

# Herbicide Resistance Update:

*How Much Trouble Are We Asking For?*



- General update on herbicide resistance
  - Focus on Group 15 herbicides
  - Holistic strategies for weed management



2,4-D LV 4

1 pt

4-6"WH

09-DSO

2,4-D LV 4

2 pt

4-6"WH

09-DSO

CLARITY

8 oz

4-6"WH

09-DSO

IGNITE 280

22 oz

+N-PAK AMS

5 %

4-6"WH

09-DSO

Spring 2018



## Project Objective

*Survey and monitor the potential evolution of weeds with resistance to dicamba and glufosinate*

# Greenhouse Screening

Seed was threshed/cleaned by each university and submitted for testing.

- ▣ Palmer amaranth – University of Arkansas
- ▣ Waterhemp – University of Missouri
- ▣ Horseweed and others - Purdue University

Year Collected	Number of Populations		
	Palmer amaranth	Waterhemp	Horseweed and other
2018	71	74	87
2019	71	138	31
2020	139	111	59
2021	62	98	---
2022	72	108	---
2023	<i>in progress</i>	<i>in progress</i>	---
Total	415	529	177

- Horseweed discontinued after 2020.
- No other weed species were submitted as species of concern.
- 2,4-D screening started for 2021 collections.



# Herbicide Resistance Screen



☐ Classified populations by herbicide response group

● 100% Mortality

■ 95-100% Mortality

◇ 75-95% Mortality

✗ <75% Mortality

No apparent risk

Possible risk

Moderate risk

High risk

Risk Level for Potential Herbicide Resistance



Glufosinate: 32 oz/A  
21 DAT  
Southern Illinois



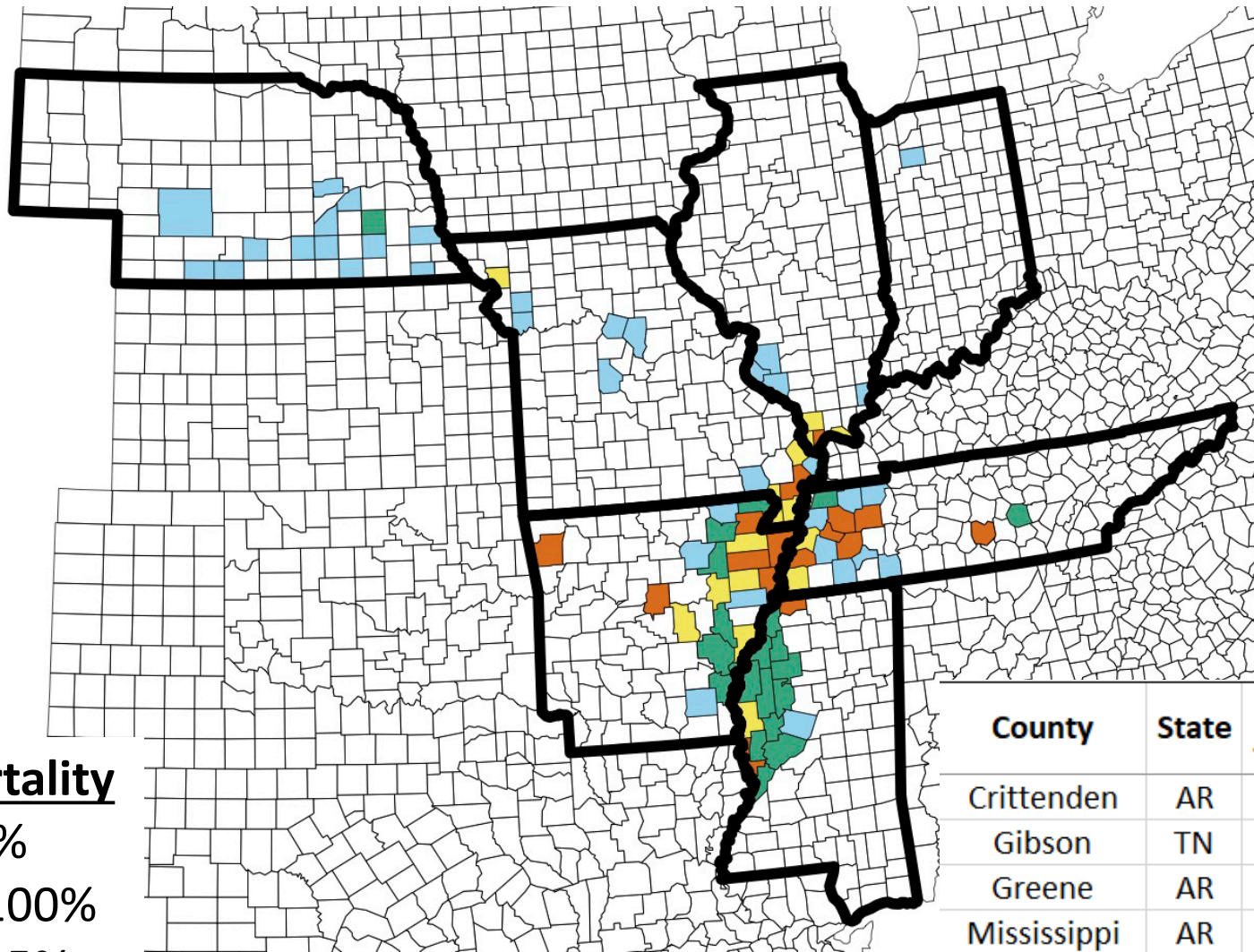
2,4-D: 1 lb ae/A  
21 DAT  
Southern Illinois



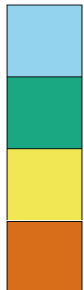
7 DAT (IN)



# Palmer Amaranth – Glufosinate



## Mortality



100%

95-100%

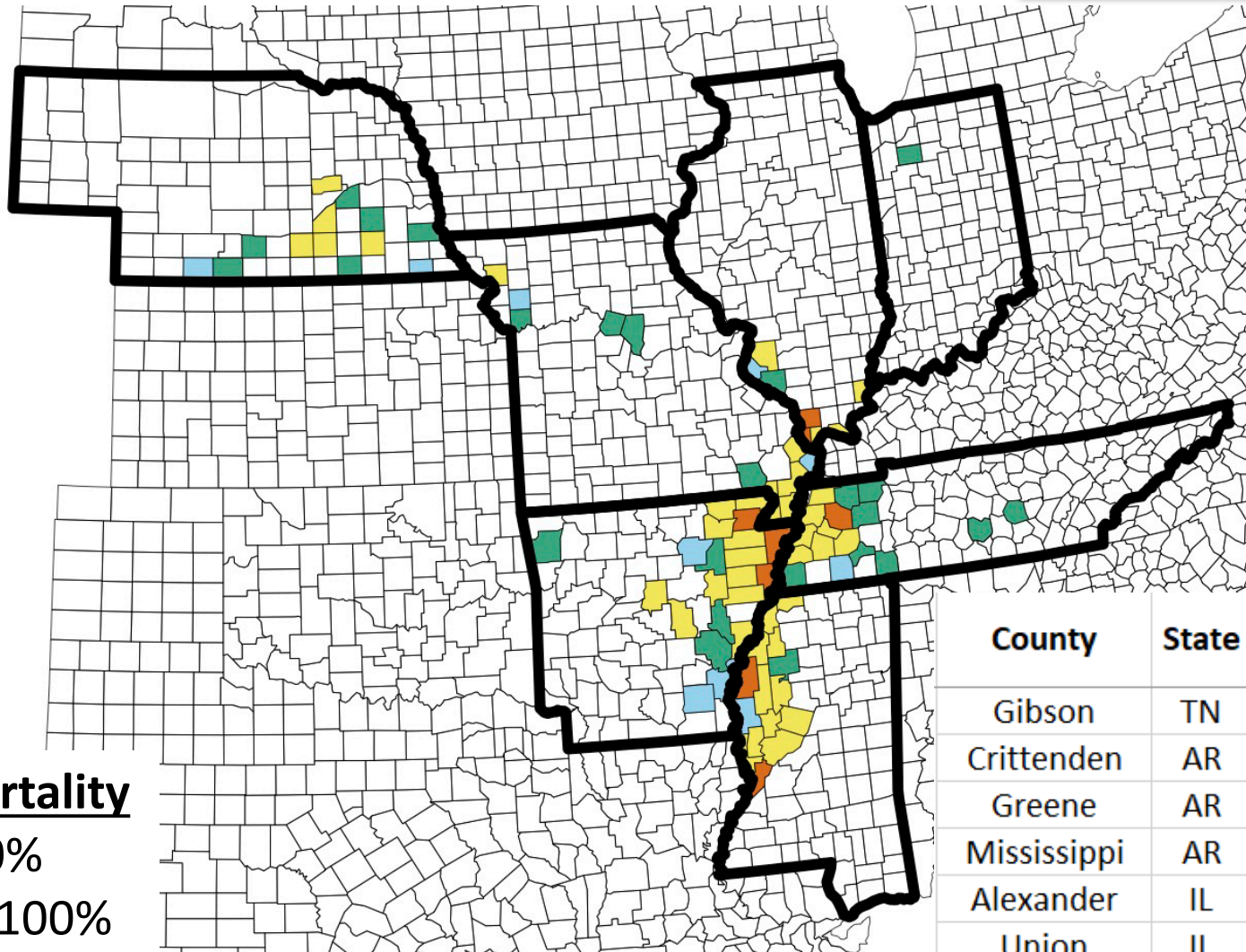
75-95%

<75%

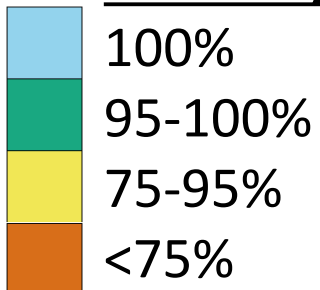
County	State	# Populations <75% Mortality
Crittenden	AR	4
Gibson	TN	3
Greene	AR	2
Mississippi	AR	2
Carroll	TN	2

\*Pooled over years (2018-2022)

# Palmer Amaranth – Dicamba



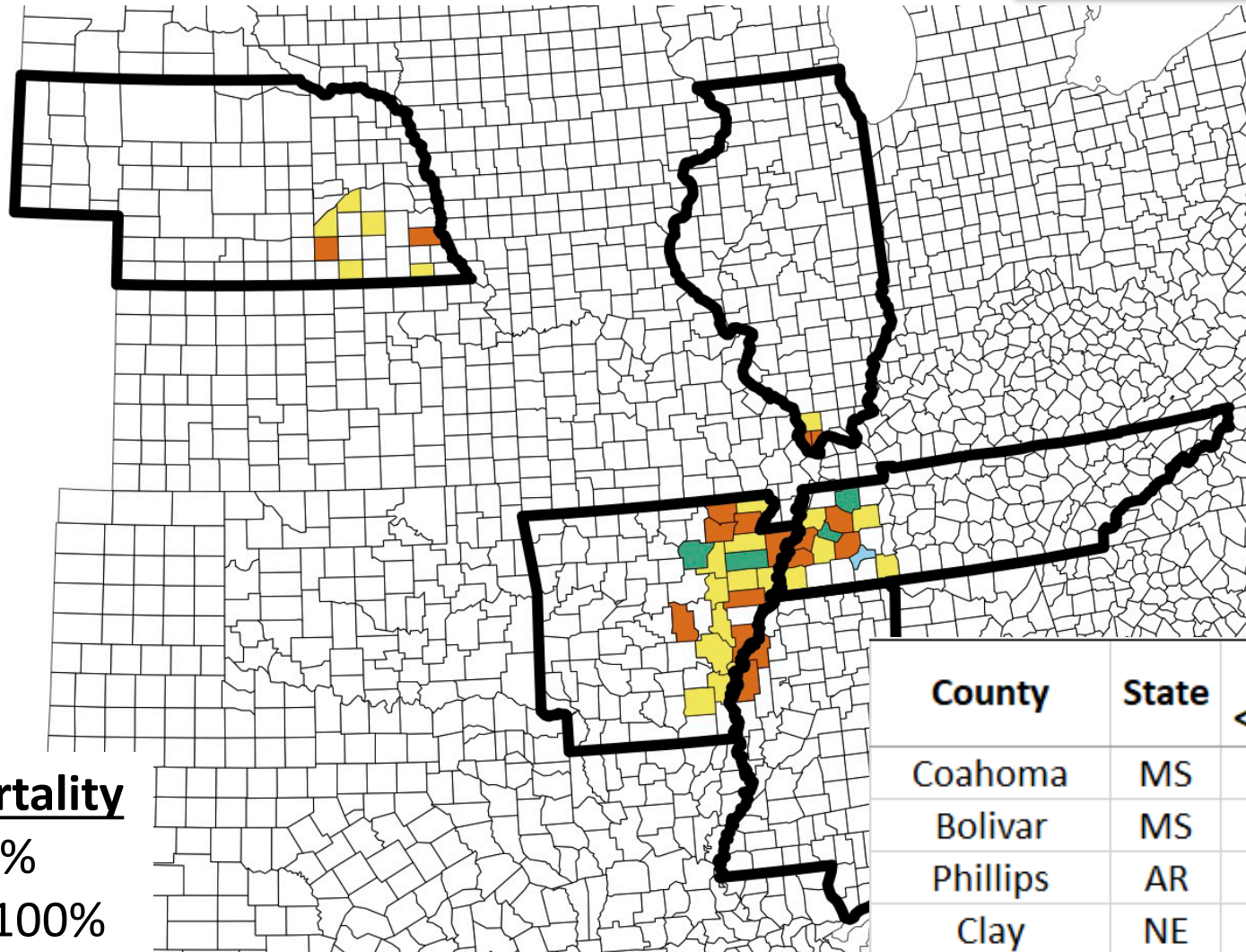
## Mortality



County	State	# Populations <75% Mortality
Gibson	TN	2
Crittenden	AR	1
Greene	AR	1
Mississippi	AR	1
Alexander	IL	1
Union	IL	1
Bolivar	MS	1

\*Pooled over years (2018-2022)

# Palmer Amaranth – 2,4-D



## Mortality

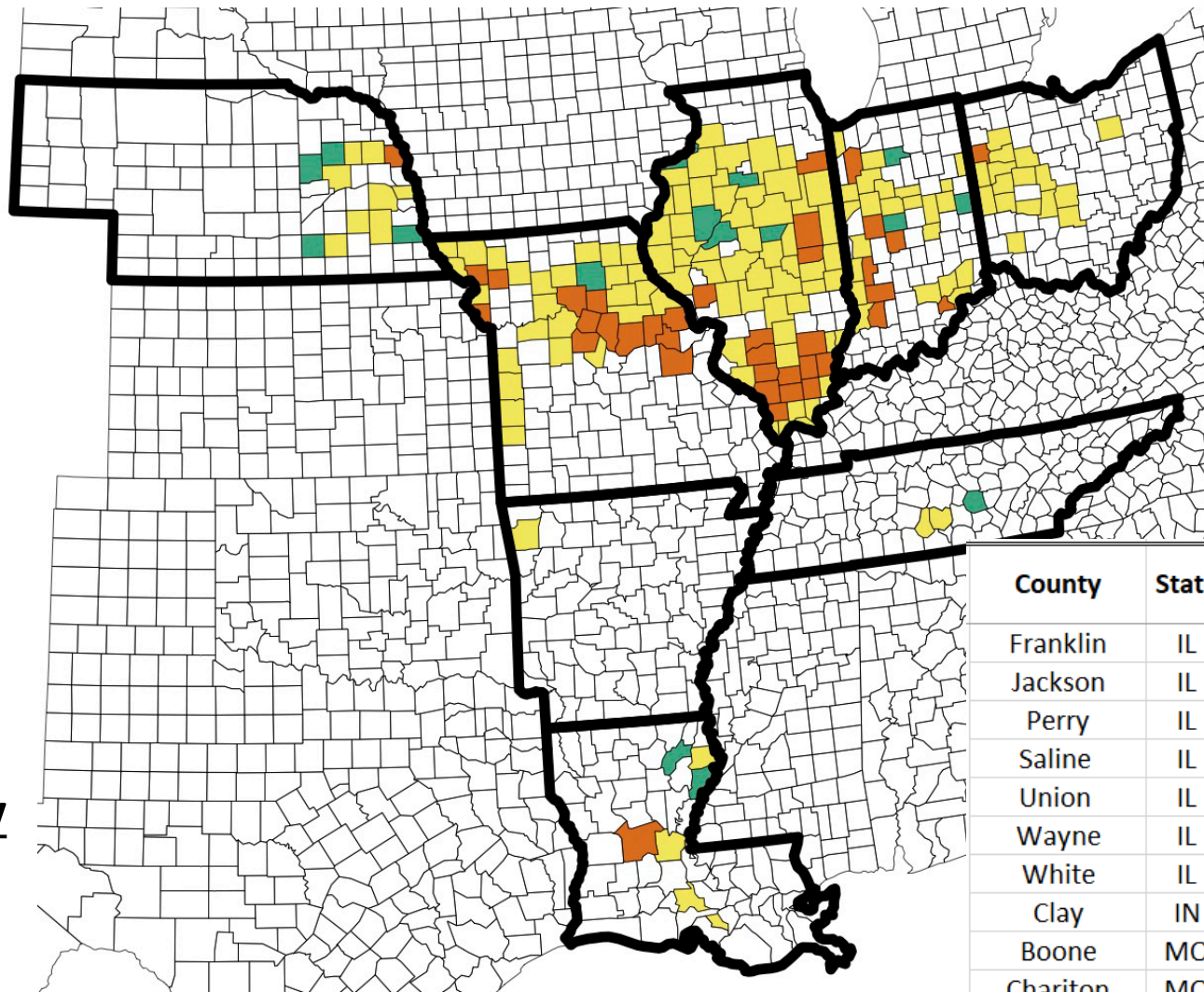


100%  
95-100%  
75-95%  
<75%

County	State	# Populations <75% Mortality
Coahoma	MS	4
Bolivar	MS	3
Phillips	AR	2
Clay	NE	2
Otoe	NE	2

\*Pooled over years (2021-2022)

# Waterhemp - Glufosinate



## Mortality

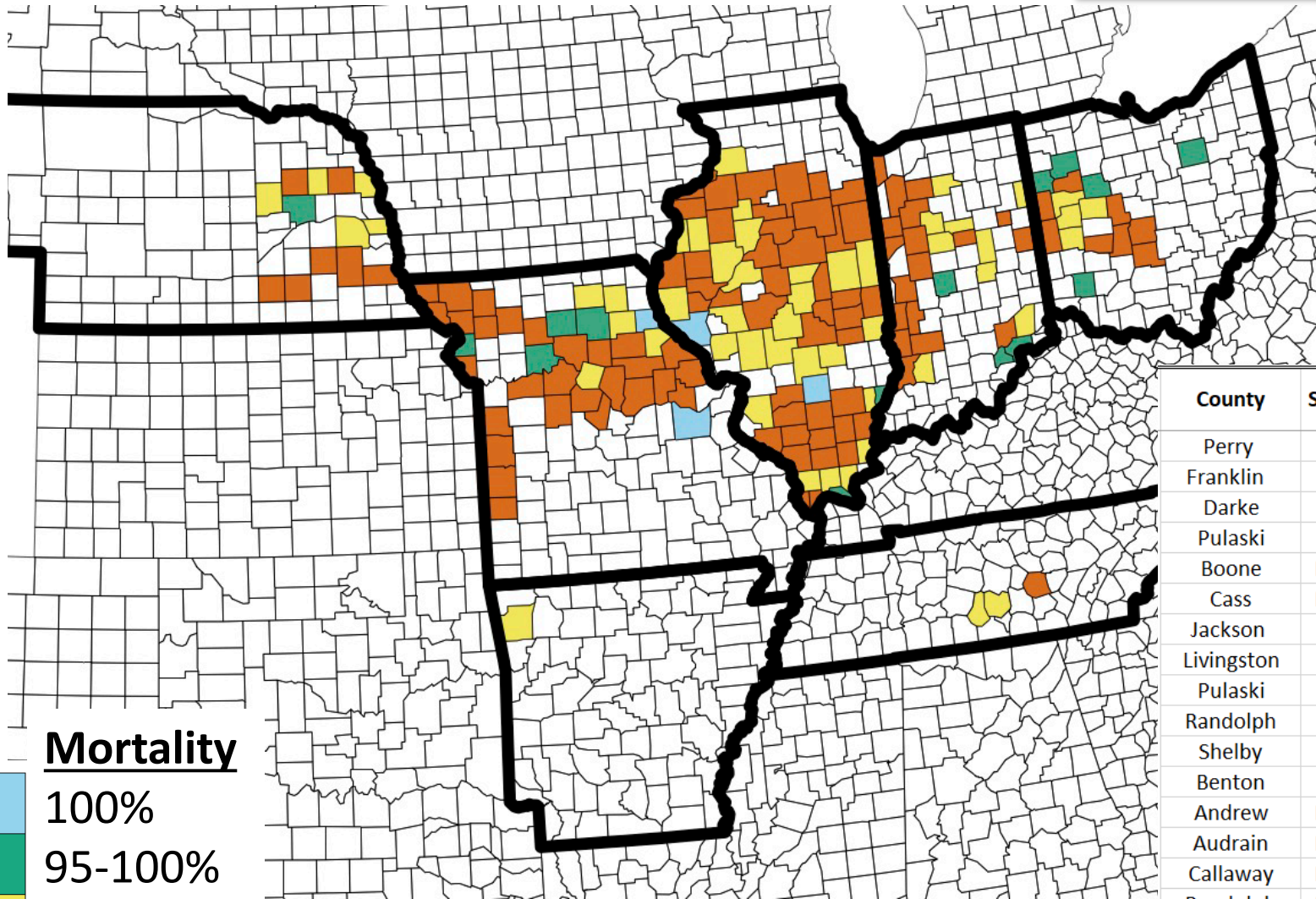


100%  
95-100%  
75-95%  
<75%

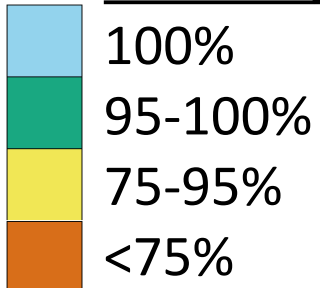
County	State	# Populations <75% Mortality
Franklin	IL	3
Jackson	IL	3
Perry	IL	3
Saline	IL	2
Union	IL	2
Wayne	IL	2
White	IL	2
Clay	IN	2
Boone	MO	2
Chariton	MO	2
Dekalb	MO	2

\*Pooled over years (2018-2022)

# Waterhemp - Dicamba



## Mortality

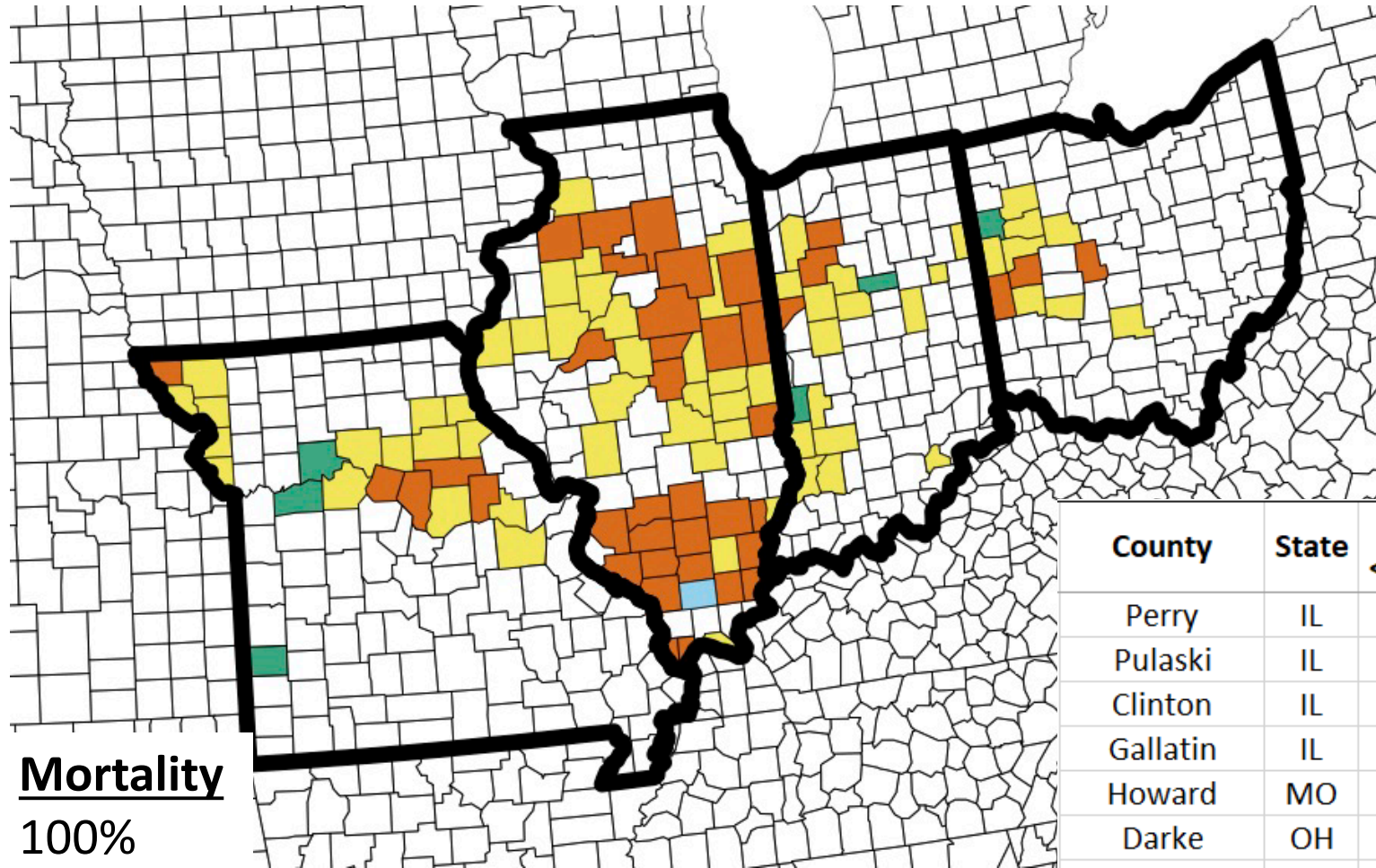


County	State	# Populations <75% Mortality
Perry	IL	7
Franklin	IL	6
Darke	OH	6
Pulaski	IN	5
Boone	MO	4
Cass	MO	4
Jackson	IL	3
Livingston	IL	3
Pulaski	IL	3
Randolph	IL	3
Shelby	IL	3
Benton	IN	3
Andrew	MO	3
Audrain	MO	3
Callaway	MO	3
Randolph	MO	3
Saline	MO	3

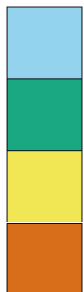
\*Pooled over years (2018-2022)



# Waterhemp – 2,4-D



## Mortality



100%

95-100%

75-95%

<75%

County	State	# Populations <75% Mortality
Perry	IL	3
Pulaski	IL	3
Clinton	IL	2
Gallatin	IL	2
Howard	MO	2
Darke	OH	2
Alexander	IL	1
Bureau	IL	1
Champaign	IL	1

\*Pooled over years (2021-2022)

# Project Outcomes



- ❑ 1,121 weed populations screened (2018-2022)
  - ▣ Fall 2023 samples in progress
- ❑ Confirmation of resistance to be conducted by each state

	Populations of Concern (<75% mortality with 1X rate)		Confirmed Resistance via Dose Response By State (no. of populations)	
Herbicide	Palmer Amaranth	Waterhemp	Palmer Amaranth	Waterhemp
Glufosinate	13	25	AR (3)	
Dicamba	8	74	TN (1)	IN (1), TN (1)
2,4-D	13	15	AR (3)	

# Herbicide Resistance in Indiana

Redroot/Smooth Pigweed	Atrazine
Common Lambsquarters	Atrazine
Jimsonweed	Atrazine
Kochia	Atrazine, cyanazine, metsulfuron-methyl
Common Ragweed	Cloransulam-methyl, imazethapyr, glyphosate
Giant Ragweed	Cloransulam-methyl, imazethapyr, glyphosate
Horseweed	Glyphosate, chlorimuron-ethyl, cloransulam-methyl
Giant Foxtail	Nicosulfuron, rimsulfuron
Johnsongrass	Nicosulfuron
Shattercane	Foramsulfuron, nicosulfuron
Common Waterhemp	Atrazine, Chlorimuron-ethyl, cloransulam-methyl, imazaquin, imazethapyr, glyphosate, fomesafen, lactofen, dicamba, mesotrione, tembotrione
Palmer Amaranth	Glyphosate, chlorimuron, cloransulam, fomesafen

Waterhemp resistance: Group 2, 4, 5, 9, 14, 27



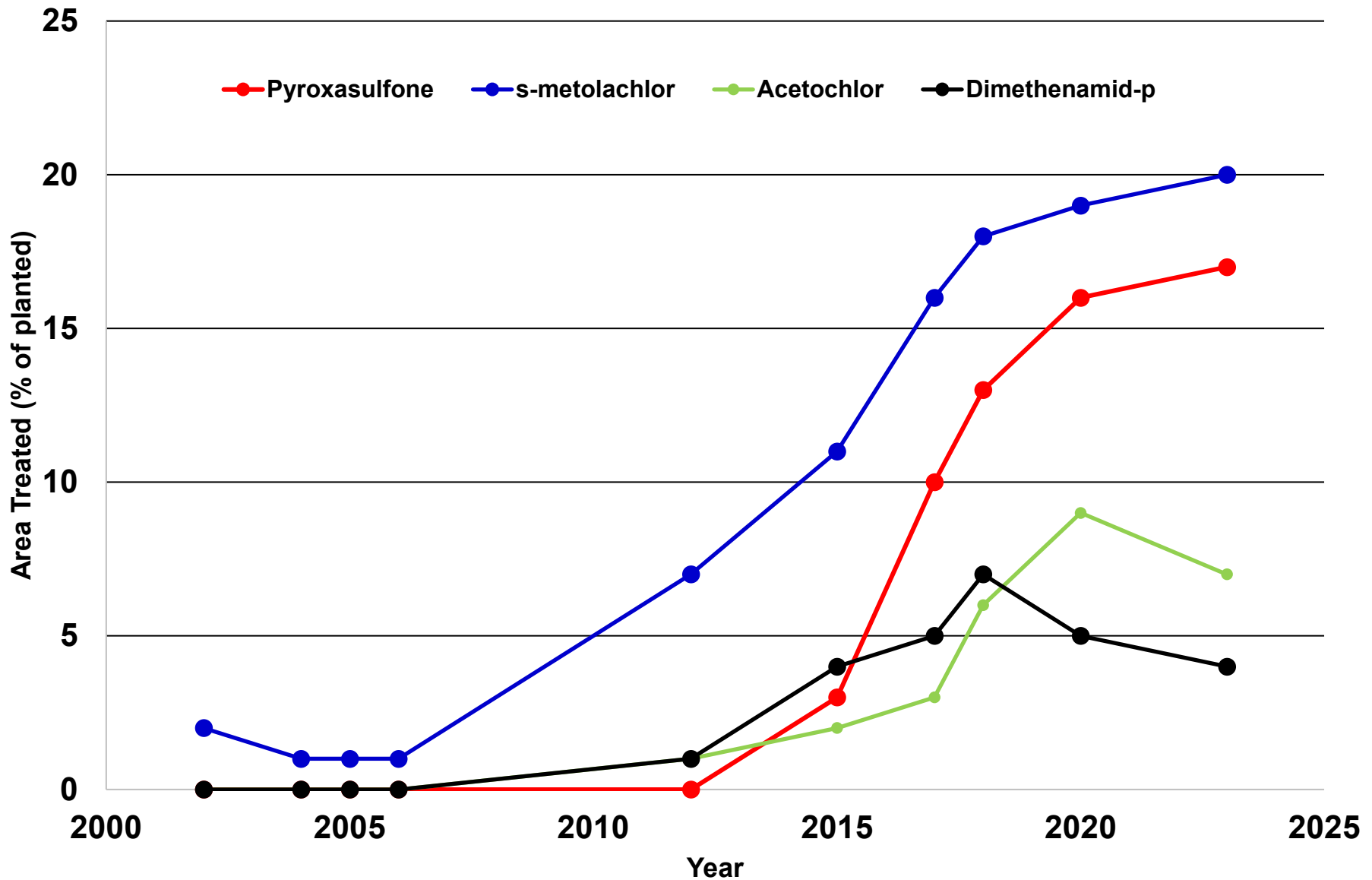
## **T or F**

Multiple applications of “reduced” rates of residual herbicides is OK, but never use reduced rates for POST herbicides.

- General update on herbicide resistance
  - Focus on **Group 15** herbicides
  - Holistic strategies for weed management



# Group 15 Herbicides in U.S. Soybean



**Table 2. Use characteristics for the primary Group 15 herbicides used in soybean.**

Characteristic	Pyroxasulfone	S-metolachlor	Acetochlor	Dimethenamid-P
<b>Application rate</b>				
Product use rate: <i>(See Table 3 for rate based on soil texture/OM)</i>	2.5-5.75 fl oz/ac (0.08-0.187 lb ai/ac; 90-210 g ai/ha)	1.0-2.0 pt/ac (0.95-1.9 lb ai/ac; 1,070-2,140 g ai/ha)	1.25-2.0 qt/ac (0.9375-1.5 lb ai/ac; 1,050-1,680 g ai/ha)	12-21 fl oz/ac (0.5625-0.98 lb ai/ac; 630-1,104 g ai/ha)
Soil factors determining labeled use rate	Soil texture	Soil texture/ Organic matter	Soil texture/ Organic matter	Soil texture/ Organic matter
Common product rate	3.25 fl oz/acre	1.33 pt/acre	48 fl oz/A	14 fl oz/A
Common use rate (lb/ac)	0.106	1.267	1.125	0.656
Ratio to pyroxasulfone	1	1:12	1:10.6	1:6.2
<b>Rotational Interval (months) to:</b>				
Clover	18	9	9	6-9
Winter wheat	0-6	4.5	4	4



# Use by Year and Crop

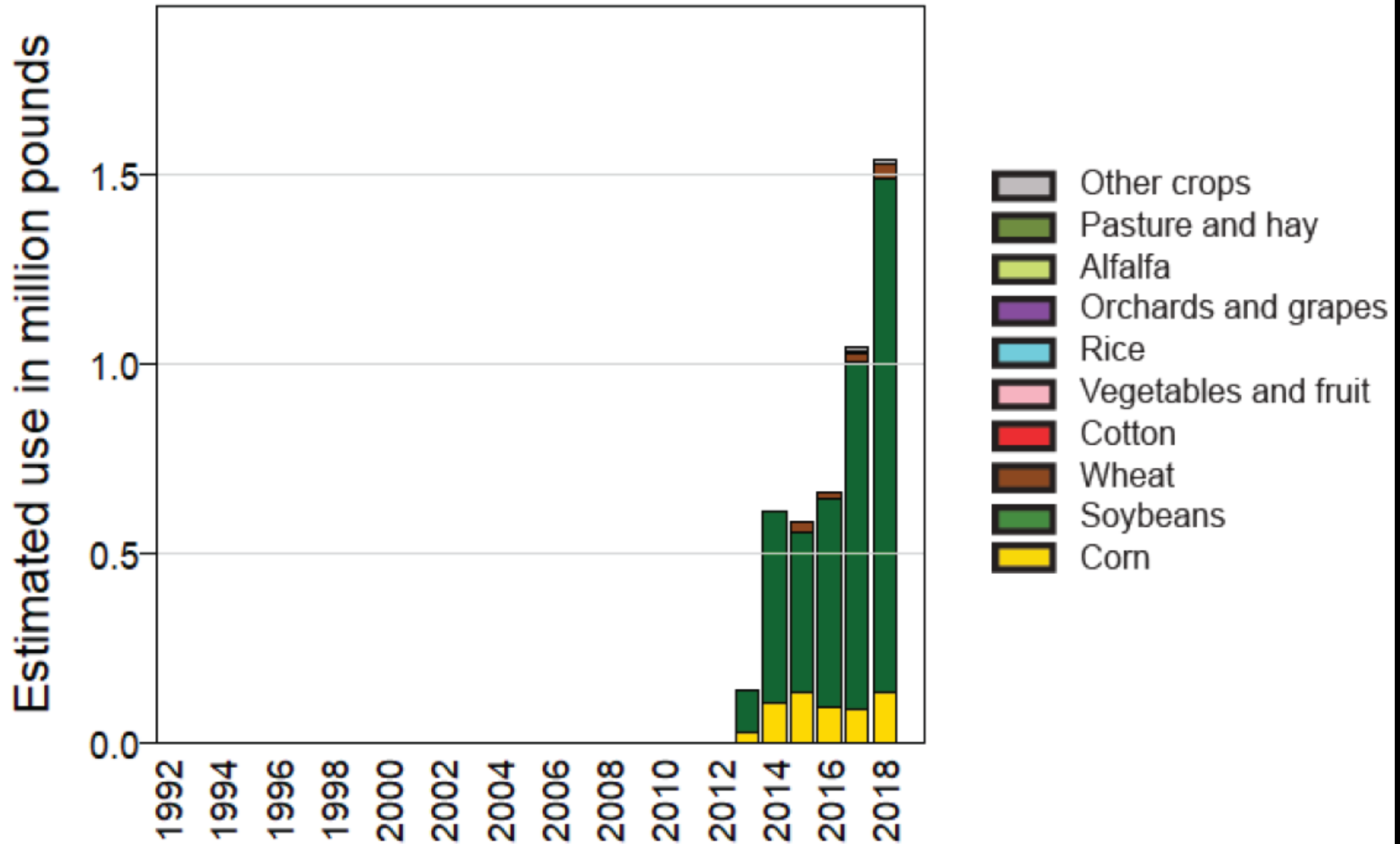


Figure 4. Historical use of pyroxasulfone by crop. Source: USGS 2024

# Pyroxasulfone Dose Response

Field Study – University of Nebraska

Species	50% Control (ED <sub>50</sub> )		90% Control (ED <sub>90</sub> )	
	28 DAT	45 DAT	28 DAT	45 DAT
	----- lb ai/acre-----			
Green foxtail	0.0294-0.0419	0.049-0.065	0.128-0.18	0.213-0.284
Large crabgrass	0.0312	0.0232	0.126	0.158
Tall waterhemp	0.0383	0.0731	0.136	0.177
Velvetleaf	0.0455	0.0678	0.177	0.267

(Knezevic et al. 2009)

# Pyroxasulfone Dose Response

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**~ 0.14 lb/ac or 4.3 oz/ac Zidua SC  
to achieve 90% control at 28 DAT**

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**~ 0.14 lb/ac or 4.3 oz/ac Zidua SC  
to achieve 90% control at 28 DAT**

**~ 0.18 lb/ac or 5.5 oz/ac Zidua SC  
to achieve 90% control at 45 DAT**

**Table 5. Pyroxasulfone rate comparison across common premix products used in corn and soybean.**

Herbicide Premix <i>(product rate)</i>	Crop	Equivalent Product Rates		
		Zidua SC (Pyroxasulfone) <i>fl oz rate (lb/acre)</i>	Component 2 <i>Product: rate (active lb/acre)</i>	Component 3
Anthem Maxx (2 fl oz)	Corn/soybean	2.0 (0.065)	Cadet: 0.28 fl oz (fluthiacet 0.002)	
Anthem Maxx (6.5 fl oz)	Corn/soybean	6.51 (0.212)	Cadet: 0.9 fl oz (fluthiacet 0.0064)	
Authority Supreme (7.7 fl oz)	Soybean	3.83 (0.125)	Spartan 4F: 4.04 fl oz (Sulfentrazone 0.127)	
Authority Supreme (11.6 fl oz)	Soybean	5.78 (0.188)	Spartan 4F: 6.03 fl oz (sulfentrazone 0.188)	
Fierce EZ (6 fl oz)	Corn/soybean	2.44 (0.079)	Valor SX: 1.96 dry oz (flumioxazin 0.062)	
Fierce EZ (7.5 fl oz)	Soybean	3.07 (0.1)	Valor SX: 2.46 dry oz (flumioxazin 0.078)	
Fierce MTZ (1 pt)	Soybean	2.44 (0.079)	Valor SX: 1.96 dry oz (flumioxazin 0.062)	Tricor 75DF: 4 dry oz (metribuzin 0.187)
Fierce MTZ (1.5 pt)	Soybean	3.7 (0.12)	Valor SX: 2.94 dry oz (flumioxazin 0.094)	Tricor 75DF: 6 dry oz (metribuzin 0.28)
Fierce XLT (4 dry oz)	Soybean	2.38 (0.078)	Valor SX: 1.93 dry oz (flumioxazin 0.062)	Classic: 1.0 dry oz (chlorimuron 0.017)
Perpetuo (10 fl oz)	Corn/soybean	4.1 (0.134)	Resource: 6.9 fl oz (flumiclorac 0.046)	
Maverick (24 fl oz)	Corn	4.0 (0.13)	Callisto: 5 fl oz (mesotrione 0.155)	Stinger: 5.5 fl oz (clopyralid 0.13)
Storen (2.4 qt)	Corn	2.76 (0.09)	Callisto: 5.95 fl oz (mesotrione 0.186) Optogen: 3.45 fl oz (bicyclopyrone 0.045)	Dual II Magnum: 1.7 pt (s-metolachlor 1.61)
Surtain (14 fl oz)	Corn	3.37 (0.11)	Sharpen: 3.08 fl oz (saflufenacil 0.069)	
Zidua Pro (4.5 fl oz)	Soybean	2.46 (0.08)	Sharpen: 0.76 fl oz (saflufenacil 0.017)	Pursuit: 3 fl oz (imazethapyr 0.046)
Zidua Pro (6.0 fl oz)	Soybean	3.28 (0.107)	Sharpen: 1.0 fl oz (saflufenacil 0.022)	Pursuit: 4 fl oz (imazethapyr 0.062)

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Fierce MTZ (1 pt)	Soybean	2.44 (0.079)	Valor SX: 1.96 dry oz (flumioxazin 0.062)	Tricor 75DF: 4 dry oz (metribuzin 0.187)
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Zidua Pro (6.0 fl oz)	Soybean	3.28 (0.107)	Sharpen: 1.0 fl oz (saflufenacil 0.022)	Pursuit: 4 fl oz (imazethapyr 0.062)

**Table 3. Application rate structure based on soil texture and organic matter content for the primary Group 15 herbicides used in soybean.**

<b>Soil Texture/ Herbicide</b>	<b>Less than 3% OM</b>	<b>3% or greater OM</b>
<b>Coarse</b>		
<b>Zidua SC</b>	2.5-3.5 fl oz/ac	2.5-3.5 fl oz/ac
<b>Dual Magnum</b>	1.0-1.33 pt/ac	1.33 pt/ac
<b>Warrant*</b>	1.25-1.6 qt/ac (<1.5% OM)	1.25-1.7 qt/ac (≥1.5% OM)
<b>Outlook</b>	12-14 fl oz/ac	14-18 fl oz/ac
<b>Medium</b>		
<b>Zidua SC</b>	3.25-5.0 fl oz/ac	3.25-5.0 fl oz/ac
<b>Dual Magnum</b>	1.33-1.67 pt/ac	1.33-1.67 pt/ac
<b>Warrant*</b>	1.25-1.7 qt/ac (<1.5% OM)	1.25-1.9 qt/ac (≥1.5% OM)
<b>Outlook</b>	14-18 fl oz/ac	18-21 fl oz/ac
<b>Fine</b>		
<b>Zidua SC</b>	4.0-5.75 fl oz/ac	4.0-5.75 fl oz/ac
<b>Dual Magnum</b>	1.33-1.67 pt/ac	1.67-2.0 pt/ac
<b>Warrant*</b>	1.25-1.9 qt/ac (<1.5% OM)	1.25-2.0 qt/ac (≥1.5% OM)
<b>Outlook</b>	14-18 fl oz/ac	18-21 fl oz/ac

*\*Application rates for Warrant are grouped into soils with “Less than 1.5% OM” and “1.5% or greater OM”*

# Characterization of multiple herbicide-resistant waterhemp (*Amaranthus tuberculatus*) populations from Illinois to VLCFA-inhibiting herbicides

Seth A. Strom<sup>1</sup>, Lisa C. Gonzini<sup>2</sup>, Charlie Mitsdarfer<sup>3</sup>, Adam S. Davis<sup>4</sup>,  
Dean E. Riechers<sup>4</sup> and Aaron G. Hager<sup>5</sup>

- ❑ Resistant to 2,4-D, HPPD, PSII, ALS and PPO
- ❑ Field PRE applications
  - **56-75% control @ 28DAT**: Nonencapsulated acetochlor, alachlor, pyroxasulfone
  - **<27% control @ 28 DAT**: metolachlor, s-metolachlor, dimethenamid-P, encapsulated acetochlor
- ❑ **Greenhouse resistance ratios**: s-metolachlor (7.5x), acetochlor (6.1x), dimethenamid-P (5.5x), pyroxasulfone (2.9x)



- General update on herbicide resistance
  - Focus on Group 15 herbicides
  - **Holistic strategies for weed management**



Waterhemp resistance: Group 2, 4, 5, 9, 14, 27





Tippecanoe Co. 2019

# Metabolic Herbicide-Resistance

- Primary mechanism for waterhemp resistance to:
  - ▣ Atrazine
  - ▣ Group 15 herbicides (metolachlor, acetochlor, etc.)
  - ▣ Group 27 herbicides (mesotrione, topramezone)
  
- Some association with waterhemp resistance to:
  - ▣ Group 2 herbicides (ALS-inhibitors)
  - ▣ Group 4 herbicides?? (2,4-D, dicamba)
  - ▣ Group 14 herbicides?? (flumioxazin, fomesafen)

# Soybean Herbicide Traits



## Three Generations of Soybean Herbicide Tolerance Traits

Technologies Provide Solutions to Address Farmer's Needs, Herbicide Resistance Challenges

**3** herbicide tolerances

**XtendFlex**  
SOYBEANS

- Glyphosate
- Dicamba
- Glufosinate

**LAUNCHED**  
in 2021 on ~16m  
commercial acres



June 29<sup>th</sup>, 2021 / Storm Lake, Iowa

**5** herbicide tolerances

**HT4**  
Fourth-Gen  
Phase 3

- Glyphosate
- Dicamba
- Glufosinate
- HPPD
- 2,4-D

Expected 2027  
launch



July 14<sup>th</sup>, 2021 / Jerseyville, Illinois

**6** herbicide tolerances

**HT5**  
Fifth-Gen  
Phase 2

- Glyphosate
- Dicamba
- Glufosinate
- HPPD
- 2,4-D
- PPO



July 14<sup>th</sup>, 2021 / Jerseyville, Illinois

Always read and follow label instructions. Products not registered in all jurisdictions.

# Multiple Choice

**What's the fastest way to evolve weed resistance to a herbicide?**

- A. Overlapping residual herbicides
- B. Follow University of Nebraska recommendations
- C. Achieve the greatest herbicide diversity possible
- D. Rely on postemergence herbicides as your main solution
- E. Let farmer's in Arkansas use it.



# Dos & Don'ts of Residual Herbicide Use

## Do:

- Obey all the Don't rules

## Don't:

- Use a single, effective herbicide MOA group for the most problematic weeds
  - Don't exacerbate PPO resistance by using just a PPO soil residual
- Hold back on residual because you have an effective POST herbicide
- Apply the residual herbicide much before you expect weed emergence
  - Don't use the same residual strategy on 'ultra early' soybeans as normal planting
- Fail to consider label restrictions and potential for excessive crop response
- Bother with the longest lasting residual herbicide as the overlapping POST herbicide if close to canopy closure.....crop canopy is your friend
- Forget to consider carryover to fall cover crops
- Overweigh herbicide chemical properties....the weather doesn't yield to logic



# Greatest Weed Management Challenges

- ❑ Multiple herbicide resistance
  - ▣ Numerous weed species
  - ▣ Broad geography
  - ▣ Resistance mechanisms continually evolving
  
- ❑ No easy solutions
  - ▣ New crop traits are for 'old' herbicides
  - ▣ Regulatory constraints on herbicide use
  - ▣ No novel herbicide sites of action developed
  
- ❑ Poor application practices
  
- ❑ Growers implementing 'band-aide' strategy
  - ▣ BMPs not adopted due to complexity



# Thank You!

