



Join the Fight Against Herbicide-Resistant Waterhemp



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The Waterhemp Conundrum:

How do you manage a weed population for which there might **not** be **any** viable postemergence herbicide options for its control and reduced residual control from many soil-applied herbicides?



Herbicide Resistance in Waterhemp

Several biological characteristics of waterhemp 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

Herbicide Resistance in Waterhemp

Resistance in Illinois waterhemp

has been documented to herbicides

from seven site-of-action (SOA) classes

- ALS inhibitors
- triazines
- PPO inhibitors
- glyphosate
- HPPD inhibitors
- auxinic herbicides (2,4-D and dicamba)
- VLCFA inhibitors (Group 15)

VLCFA-inhibitors

- **Group 15 Herbicides**

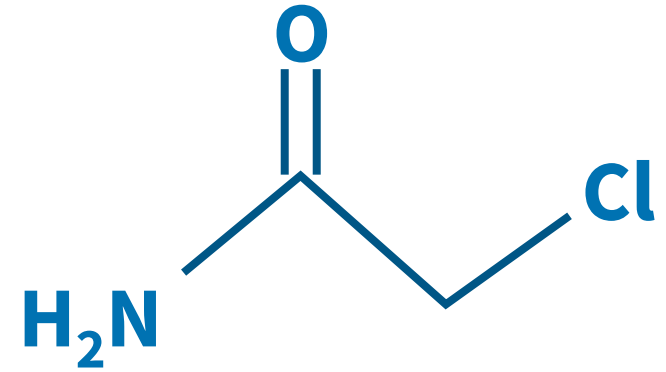
Discovered in the 1950s

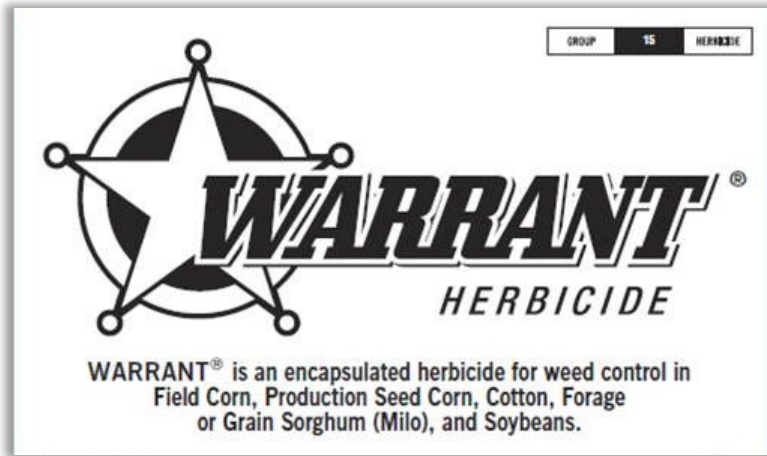
- **Preemergence (PRE) activity**

- **Target VLCFA elongases**

- Plants starve for very long chain fatty acids (VLCFAs)
- Essential for the formation of cuticle waxes and cellular membranes

- **Sensitive plants either fail to emerge or remain in an arrested state of growth after emergence**





Old Chemistries Today

Important for PRE control of
annual monocots and small-seeded dicots

Waterhemp and Palmer amaranth

Residual components in many herbicide premixes

Especially in soybean production

Important components of
layered residual herbicide programs in soybean

Extend soil-residual control after POST application

Resistance is rare

~13 species worldwide, only three dicot species (two species of *Amaranthus*)

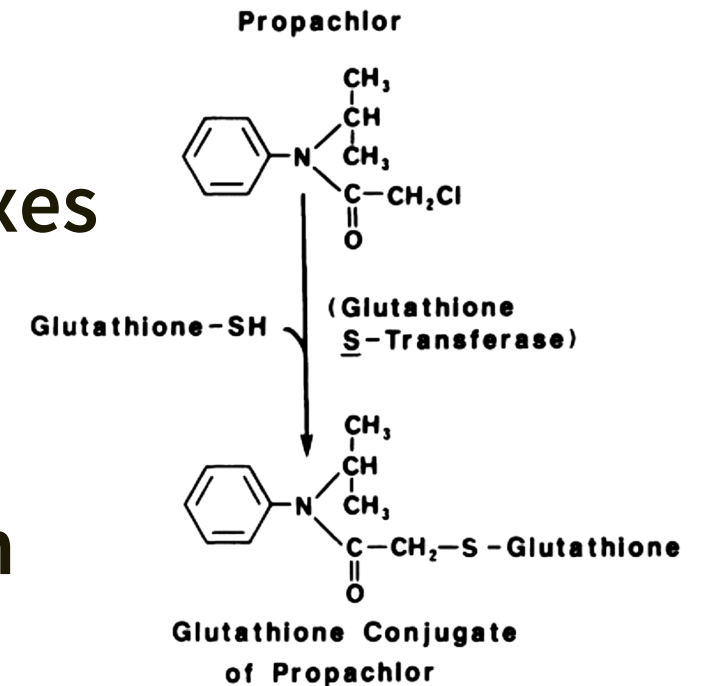


Figure 1. Metabolism of propachlor to the glutathione conjugate

Fuerst 1987

Callisto
12 fl oz/A
14 DAT

103

06.22.2010 14:38

Responses of an HPPD Inhibitor-Resistant Waterhemp (*Amaranthus tuberculatus*) Population to Soil-Residual Herbicides (Hausman et al. 2013)

Table 4. Mean estimates^a of control and density of McLean Co., IL waterhemp 30 and 60 d after treatment (DAT) of soil-applied herbicides in corn.

Herbicide	Rate g ai ha ⁻¹	2010				2011			
		Control		Density		Control		Density	
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
		%		plants m ⁻²		%		plants m ⁻²	
Isoxaflutole	105	65 cd	57 c	443 cde	103 cde	62 c	25 de	217 ab	120 ab
Isoxaflutole	210	90 a	87 a	48 g	9 fg	83 ab	48 bc	55 cde	55 cd
Isoxaflutole + safener ^b	105	68 cd	60 bc	263 def	69 def	62 c	27 de	263 a	145 a
Isoxaflutole + safener ^b	210	87 ab	85 a	137 fg	32 efg	73 bc	38 cd	105 bc	89 abc
Mesotrione	210	53 d	50 c	417 cde	141 bcd	58 c	38 cd	65 cd	67 bc
Mesotrione	420	73 bc	48 c	191 efg	51 efg	83 ab	62 b	33 de	25 de
Atrazine	1680	8 e	7 d	859 ab	292 ab	58 c	17 e	191 ab	141 a
Atrazine	3360	13 e	8 d	520 bcd	248 abc	78 bc	22 de	115 bc	129 a
Acetochlor	1680	87 ab	82 ab	125 fg	49 defg	83 ab	62 b	19 de	16 e
Acetochlor	3360	93 a	88 a	93 fg	4 g	94 a	85 a	5 e	5 e
S-metolachlor	1600	17 e	7 d	596 abc	215 abc	18 d	17 e	200 ab	120 a
Nontreated	—	—	—	1067 a	363 a	—	—	260 a	145 a

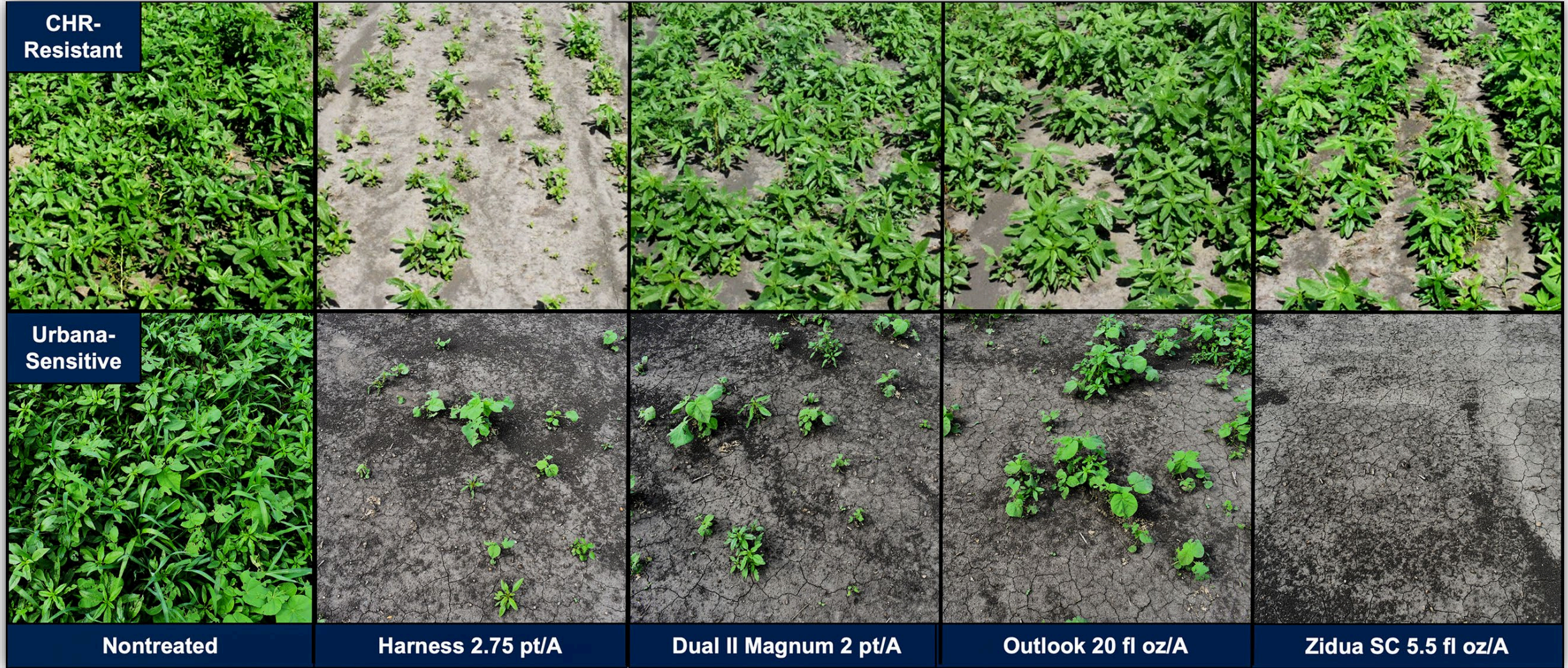
^a Means with the same letter within a column are not significantly different at $\alpha = 0.05$ (separated by the SAS macro %pdmix800).

^b Cyprosulfamide.

Background

- Less than expected PRE control of the first HPPD-resistant population from **McLean Co., Illinois (MCR)** with S-metolachlor
- Similar observations on another HPPD-resistant population from **Champaign Co., IL (CHR)**
- Very few Group 15 products provide acceptable PRE control of CHR
- Previous greenhouse experiments revealed a large difference between progeny of CHR and a known sensitive in response to acetochlor and S-metolachlor

Field Results 28 DAT 2020



Greenhouse Dose-Response

Materials and Methods

- 15 seeds planted per container
 - 1801 cell pack inserts (8 x 8 cm)
 - 1:1:1 sand, soil, peat with 3.5% OM and pH of 6.4
- Applied herbicides (PRE)
- Treated pots covered with untreated soil
 - Busi and Powles (2016) Pest Management Science
- Placed in overhead mister

Herbicides

Dual II Magnum

0.125 fl oz – 1 gallon

Harness

0.04 fl oz – 2.6 pts

Outlook

0.07 fl oz – 66 fl oz

Zidua SC

0.02 fl oz – 21 fl oz

- Rates set on $\log_{3.16}$ scale
- Survival and biomass recorded 21 DAT
- Analyzed in the drc package in R

Results 21 DAT: Dual II Magnum



CHR-M6

MCR-NH40

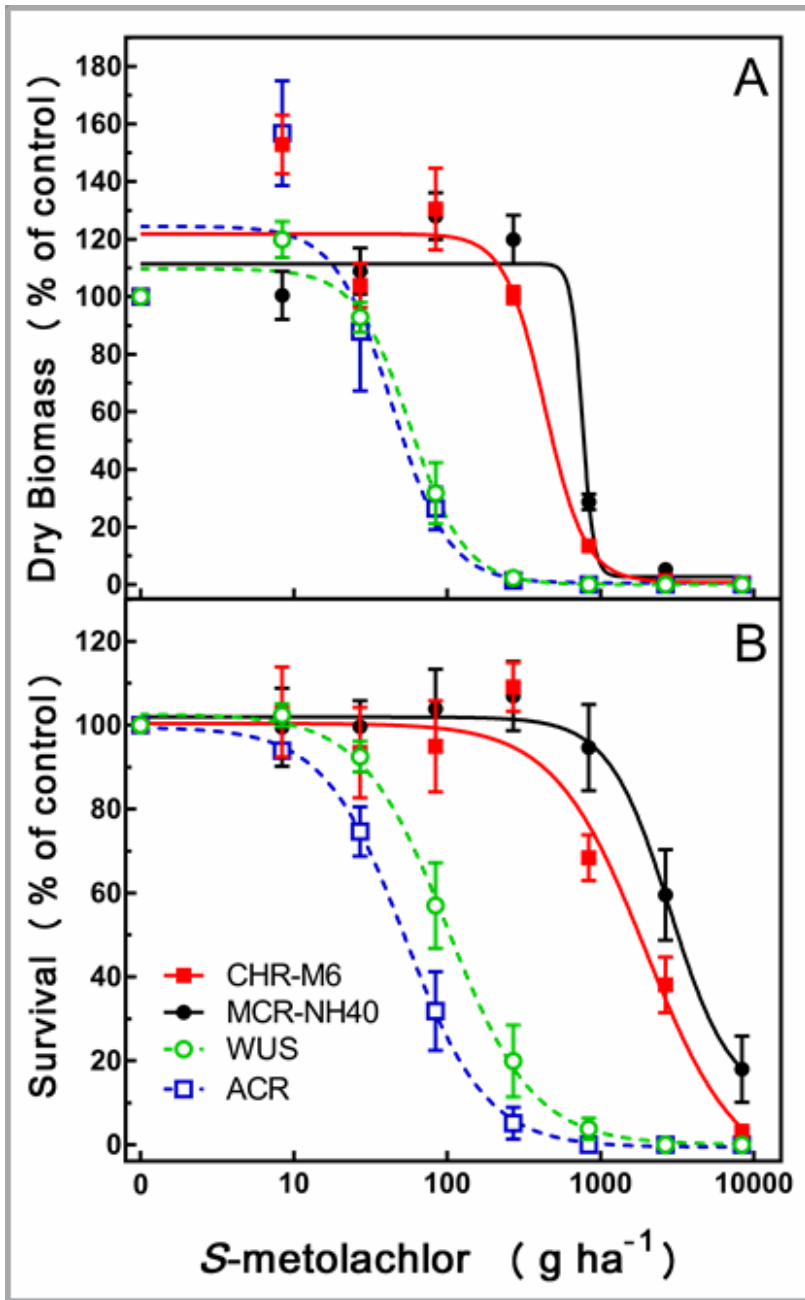
WUS

ACR

0 8.4 27 84 270 840 2,700 8,400 g ha⁻¹

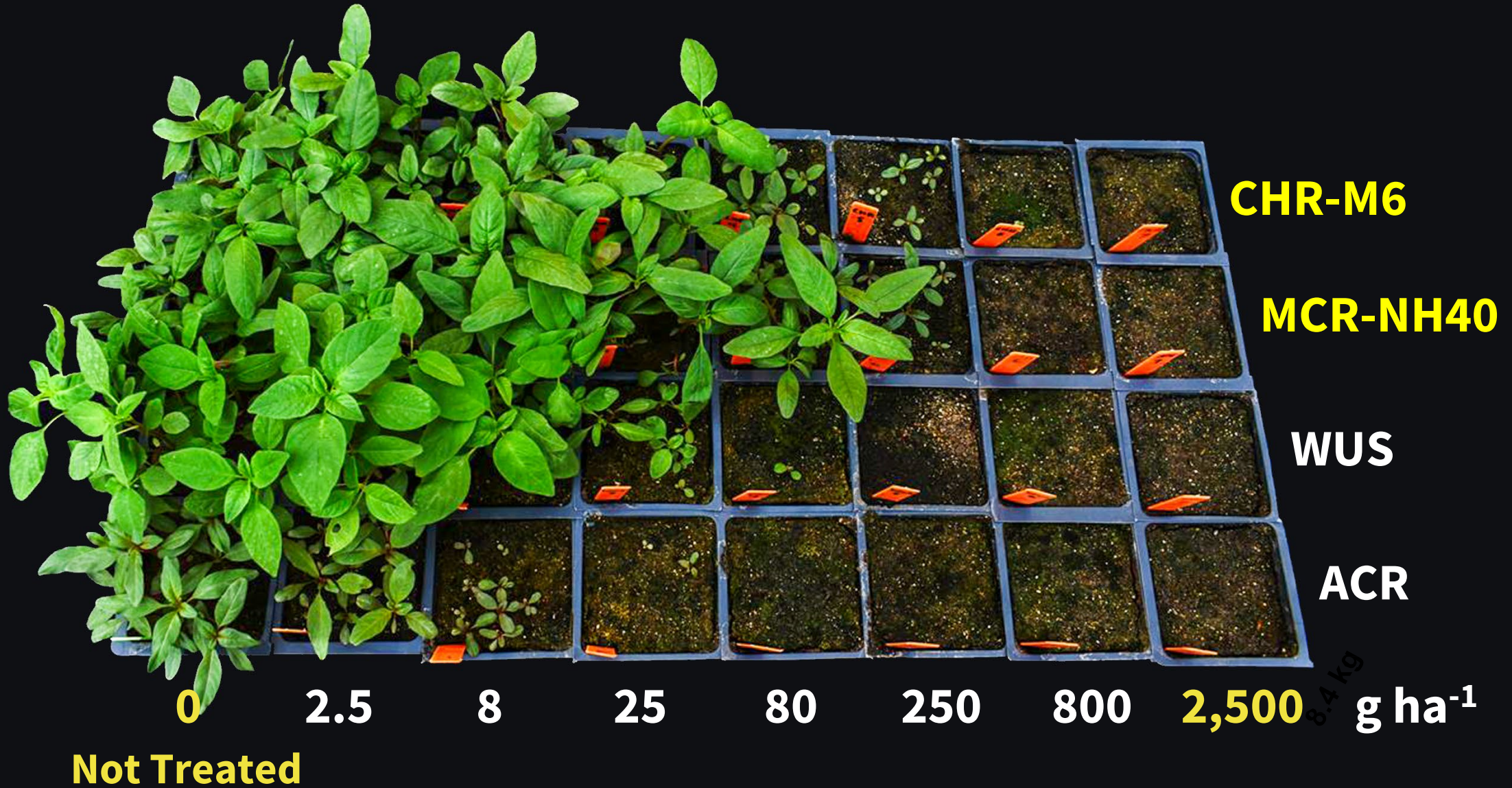
Not Treated

Results 21 DAT: Dual II Magnum

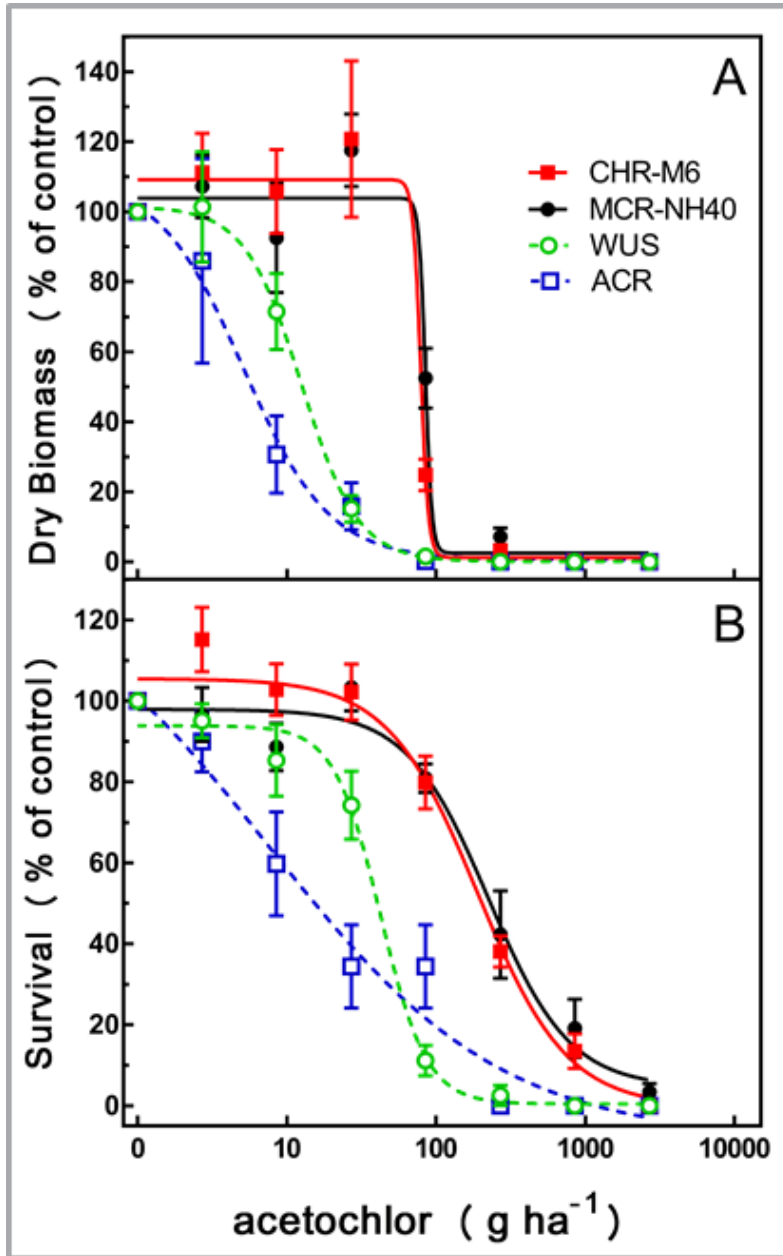


Population	LD ₅₀	R:S	GR ₅₀	R:S
CHR-M6	1,808	18	431	7.5
		34		9.9
MCR-NH40	3,360	33	742	13
		64		17
WUS	101		57	
ACR	53		44	

Results 21 DAT: Harness



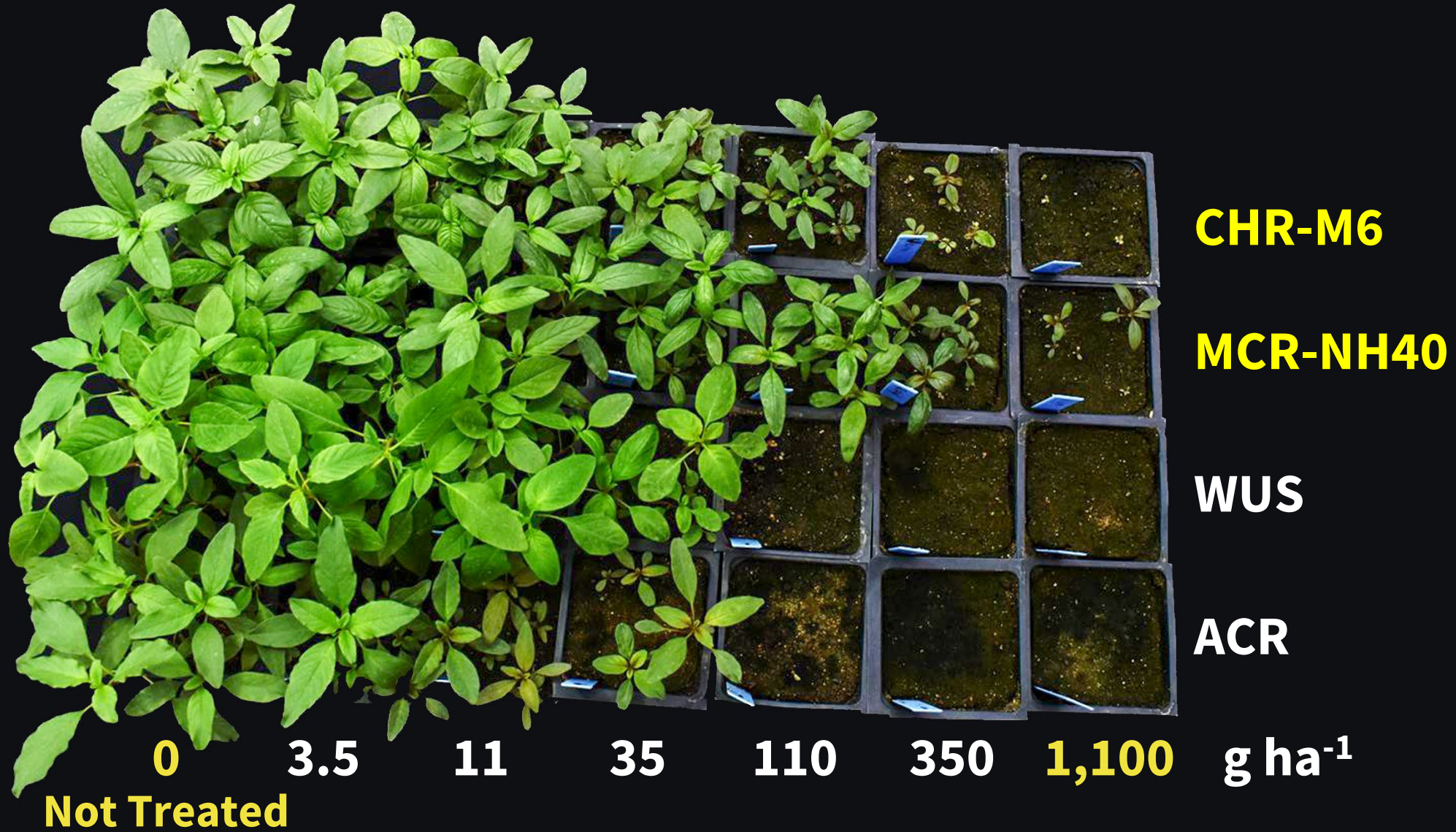
Results 21 DAT: Harness



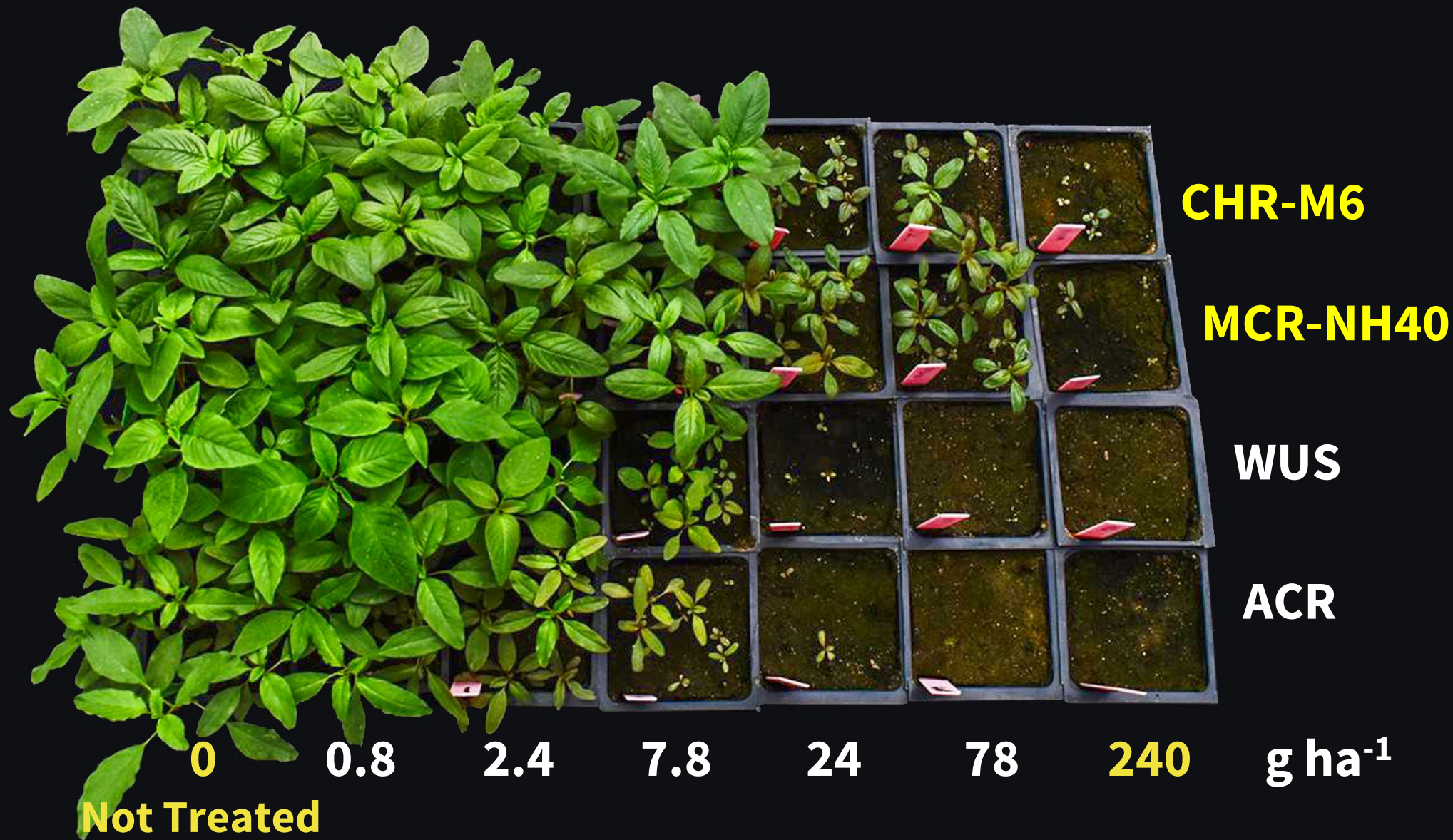
Population	*LD ₅₀	R:S	*GR ₅₀	R:S
CHR-M6	178	4.5	72	6.1
		14		13
MCR-NH40	226	5.7	80	6.7
		18		15
WUS	40		12	
ACR	13		5	

*Expressed as g ha⁻¹

Results 21 DAT: Outlook



Results 21 DAT: Zidua SC



Resistance ratios for two Illinois waterhemp populations resistant to Group 15 herbicides. LD₅₀ values represent the rates required to reduce waterhemp emergence/survival by 50 percent.

Herbicide	Resistant populations (CHR-M6 & MCR-NH40)	Sensitive populations (ACR & WUS)	R/S ratio
	LD ₅₀ (g ai ha ⁻¹)		
S-metolachlor	1,808–3,360	53 – 101	18 – 64
Dimethenamid	729–1,463	26 – 35	21 – 56
Pyroxasulfone	65–153	9 – 10	7 – 17
Acetochlor	178–226	13 – 40	5 – 18

Summary

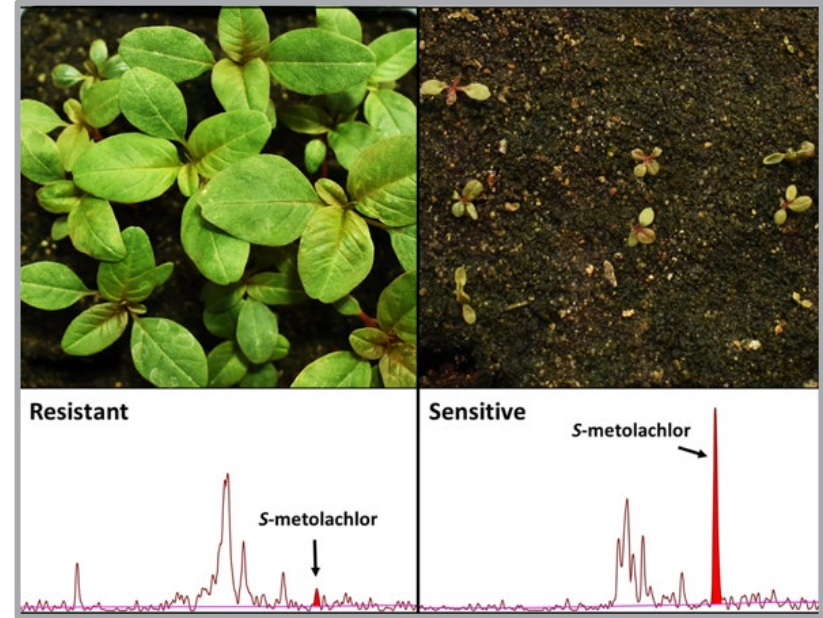
- CHR and SIR are resistant to S-metolachlor due to enhanced metabolism relative to sensitive populations
- Resistant waterhemp metabolizes S-metolachlor as rapidly as corn
- Resistant waterhemp possess increased GST-activity in comparison to sensitive waterhemp, but much less than corn

Summary

- **Metabolomics revealed that resistant waterhemp have metabolite profiles that differ from sensitive waterhemp**
- **Results indicate more intricate, coordinated pathway(s) for S-metolachlor metabolism in resistant waterhemp than in sensitive waterhemp or corn**

Implications of Resistance

- Two Illinois waterhemp populations are resistant to VLCFA-inhibiting herbicides
- VLCFA-inhibitor efficacy and residual activity can be drastically reduced
- Grower may need to implement earlier postemergence applications
- Overlapping residual herbicide applications



Implications of Resistance

- Apply multiple effective SOAs each season
- Integrated management practices with nonchemical control methods
- Distribution of Group 15-resistance is poorly understood
- Not all herbicide failures are due to resistance

How far has Herbicide-Resistant Waterhemp spread?



Training video

go.illinois.edu/waterhempsurvey

University of Illinois Waterhemp Resistance Survey



College of Agricultural, Consumer and Environmental Sciences
Crop Sciences



Sample submission form

go.illinois.edu/fd-waterhemp



University of Illinois Waterhemp Resistance Survey Submission Form

Thank you for submitting waterhemp seed samples for our new research with resistance to Group 15 herbicides at the University of Illinois Urbana-Champaign. Please complete this form to the best of your ability and submit your samples in separate paper bags.

Mail samples to
 Dr. Aaron Hager
 AE102 Turner Hall
 1102 S Goodwin Ave
 Urbana, IL 61801



OFFICE USE ONLY
 Population: _____

Guidelines for submission:

- Please watch a short video on how to collect waterhemp samples at <https://go.illinois.edu/waterhempsurvey>
- Submit **two separate bags** of waterhemp seed from two female plants (**one female per bag**) at least **30 feet apart from one another**.
- Staple one of the two pages in this document to each bag.
- Fill out each paper to the best of your knowledge to aid in data comparison. Leaving an unknown field blank is acceptable.
- Example coordinates of field: **Latitude** N 40.08755 **Longitude**: W 88.22785

Contact Name:

Phone Number:

Date Collected


Current Crop in Field:

Coordinates of Field (hddd.dddd):

Latitude:

Longitude:

County:



Herbicide History:	PRE	POST
2021		
2022		
2023		

Staple to sample bag 1

University of Illinois Waterhemp Resistance Survey Submission Form

USE COORDINATES FROM FIRST PAGE

Coordinates of Field (hddd.dddd):

Latitude:

Longitude:

County:

OFFICE USE ONLY
 Population: _____

General Comments:
 (level of weed control throughout field, other species poorly controlled, etc.)



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Staple to sample bag 2

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Survey for Resistance to Group 15 Herbicides in Illinois Waterhemp

Aaron Hager
 Department of Crop Sciences
 University of Illinois
 September 8, 2023

Recommended citation format: Hager, A. "Survey for Resistance to Group 15 Herbicides in Illinois Waterhemp." Department of Crop Sciences, University of Illinois, September 8, 2023.
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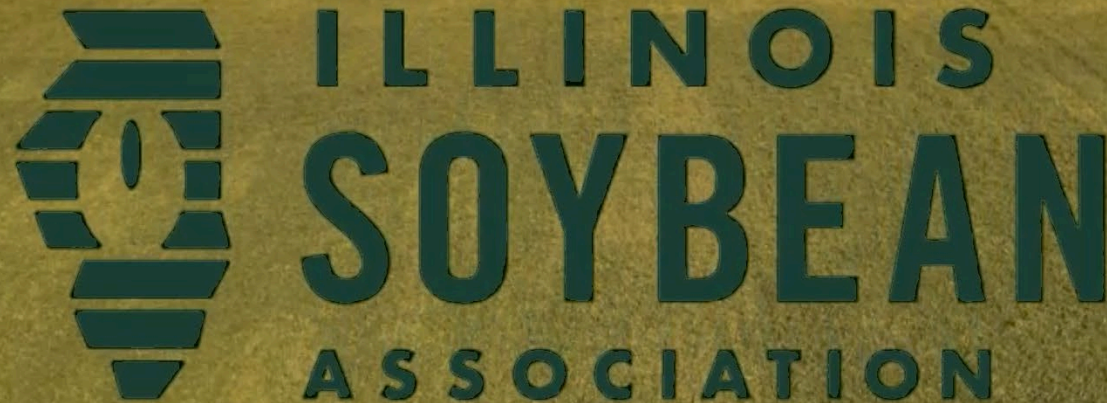
The continual evolution of weed species and populations resistant to herbicides from one or more site-of-action groups represents one of the most daunting challenges facing Illinois soybean producers. Waterhemp has evolved resistance to herbicides from more site-of-action groups than any other Illinois weed species, including resistance to Group 15 herbicides (products such as Dual II Magnum, Zidua, Warrant, Outlook, etc.). Soil-residual herbicides are components of an integrated weed management program that provide several benefits, including reducing the intensity of selection for resistance to foliar-applied herbicides. However, the relatively recent discovery of resistance to Group 15 herbicides is yet another example of how waterhemp continues to challenge herbicide-only management programs.

Compared with resistance to foliar-applied herbicides, resistance to soil-applied herbicides generally is more difficult to detect in the field. Resistance to foliar-applied herbicides manifests as treated plants (assuming appropriate application rate and timing) that are not controlled, whereas resistance to soil-applied herbicides manifests as a reduced duration of residual control. Because the duration of residual control can also vary substantially from field to field and year to year due to climatic and soil factors, it is difficult for farmers to "observe" resistance to preemergence herbicides. Consequently, we hypothesize that waterhemp resistance to Group 15 herbicides is more extensive in the state than Illinois soybean producers realize.

Our weed science program has characterized two Illinois waterhemp populations resistant to Group 15 herbicides and, as stated previously, we suspect this type of resistance is more widespread. Group 15 herbicides are commonly premixed with other herbicides; a search of Group 15 products labeled for use in Illinois revealed thousands of commercially available products that contain one or more of these active ingredients. Additionally, soybean farmers who rely on a "layered residual" to extend weed control following the postemergence herbicide application have only Group 15 herbicides from which to select. A more comprehensive assessment of Group 15 resistance across the soybean producing areas in Illinois would provide the data necessary to refine herbicide recommendations to help slow the evolution of additional Group 15-resistant populations.




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Please submit your questions



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Thank you for your assistance in our research!

go.illinois.edu/fd-waterhemp



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Current Crop in Field: _____ **County:** _____

Herbicide History:

	PRE	POST
2021		
2022		
2023		

Staple to sample bag 1

Staple to sample bag 2

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