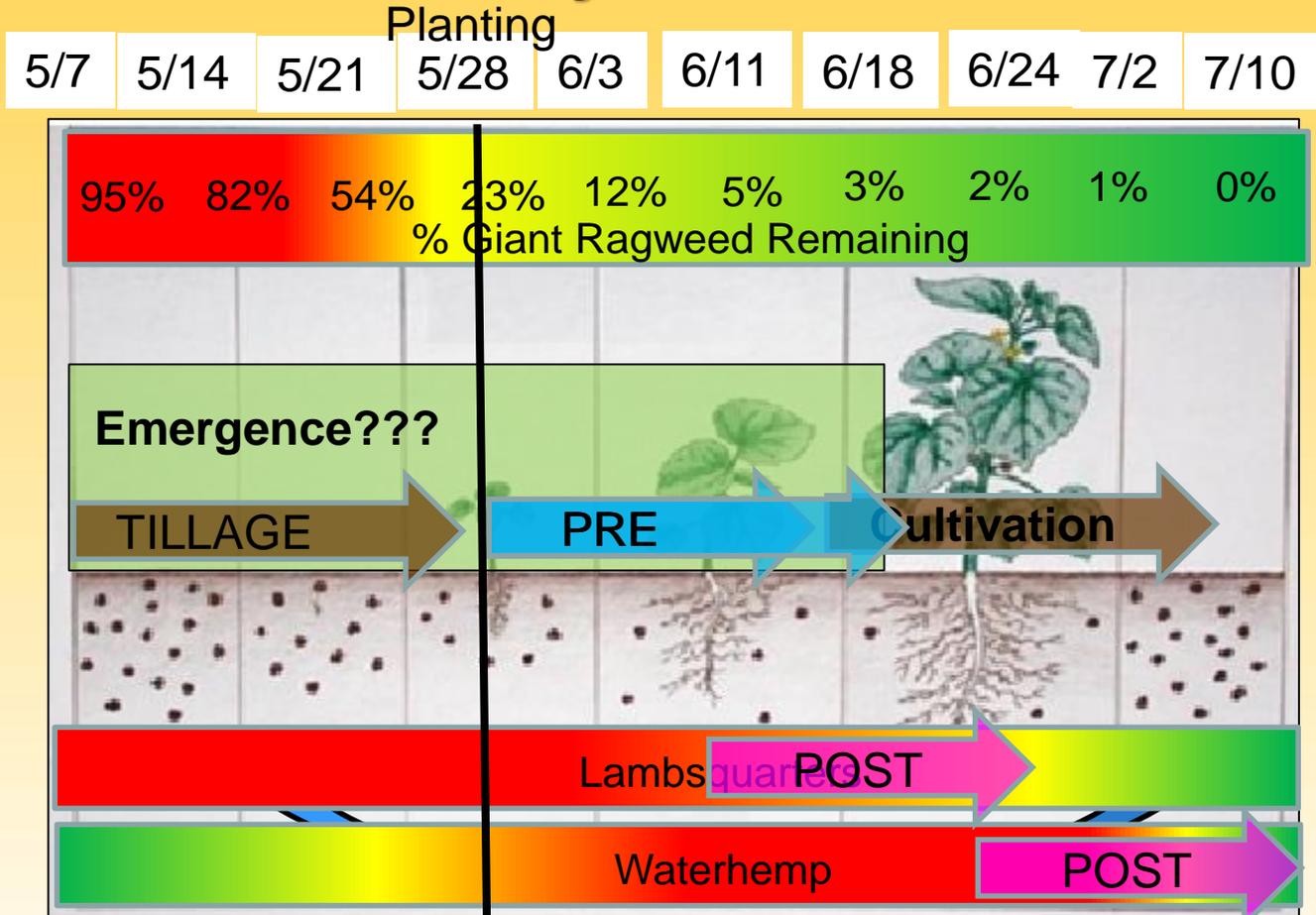
**A = PRE, B = POST I (June 8, 2015)**



# Integrated Weed Management Game of Percentages

# Not So Simple

## How much to rely on Herbicides??



Life Cycle of Annual Weeds

From Chee-Sanford et al. (2006).



# THE REINFORCEMENTS...

**CROP ROTATION**



**PLANTING DATE**



**HAND PULLING**



**Mechanical**



**COVER CROPS**

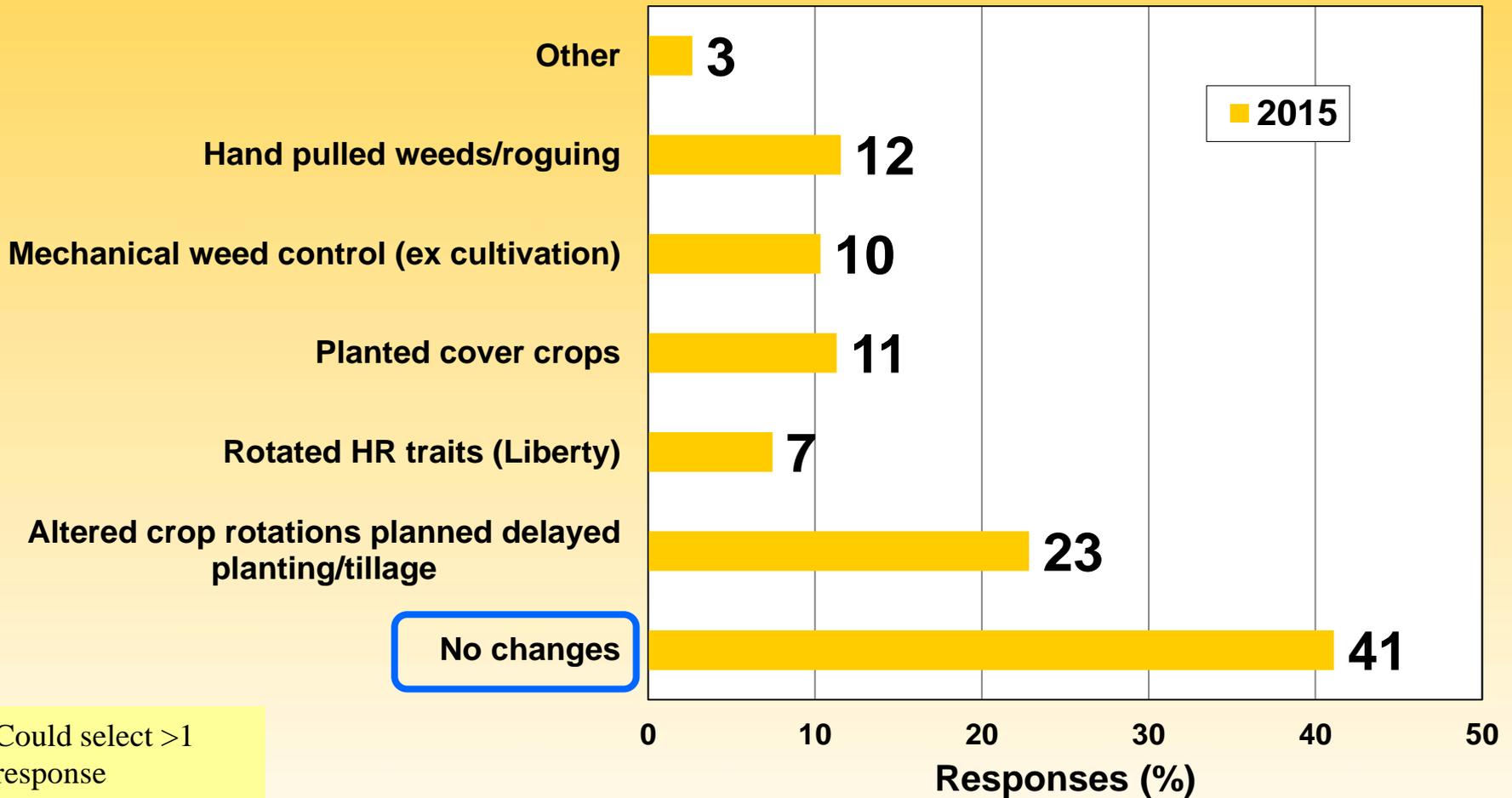


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# In 2014, I used the following weed management practice(s) on land I farm

(Responses: 416 in 2015)



# Crop Rotation Study

Jared Goplen

UM Graduate Student, Weed Science



# Discovery #1

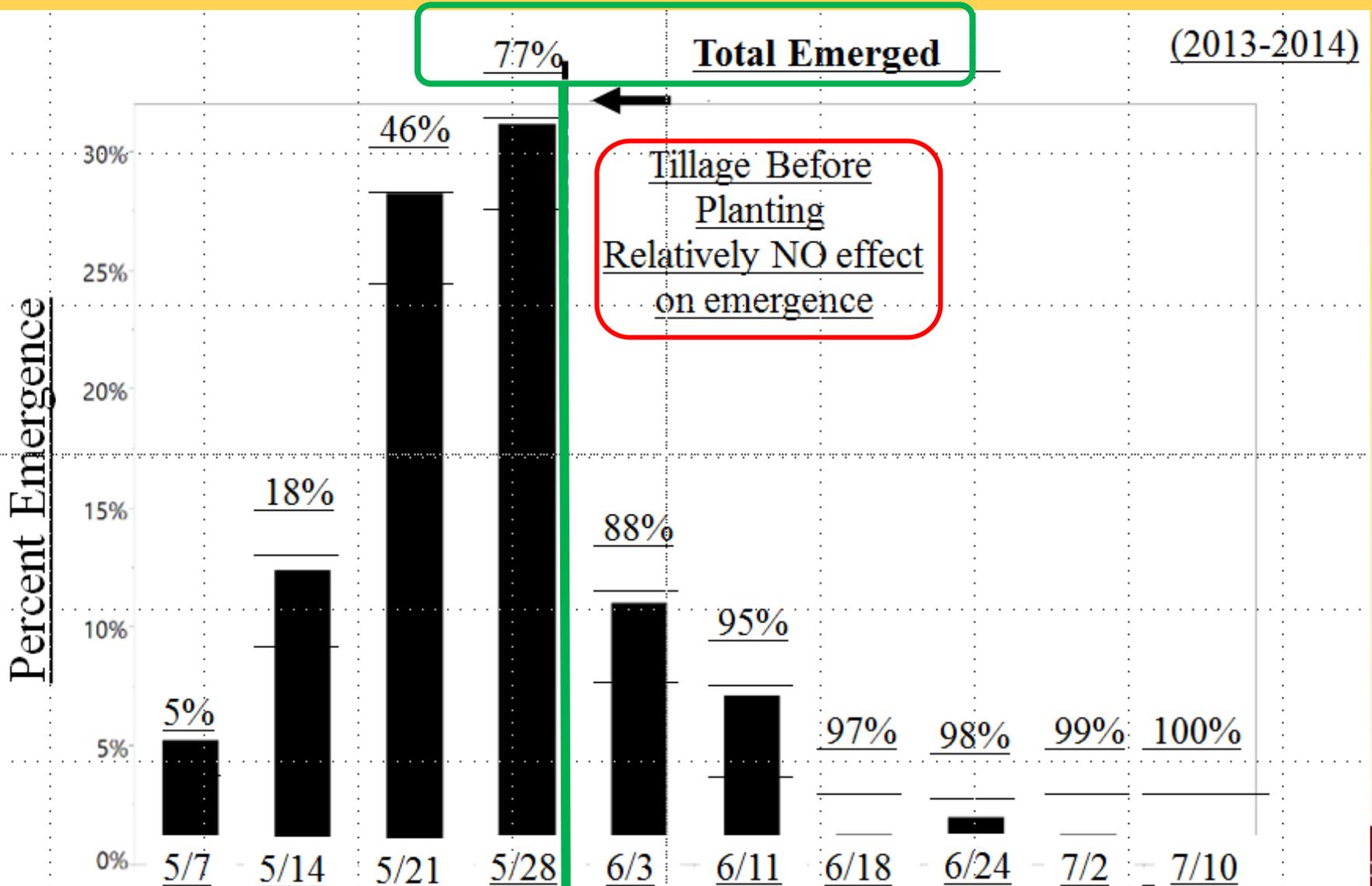
## Giant Ragweed

- **Zero Weed Threshold = 97%**  
seed bank depletion in **2 years** in any  
crop rotation.
- How to maintain Zero Weed Threshold?



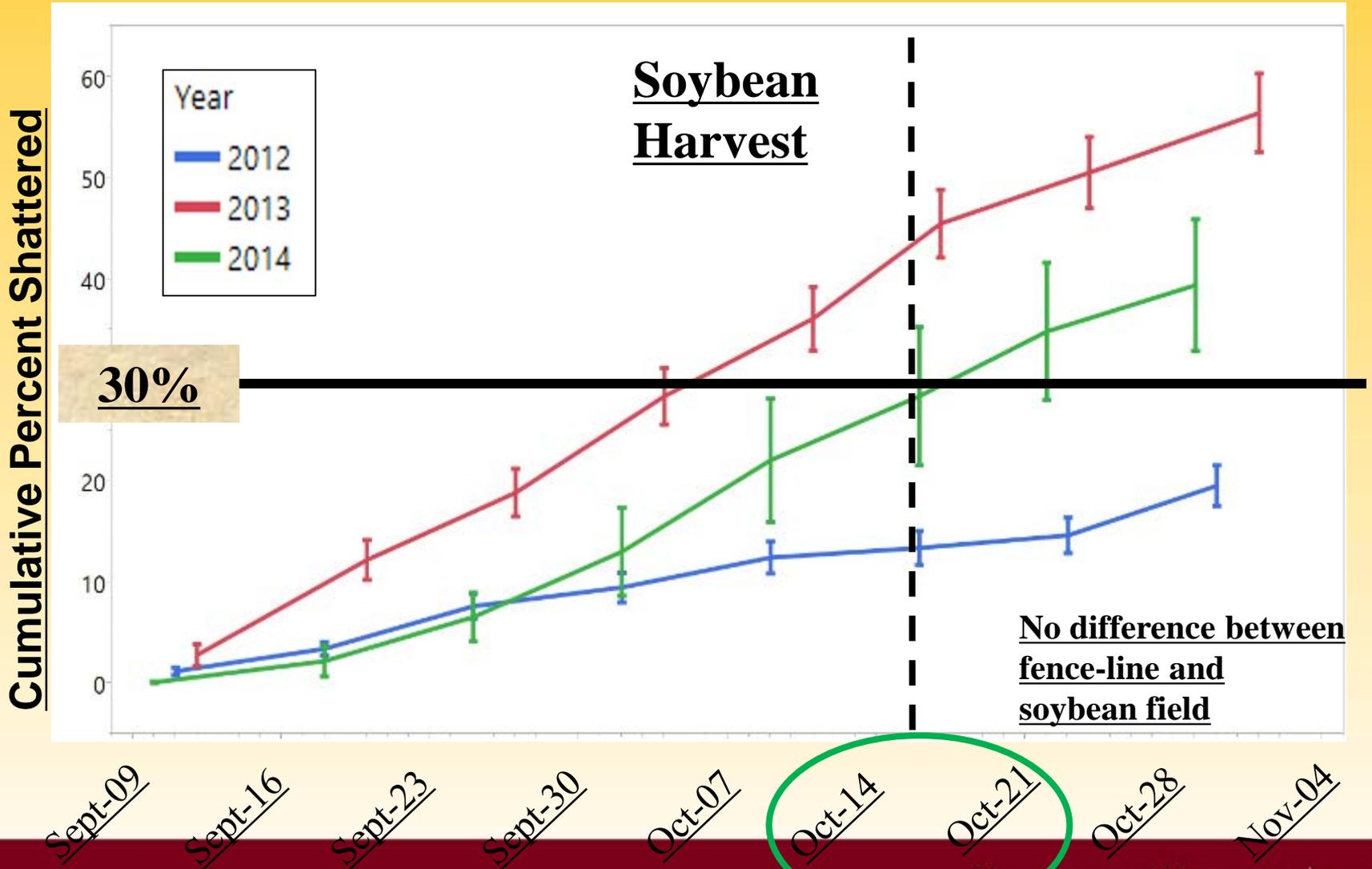
# Discovery #2

## Giant Ragweed Emergence



# Discovery #3

## Cumulative Percent of Seed Shattered



# How to maintain Zero Weed Threshold?

## 1. Crop Rotation:

- a) Fewer weed escapes in alfalfa and wheat treatments
- Less total emergence
  - Competitive
  - Different Sites of Action
  - Harvest schedule

## 2. Alter Timing

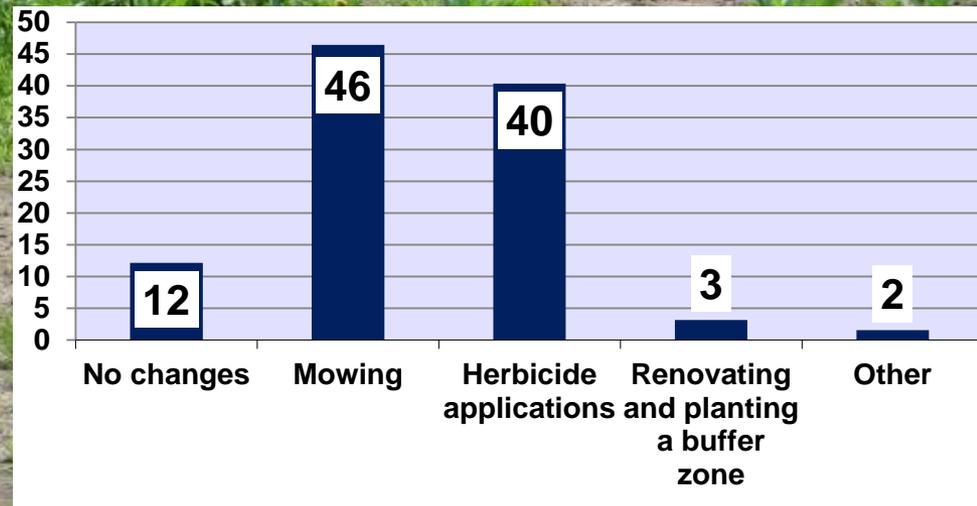
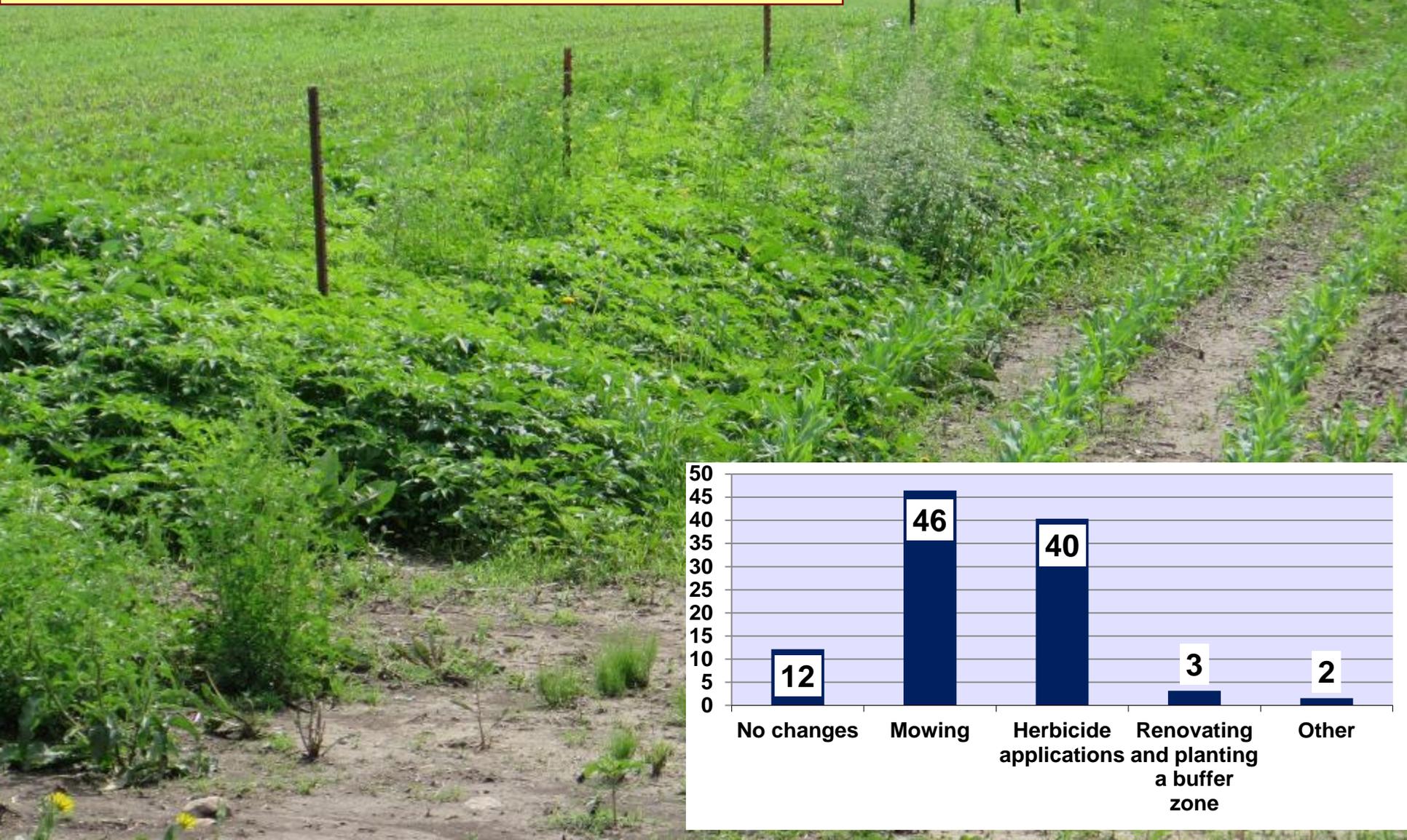
- a) Change planting, tillage, and herbicide application schedules to better target giant ragweed.
- b) 95% of giant ragweed emerged by June 9<sup>th</sup>

## 3. Giant Ragweed retains seed well into the fall

- a) **Only ~30% shattered by Oct. 15**
- b) Be mindful of seed retention: Mow your **Fence-lines**



**Make a conscious effort to control weeds in your fence rows / waterways**



# Which Message(s) will you address in 2016?

- **It's not simple anymore**
- **You need to map your weeds**
- **You need to keep fencerows, waterways clean**
- **You need to prevent weeds from going to seed**
- **You need to mix up your SOA's**
- **You need to use PRE's & maximum rates**
- **You need a more robust herbicide plan**
- **You need to dig out the iron**
- **New herbicides alone will Not take care of things.**



# Diversification decisions to consider

- Field map to strategically focus
- Plan – multiple years to address seed bank
- Plan “a” and Plan “b”
  - ✓ Plan “a” should always focus on early-season weed control
  - ✓ Plan “b” should target weeds <3 inches tall
- Decisions you will need to consider
  - ✓ Cost – short- and long-term
  - ✓ Time to implement
  - ✓ Labor requirements



# What is your opinion?

**If weeds resistant to multiple herbicides were to be confirmed in your community, which of the following statements would best describe your opinion about your neighbors' management decisions. (*Please select one answer only*)**

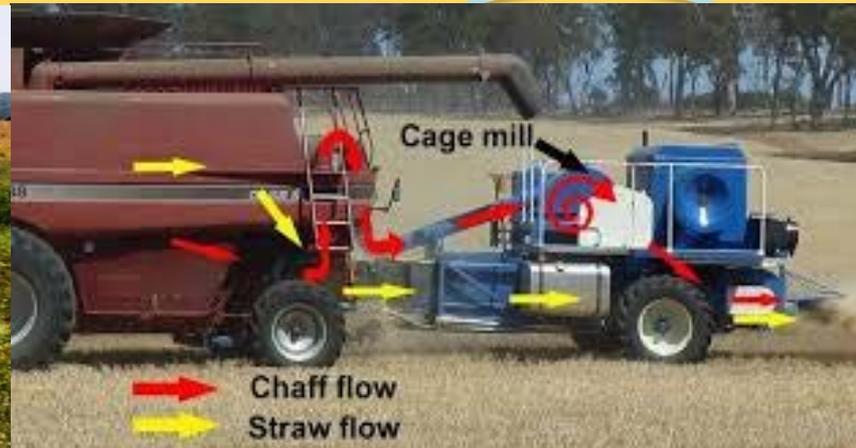
A. My neighbors' herbicide resistance management decisions would have no impact on my ability to manage herbicide resistance on my farm.

B. Even if my neighbors do not manage herbicide resistance, I could still effectively manage it on my own farm.

C. If my neighbors do not manage herbicide resistance, there is no way I could effectively manage it on my own farm.



# Rethink our weed management strategies



New technologies that need to be explored

