Show Me the Weeds:

What might weed management look like in 2023 and beyond?

Dr. Kevin Bradley, University of Missouri

Some Thoughts on Weed Management in 2023 and Beyond

M ORE COMPLEX herbicide labels, registrations, requirements, etc.

Get used to these kinds of labels in the future…

For land with **Hydrologic Soil Groups* A & B**: The land manager/applicator must effectively implement measures in the following tables to equal a **minimum of 4 credits**.

For land with **Hydrologic Soil Groups* C & D**: The land manager/applicator must effectively implement the measures in the following tables to equal a **minimum of 6 credits**.

Mitigation Measures			Credits
Reduce number of applications - Reduced number of applications of Enlist products per year. Applications may be made at any time during crop development but must maintain a minimum 12-day retreatment interval.		3 applications	0
		2 applications	2
		1 application	4
Residue Tillage Management: no till, strip-till, ridge-till and mulch-till			4
Vegetative Filter Strips	30 ft off-field vegetative buffer on down slope	HSG A or B	2
		HSG C or D	0
	100 ft off-field vegetative buffer on down slope	HSG A or B	4
		HSG C or D	1
Field border: border with dense vegetative stands with a minimum width of 30 ft.			2
Cover Crop			2
Vegetative Barrier: Permanent strips of dense vegetation along the contours of the field with a minimum width of 3 ft.			2
Contour Buffer Strips or Terrace			2
Grassed Waterway			2
Water and Sediment Basin			1
Contour Farming or Contour Strip Cropping			1

*Hydrologic Soil Group (HSG) definitions: A = Sand, loamy sand, or sandy loam; B = Sandy clay loam; C = Silt loam or loam; D = Clay loam, silty clay loam, sandy clay, silty clay or clay.

Applicators/Land Managers must meet minimum criteria described for each mitigation measure as outlined on Enlist.com/mitigationmeasures to receive credits.

POLITICS

EPA Proposes Five Changes to Atrazine Labels, Introduces "Picklist" Mitigation

EPA Atrazine 070122

The US EPA's Role in Herbicide Registration

1. **Must meet the standards of Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)**
   - **"*Reasonable* *certainty of no harm*"**
   - **"*No unreasonable adverse effects*"**

2. **Must also meet the standards of the Endangered Species Act (ESA)**
   - **protects endangered and threatened species and the habitats upon which they depend.**
   - **Signed into law in 1973 and has not had any major revisions since**
   - **Requires federal agencies to ensure that action they take *will not:***
     - → **"Jeopardize the continued existence of *any* listed species", or**
     - → **"Destroy or adversely modify *any* critical habitat for those species."**
     - → **Drift, leaching, runoff and volatility are all possible routes of exposure that are considered**

Why should you care about ESA?

What are we protecting?

- 1674 species currently (the list is growing)
- Missouri has 36 species
- most are plants
- an updated decision will be released on Monarchs in 2024; this could impact how we do weed management in the U.S.

This is a statute that only considers risk to threated or endangered species. It does not consider the potential benefits of any pesticide use.

As of January 11, 2022, the potential effects of all new pesticide active ingredients on threatened and endangered species will be considered.

Some Thoughts on Weed Management in 2023 and Beyond

M ORE COMPLEX herbicide labels, registrations, requirements, etc.

I NTEGRATED APPROACHES that don't just rely on herbicides alone will become more and more important.

Autonomous Weeding/Use of Robots

Bosch's Giant Robot Can Punch Weeds to Death

By Evan Ackerman
Posted 12 Nov 2015 | 20:00 GMT

Photo: Deepfield Robotics

At IROS last month, researchers from a Bosch startup called Deepfield Robotics presented a paper on "Vision-Based High-Speed Manipulation for Robotic Ultra-Precise Weed Control," which has like four distinct exciting-sounding phrases in it. We wanted to write about it immediately, but Deepfield asked us to hold off a bit until their fancy new website went live, which it now has. This means that we can show you video of their enormous agricultural robot that can autonomously detect and physically obliterate individual weeds in a tenth of a second.

Given the scale of farming today, treating weeds chemically is really the only practical way for humans to keep them under control, because you can use tractors or airplanes to cover large areas in a short amount of time. But all of those necessarily deadly (to weeds) chemicals then get on the plants we don't want to kill (because we want to eat them), as well as getting washed into the soil. The most organic and eco-friendly way of dealing with weeds is the old-fashioned way: physically removing them. "Physical removal" can mean

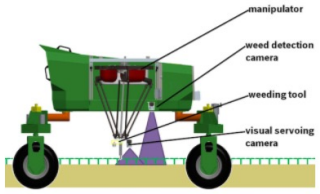


Image: Deepfield Robotics

FarmWise launches autonomous weeding robot

JANUARY 7, 2019 BY SAM FRANCIS

Deere is paying over $300 million for a start-up that makes 'see-and-spray' robots

- Blue River's robots affix to tractors and can precisely identify and spray herbicides, pesticides or fertilizers to plants in need.
- The start-up had raised about $31 million in venture funding.

Lora Kolodny | @lorakolodny
Published 8:08 PM ET Wed, 6 Sept 2017 | Updated 10:22 PM ET Wed, 6 Sept 2017

CNBC

Michael Newberg | CNBC

Sam Allen, CEO of John Deere at CONEXPO in Las Vegas on March 7. 2017.

Deere is bringing more robots to the farm.

The maker of John Deere agricultural equipment said on Wednesday that it's acquiring robotics start-up Blue River Technology for $305 million. The deal is expected to close in September.

Precision Sprayers

About WEED-IT Video's News

WEED·IT precision spraying

Home Cases Solutions Knowledge Centre ROI Calculator Find a distributor Contact

WEED-IT Precision Spraying

Since 1999, WEED-IT is the most accurate, fastest and most easy to use weed detection and elimination technology available. By spraying only weeds, it helps you save up to 90% on chemical costs!

See how WEED-IT can work for you too!

New

WEED-IT Quadro >

See how our newest WEED-IT Quadro technology once again sets the standards!

Calculate your ROI >

How much can you save by changing to the WEED-IT way of weeding?

JOHN DEERE Equipment Finance Parts & Service

Home > News > All News > 2021mar02 John Deere Launches See And Spray Select

NEWS RELEASES MARCH 02, 2021

John Deere launches See & Spray™ Select for 400 and 600 Series Sprayers

See & Spray™ Select can help farmers reduce their herbicide use by 77% on average by targeting and spraying only weeds on fallow ground.

UAV Sprayers

Exploring the use of Sterile Pollen

WeedOUT
Innovative Bioherbicide Solutions

Weed Resistance | Our Solution | News | Our Vision | About Us | Contact Us

Exploiting sterility to win the battle against resistant weeds

WeedOUT brings a totally new strategy into the world of weed control by developing a novel biological herbicide to fight off resistant weeds.

WeedOUT's unique **weed pollen** possesses 2 major properties:

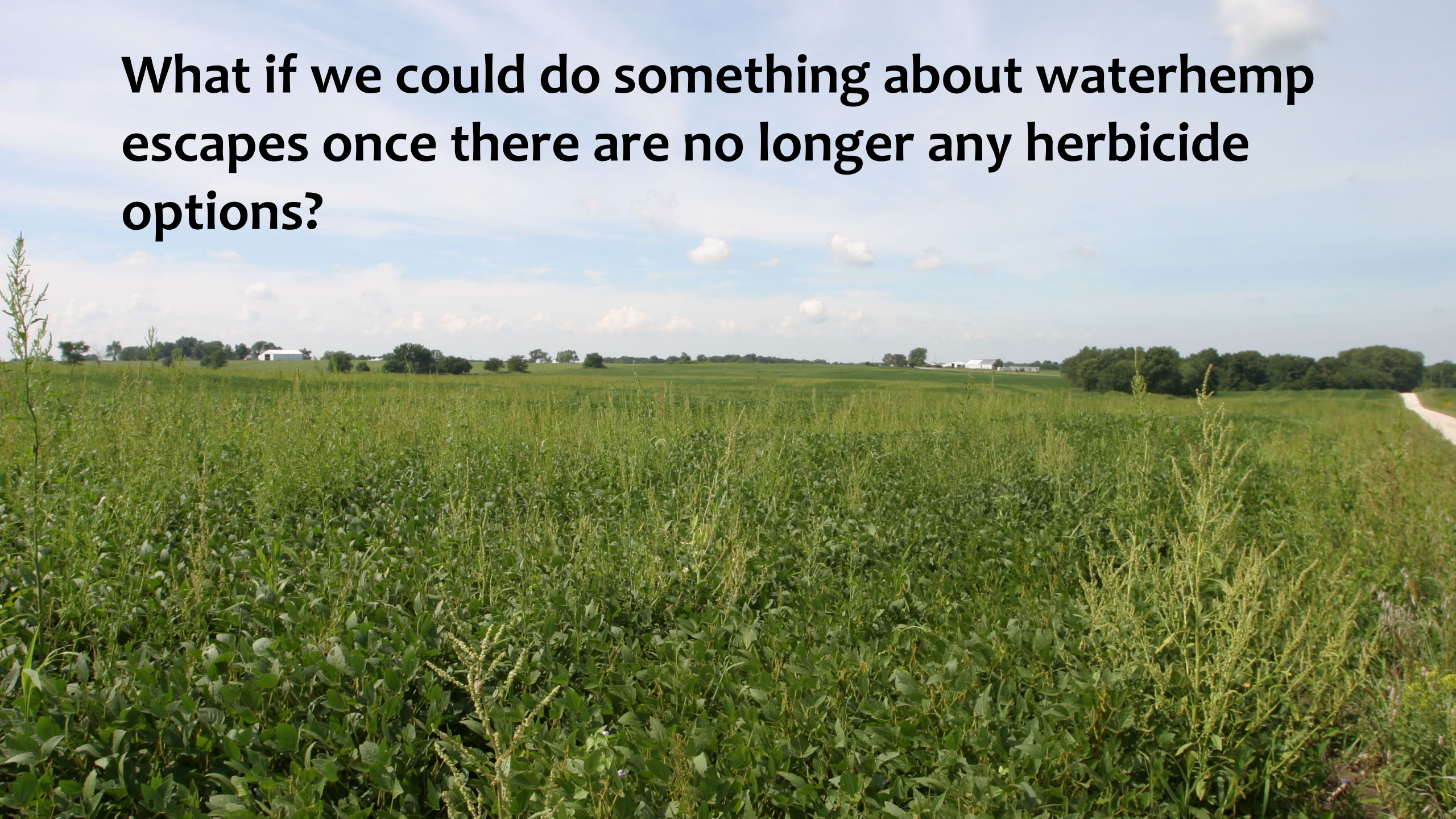
- It competes successfully with naturally occurring weed pollen and fertilizes the ovule
- It leads to the formation of **aborted** seeds

Susceptible weeds are destroyed by chemical herbicides. However, escaper resistant weeds that were not affected by the herbicides mature and reproduce. Consequently, their proportion in the total weed population increases rapidly and leads to an evolutionary drift. Our groundbreaking solution is designed to outcompete naturally occurring pollen and accordingly **get evolution back on track**.

WeedOUT's novel technology is based on the development of a unique proprietary weed pollen, which is applied during weed flowering period via artificial pollination to prevent the generation of viable resistant weed seeds.

- New mechanism of action for weed control that is orthogonal to all currently available solutions
- Green, non-toxic, biologically based solution to outcompete naturally occurring pollen and to inhibit soil seed bank replenishment


CASE IH
WEED ZAPPER

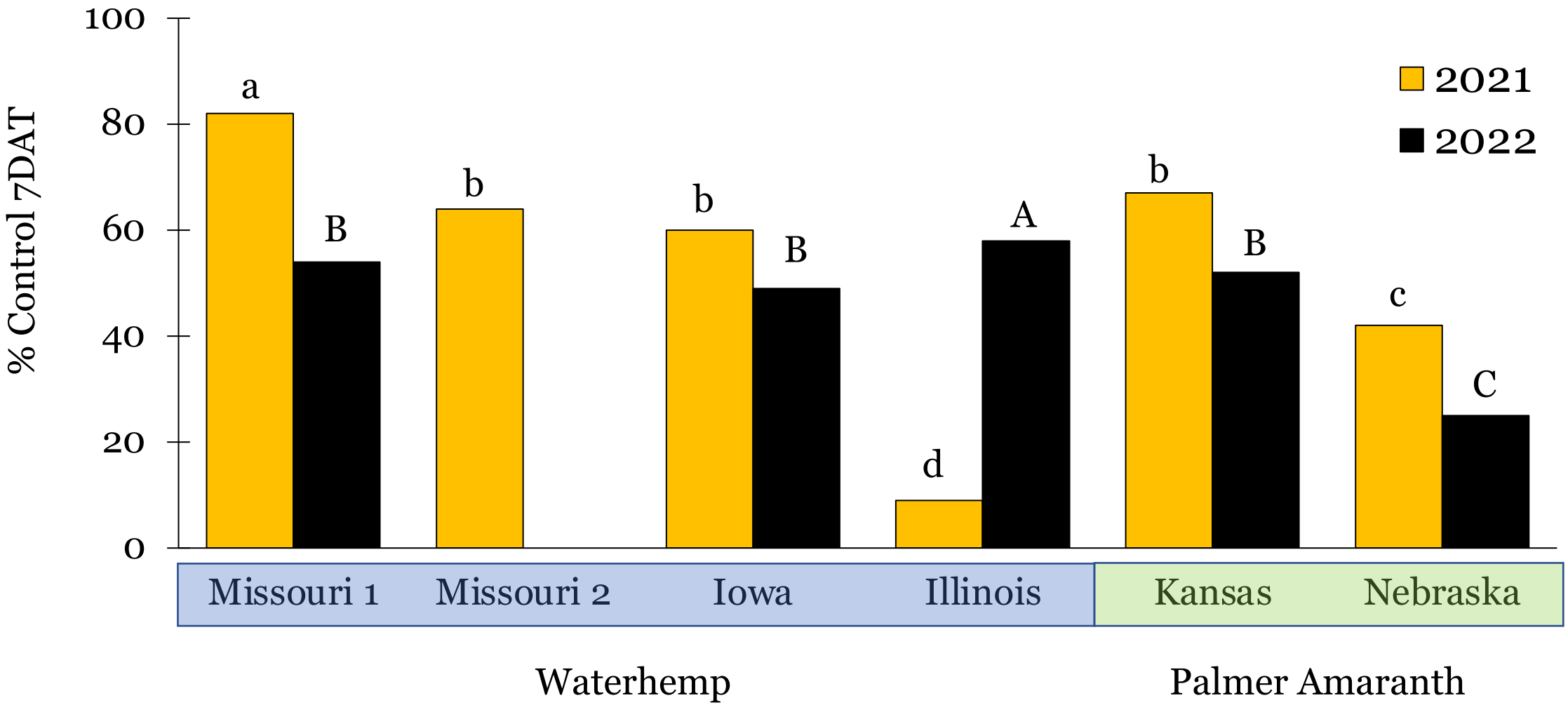


What if we could do something about waterhemp escapes once there are no longer any herbicide options?

What we think we've learned so far…

- This is not a weed management tool. This is a weed rescue tool.
- Size, plant moisture, boom height all matter.
- Can be effective on some of our most problematic resistant weeds. Can also be extremely variable on those same weeds.

Response of Pigweed Species To Electrocution



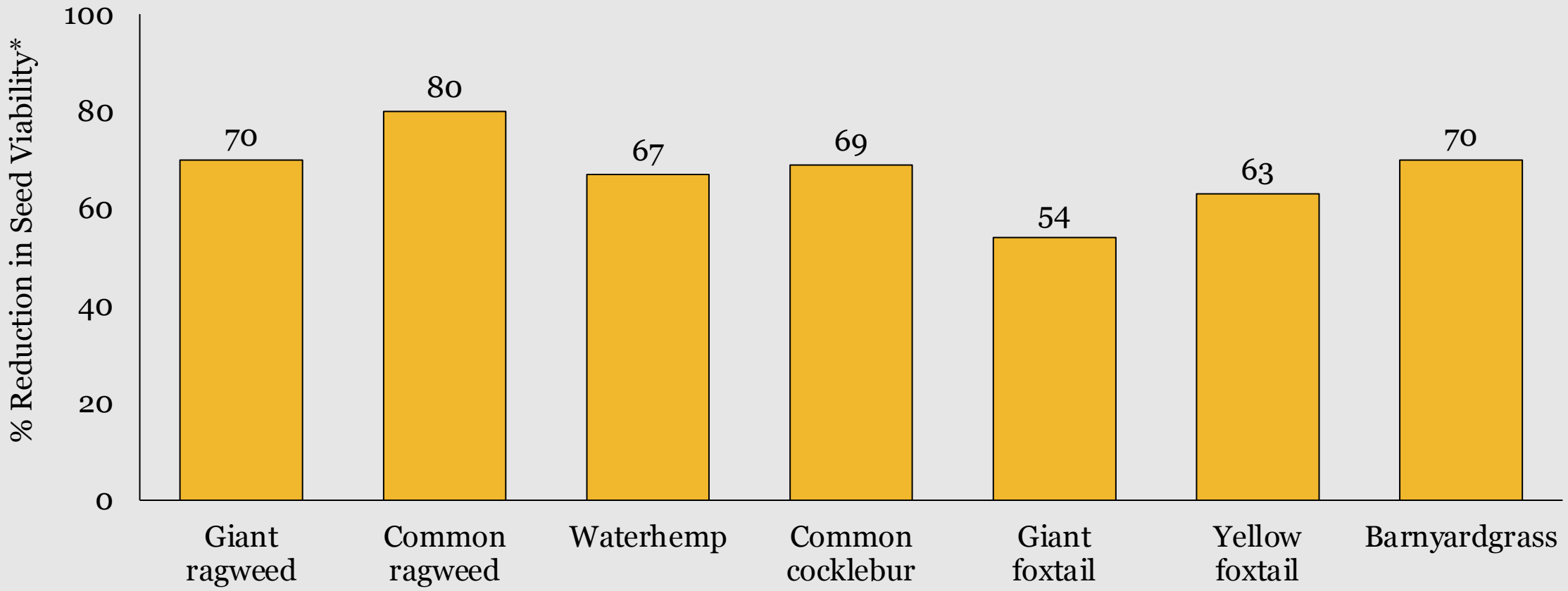
*Bars followed by the same letter within a year are not different, LSD <0.05

Mizzou weed science

What we think we've learned so far…

- This is not a weed management tool. This is a weed rescue tool.
- Size, plant moisture, boom height all matter.
- Can be effective on some of our most problematic resistant weeds. Can also be extremely variable on those same weeds.
- Can substantially reduce weed seed viability.

Influence of Electrocution on Weed Seed Viability



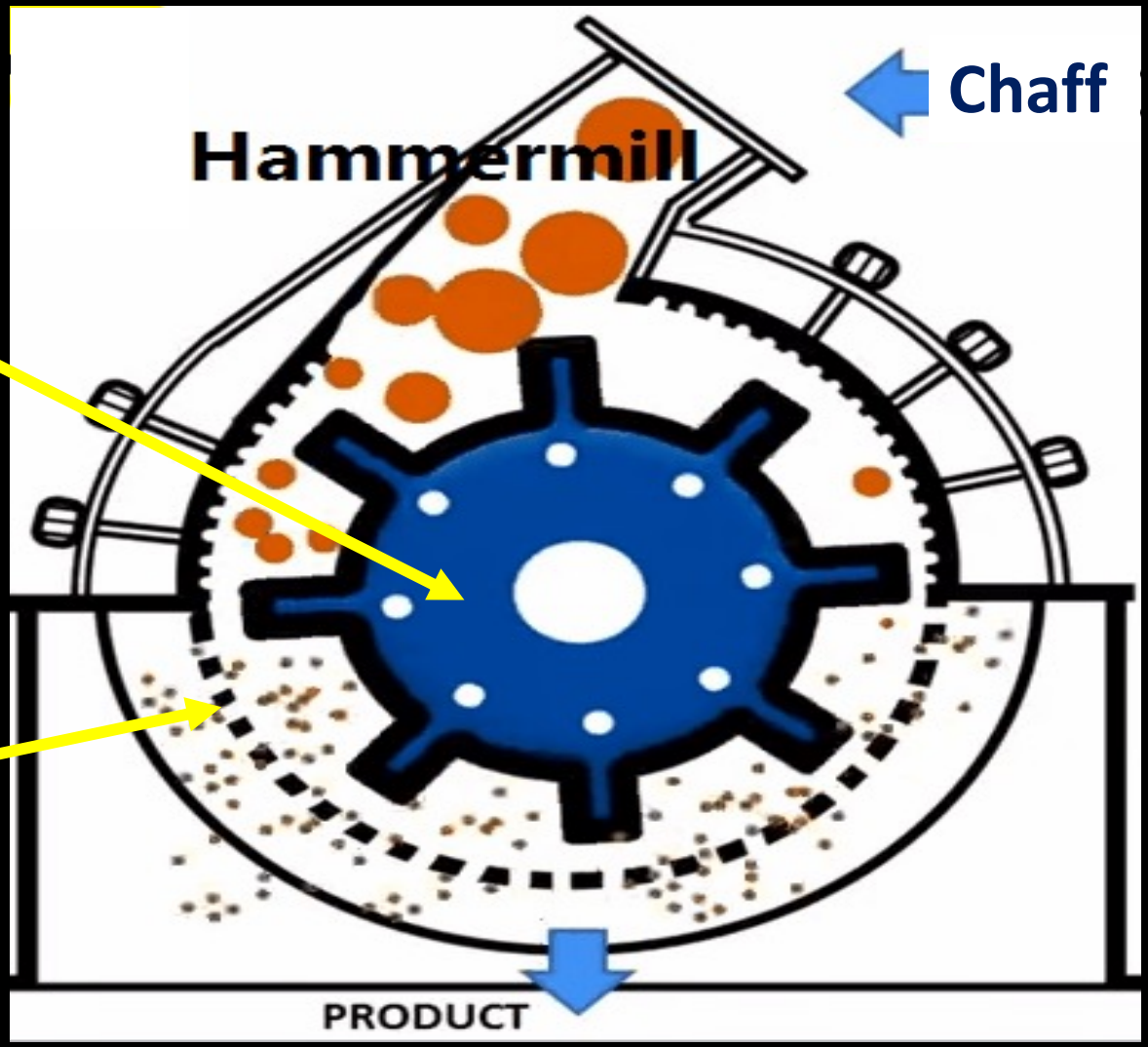
*Based on viability of non-treated seed of that species

Will On-combine Seed Destruction Devices Become “Standard” in the United States ?

Basic Hammer Mill/Cage Mill Concept

Rotating Bars

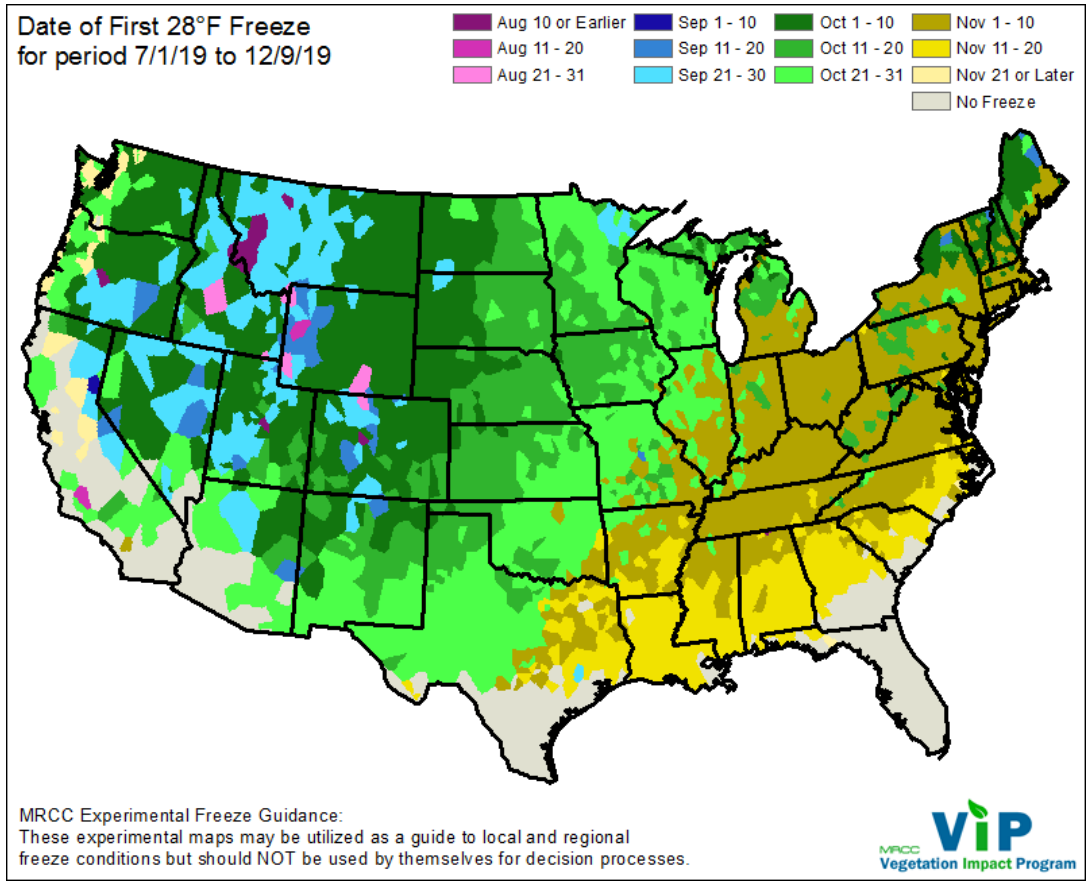
Stationary Bars



slide provided by Dr. Tom Barber, University of Arkansas

On-combine Impact Mills for use in U.S. Soybean

Date of First Freeze, 2019



1. The earlier the frost(s), the better. "Green" weeds with high moisture content have proven difficult.

On-combine Impact Mills for use in U.S. Soybean

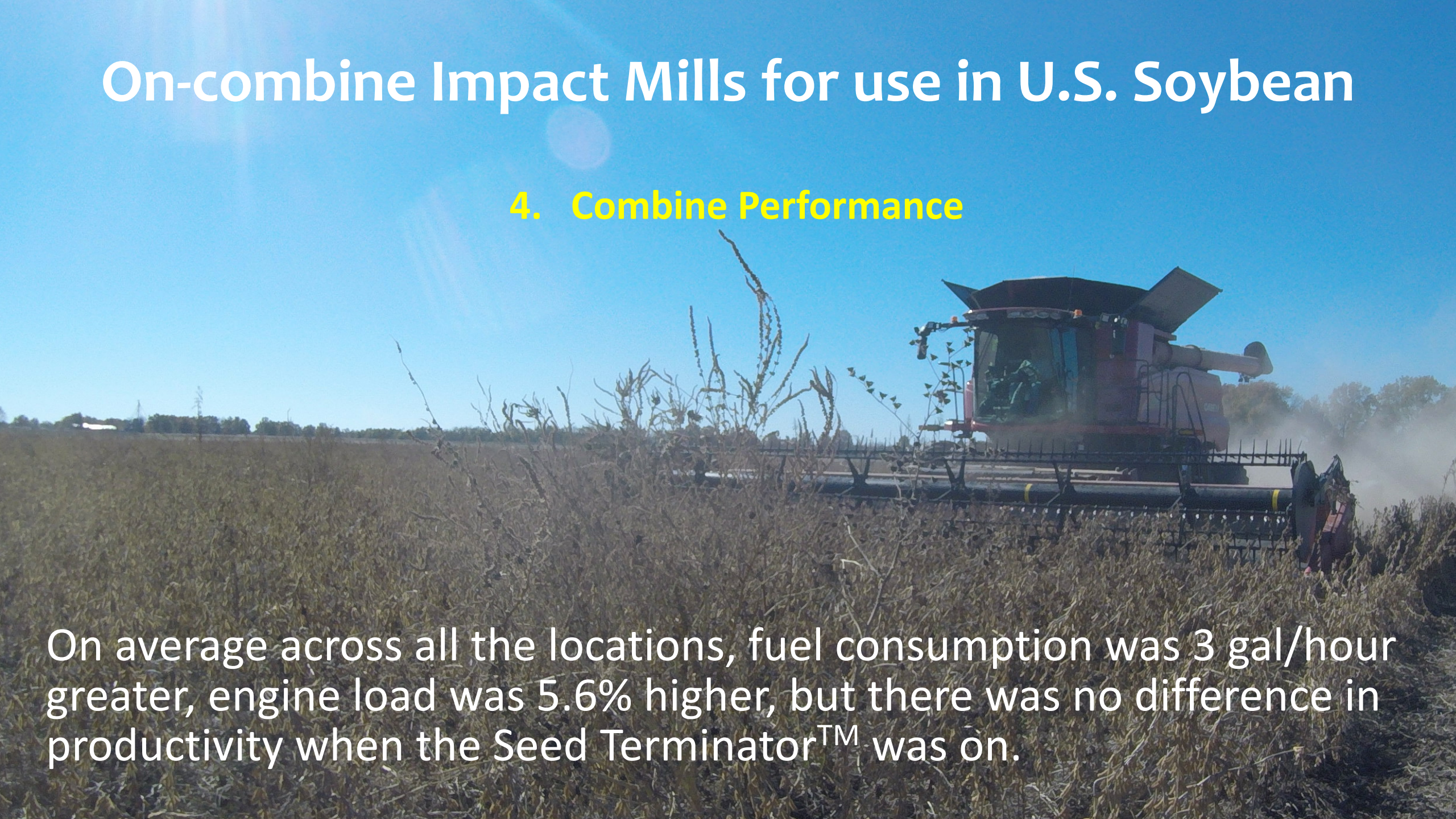
2. Some degree of header loss of weed seed is likely to occur (~31% of available waterhemp seed in a field).

On-combine Impact Mills for use in U.S. Soybean

3. The majority of weed seed that enters the combine appears to make it into the seed terminator. Approximately 94% of waterhemp seed that comes out of the Seed Terminator are damaged (= non-viable).

On-combine Impact Mills for use in U.S. Soybean

4. Combine Performance



On average across all the locations, fuel consumption was 3 gal/hour greater, engine load was 5.6% higher, but there was no difference in productivity when the Seed Terminator™ was on.

On-combine Impact Mills for use in U.S. Soybean

5. Significant reductions in the waterhemp seed bank were observed in 3 out of 5 locations.

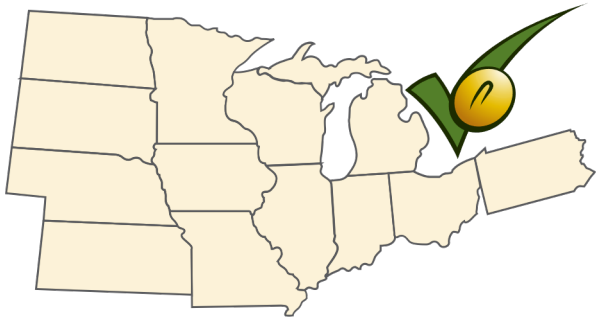
On-combine Impact Mills for use in U.S. Soybean

6. Current costs of these implements are approximately $70-75k. We found operating costs to be ~$5/acre more than operating a conventional combine.

This research would not have been possible without cooperation/funding from the following:

SEED TERMINATOR

NCSRP NORTH CENTRAL SOYBEAN RESEARCH PROGRAM



UNITED SOYBEAN BOARD™

CASE IH AGRICULTURE

MISSOURI SOYBEANS

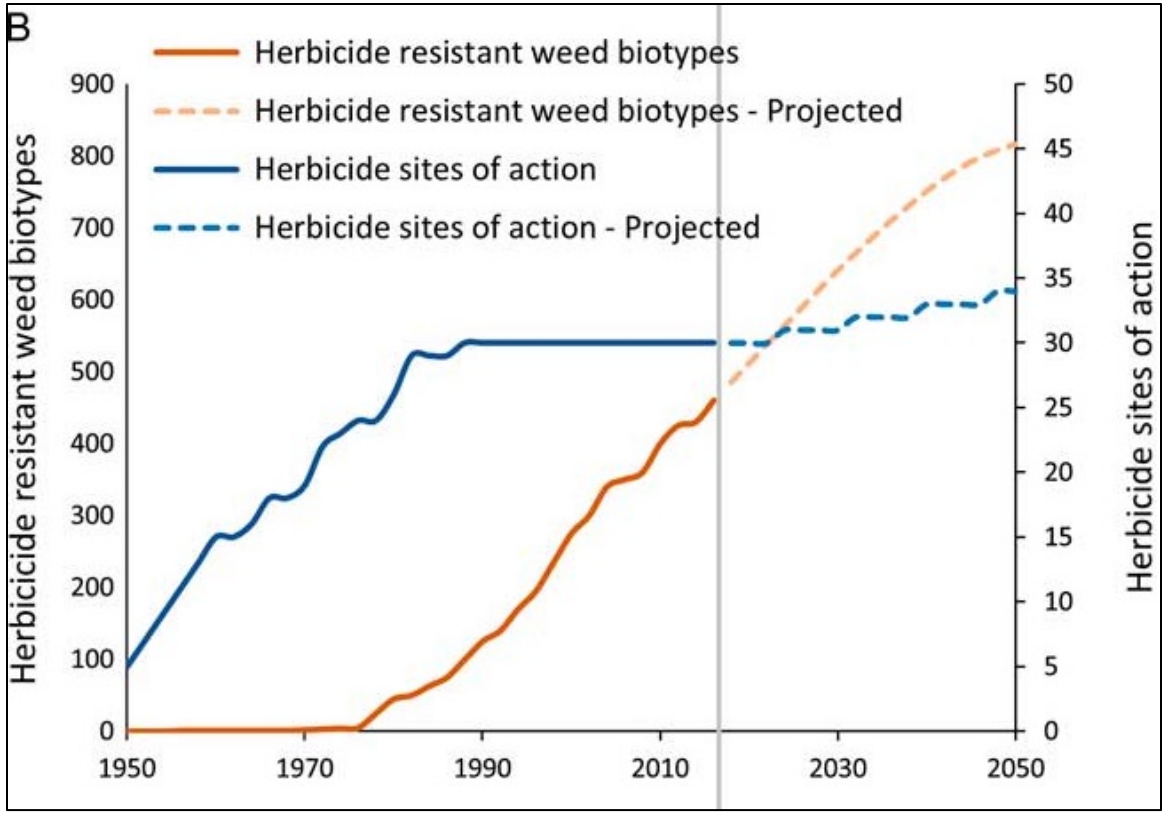
Some Thoughts on Weed Management in 2023 and Beyond

M ORE COMPLEX herbicide labels, registrations, requirements, etc.

I NTEGRATED APPROACHES that don't just rely on herbicides alone will become more and more important.

Z ERO TOLERANCE for resistant weeds. Because these "new" resistant weeds aren't like what mom used to make.

Where are we now?



Westwood et al. 2017

Where are we now?

HOME > CROPS > DICAMBA-RESISTANT WATERHEMP IDENTIFIED IN ILLINOIS, TENNESSEE

Dicamba-Resistant Waterhemp

Dicamba-Resistant Waterhemp Identified in Illinois, Tennessee

11/11/2021 | 8:07 AM CST

By Emily Unglesbee , DTN Staff Reporter

Connect with Emily:

@Emily_Unglesbee

The country's first confirmed dicamba-resistant waterhemp populations hail from Champaign County, Illinois, and Montgomery County, Tennessee. (DTN Photo by Pamela Smith)

ROCKVILLE, Md. (DTN) -- Scientists from both Tennessee and Illinois have confirmed dicamba-resistant waterhemp in their respective states this week.

The Illinois weed population, collected from Champaign County, shows 5- to 10-fold levels of resistance to dicamba compared to susceptible populations, said University of Illinois weed scientist Aaron Hager. Overall, it is a 6-way resistant weed population, with resistance to Group 4 (auxins, including dicamba and 2,4-D), Group 2 (ALS-inhibitors), Group 5 (triazines), Group 14 (PPO-inhibitors), Group 27 (HPPD-inhibitors) and Group 15 (VLCFA-synthesis inhibitors, such as S-metolachlor).

In Montgomery County, Tennessee, waterhemp collected from fields in the Cumberland River bottoms are showing roughly 4.5-fold levels of resistance to dicamba, said Larry Steckel, University of Tennessee Extension weed scientist, who worked with Purdue University scientists to confirm his findings. The Tennessee waterhemp populations are also resistant to Group 9 (glyphosate), Group 14 (PPO-inhibitors) and Group 2 (ALS-inhibitors), although surprisingly, 2,4-D is still effective on them, Steckel said.

07 JUL 2021

Tweet

Dicamba and 2,4-D: No longer "Palmer amaranth Herbicides" in Some Fields

Author: Larry Steckel, Extension Weed Specialist and Delaney Foster Graduate Research Assistant Comments Off

Picture 1. Palmer amaranth escapes 18 days after 12.8 ozs Engenia+ 32 ozs glyphosate. A farmer's field, Lauderdale county, TN

For the past week we have been getting reports along with a good many pictures of Palmer amaranth escaping dicamba application/s from retailers and consultants scouting fields (Picture 1 and 2). As one retailer so aptly described it today "there are spots in fields where the lack of Palmer control is frightening".

Waterhemp Scores Again

Illinois Scientists Find New Resistance in Waterhemp

2/8/2019 | 4:22 PM CST

By Pamela Smith , Crops Technology Editor

Connect with Pamela:

@PamSmithDTN

Waterhemp is one tough weed. Now it has begun to outsmart a group of important residual herbicides. (DTN photo by Pamela Smith)

DECATUR, Ill. (DTN) -- Waterhemp has just thumbed its nose at another group of herbicides.

Waterhemp resistant to Group 15 herbicides (very long chain fatty acid inhibitors) has officially been found in Illinois research plots. It is the first dicot (broadleaf) weed in the world to outmaneuver herbicides within the Group 15 chemical family. While scientists aren't sure how widespread the issue is, University of Illinois weed scientist Aaron Hager said the discovery is yet another warning to change weed management behaviors now.

"Waterhemp has now shown the ability to resist seven different herbicide sites of action," Hager said. "Farmers have been leaning heavily on the Group 15 herbicides across all crops as they battle resistant weeds. This is another example of how important it is to diversify weed control approaches to keep the effectiveness of this tool," Hager said.

Syngenta has been collaborating with Illinois scientists on their findings and providing important background information, confirmed Dane Bowers, Syngenta's technical lead for herbicides, and Gordon Vail, Syngenta's technical product lead on S-metolachlor, one of the Group 15 herbicides.

S-metolachlor is the active ingredient commonly sold by Syngenta under the trade name Dual Magnum. It is also found as a component in many popular herbicide premixes.

"We feel it is important as a manufacturer to alert farmers to these findings and work alongside weed scientists to keep these herbicides effective as long as possible," said Vail. "The reality is not any one product or class of chemistry by itself is good enough. We need them all."

Go down through the sites of action commonly used in corn and soybean crops today and nearly all have had some level of resistance confirmed, Bowers added. "This is the age we live in. Resistance to a particular AI (active ingredient) or site of action doesn't invalidate or devalue that active. It can still be extremely important across a wide geography to control other weed species," he said.

A CRACK IN ARMOR

What makes this discovery unique is the Group 15 herbicides have been fairly resilient. Worldwide, there are only five cases of grass weeds that have been confirmed resistant to very long chain fatty acid inhibitor (Group 15) herbicides. Most of those cases are in wheat and rice. The only confirmed Group 15 resistance in the United States had been in monocot (grass) in Idaho, Washington and Oregon.

Weed Science

www.cambridge.org/wsc

Resistance of Palmer amaranth (*Amaranthus palmeri*) to *S*-metolachlor in the midsouthern United States

Koffi Badou Jeremie Kouame[1], Matthew B. Bertucci[2], Mary C. Savin[3], Taghi Bararpour[4], Lawrence E. Steckel[5], Thomas R. Butts[6], Cammy D. Willett[7], Fellipe G. Machado[8] and Nilda Roma-Burgos[3]

[1]Graduate Student, Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, AR, USA; [2]Assistant Professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, AR, USA; [3]Professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, AR, USA; [4]Assistant Extension/Research Professor, Department of Plant and Soil Sciences, Mississippi State University, Stoneville, MS, USA; [5]Professor and Extension Weed Scientist, Department of Plant Sciences, University of Tennessee, TN, USA; [6]Assistant Professor and Extension Weed Scientist, University of Arkansas System Division of Agriculture, Lonoke, AR, USA; [7]Research Soil and Environmental Scientist, University of Missouri, Division of Applied Social Sciences, Columbia, MO, USA and [8]Graduate Student, Departamento de Agronomia, Universidade Estadual de Maringá, Maringá (PR), Brazil

Research Article

Cite this article: Kouame KBJ, Bertucci MB, Savin MC, Bararpour T, Steckel LE, Butts TR, Willett CD, Machado FG, Roma-Burgos N (2022) Resistance of Palmer amaranth (*Amaranthus palmeri*) to *S*-metolachlor in the midsouthern United States. Weed Sci. **70**: 380–389. doi: 10.1017/wsc.2022.37

Received: 30 December 2021
Revised: 16 April 2022
Accepted: 6 June 2022
First published online: 14 July 2022

Associate Editor:
Mithila Jugulam, Kansas State University

Keywords:
Herbicide resistance; preemergence herbicides

Author for correspondence:
Nilda Roma-Burgos, Department of Crop, Soil, and Environmental Sciences, University of Arkansas, 1366 Fayetteville, AR 72704. (Email: nburgos@uark.edu)

Abstract

Palmer amaranth (*Amaranthus palmeri* S. Watson) is one of the most problematic weeds in many cropping systems in the midsouthern United States because of its multiple weedy traits and its propensity to evolve resistance to many herbicides with different mechanisms of action. In Arkansas, *A. palmeri* has evolved metabolic resistance to *S*-metolachlor, compromising the effectiveness of an important weed management tool. Greenhouse studies were conducted to evaluate the differential response of *A. palmeri* accessions from three states (Arkansas, Mississippi, and Tennessee) to (1) assess the occurrence of resistance to *S*-metolachlor among *A. palmeri* populations, (2) evaluate the resistance level in selected accessions and their resistant progeny, (3) and determine the susceptibility of most resistant accessions to other soil-applied herbicides. Seeds were collected from 168 crop fields between 2017 and 2019. One hundred seeds per accession were planted in silt loam soil without herbicide for >20 yr and sprayed with the labeled rate of *S*-metolachlor (1,120 g ai ha^{-1}). Six accessions (four from Arkansas and two from Mississippi) were classified resistant to *S*-metolachlor. The effective doses (LD_{50}) to control the parent accessions ranged between 73 and 443 g ha^{-1}, and those of F_1 progeny of survivors were 73 to 577 g ha^{-1}. The resistance level was generally greater among progeny of surviving plants than among resistant field populations. The resistant field populations required 2.2 to 7.0 times more *S*-metolachlor to reduce seedling emergence 50%, while the F_1 of survivors needed up to 9.2 times more herbicide to reduce emergence 50% compared with the susceptible standard.

Introduction

Palmer amaranth (*Amaranthus palmeri* S. Watson) is one of the most common, problematic, and economically detrimental weeds throughout the southern United States (Ward et al. 2013). It is one of the two most troublesome weeds in Arkansas, Louisiana, Mississippi, and Tennessee (Riar et al. 2013). Glyphosate-resistant *A. palmeri* infestations occurred in 16% of scouted areas in Louisiana and in 54% of scouted areas in Mississippi, Tennessee, and Arkansas (Riar et al. 2013). The average cost of hand weeding *A. palmeri* was US$59 ha^{-1} (Riar et al. 2013). *Amaranthus palmeri* emerges continuously from late spring to late summer as long as the soil temperature is favorable (between 22 and 32 C; Chahal et al. 2021; Keeley et al. 1987).

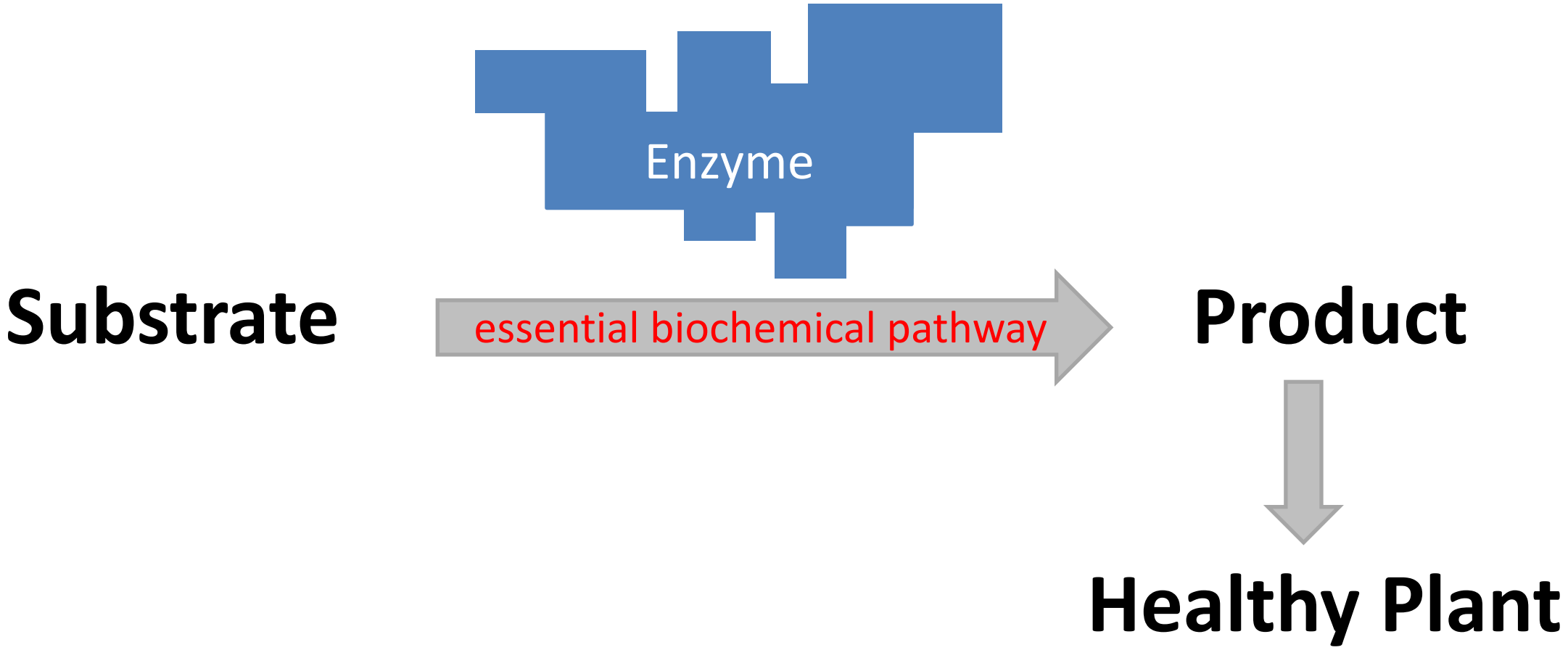
The propensity of *A. palmeri* to evolve resistance to many herbicides has made it difficult to control. To date, it is resistant to 5-enolpyruvyl-shikimate-3-phosphate synthase–inhibiting herbicides (Culpepper et al. 2006; Norsworthy et al. 2008), acetolactate synthase (ALS)-inhibiting herbicides (Burgos et al. 2001; Gaeddert et al. 1997; Horak and Peterson 1995), microtubule-inhibiting herbicides (Gossett et al. 1992), 4-hydroxyphenylpyruvate dioxygenase–inhibiting herbicides (Jhala et al. 2014; Nakka et al. 2017b), photosystem II (PSII)-inhibiting herbicides (Nakka et al. 2017a), protoporphyrinogen oxidase (PPO)-inhibiting herbicides (Salas et al. 2016; Salas-Perez et al. 2017; Varanasi et al. 2018a, 2018b), and auxin mimic– and glutamine synthetase–inhibiting herbicides (Heap 2021). *Amaranthus palmeri* has also evolved resistance to very-long-chain fatty acid (VLCFA)-inhibiting herbicides in Arkansas (Brabham et al. 2019; Rangani et al. 2021).

VLCFAs are important components of lipids such as triacylglycerols (accumulated in seeds), some sphingolipids and phospholipids found in cell membranes, and cuticular waxes on plant

https://doi.org/10.1017/wsc.2022.37 Published online by Cambridge University Press

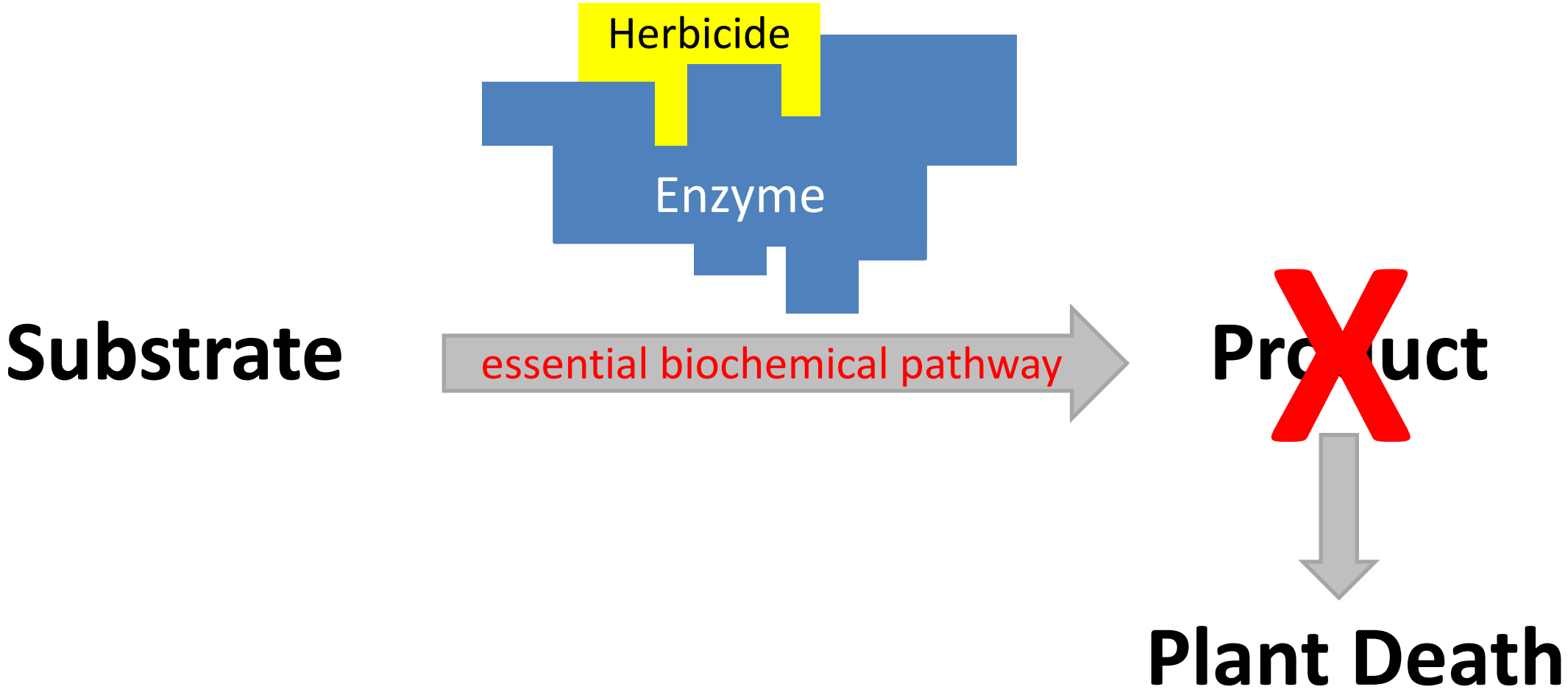
It's not just about more pigweeds with more resistance. It's the type of resistance mechanism(s) that are being found that is truly concerning.

"Old" Type of Resistance Mechanisms in Pigweeds:
Target Site Resistance



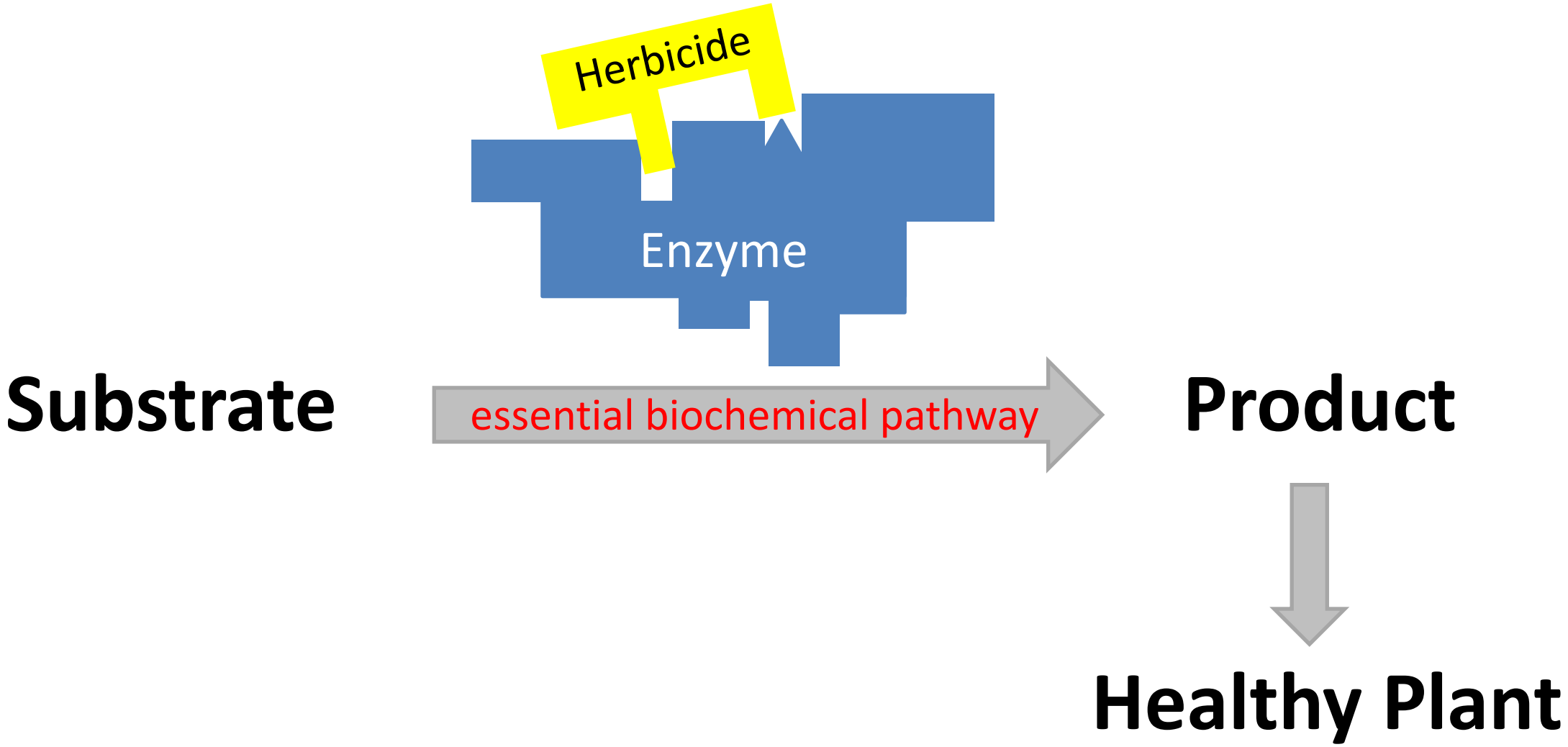
For more info, see Dr. Pat Tranel's "Why Care About Metabolic Herbicide Resistance" video on YouTube

"Old" Type of Resistance Mechanisms in Pigweeds:
Target Site Resistance



For more info, see Dr. Pat Tranel's "Why Care About Metabolic Herbicide Resistance" video on YouTube

"Old" Type of Resistance Mechanisms in Pigweeds:
Target Site Resistance



For more info, see Dr. Pat Tranel's "Why Care About Metabolic Herbicide Resistance" video on YouTube

"Old" Type of Resistance Mechanisms in Pigweeds:

Target Site Resistance

- Target enzyme is modified in some way, usually so that the herbicide can't bind
- Common with Group 2 (ALS), 5 (triazine), 14 (PPO), 9 (glyphosate)
- Can confer resistance to other herbicides within the same group but <u>never</u> to herbicides in other groups
- Common in 1990's and early 2000's

What has always been our recommendation for the control of these “old types” of resistant weeds?

HERBICIDE CLASSIFICATION

TakeACTION Herbicide-Resistance Management

Repeated use of herbicides with the same site of action can result in the development of herbicide-resistant weed populations.

by MODE OF ACTION *(effect on plant growth)*

by PREMIX

SITE OF ACTION GROUP	CHEMICAL FAMILY	ACTIVE INGREDIENT	PRODUCT EXAMPLES (TRADE NAMES)
5			
2			
9			
4			
10			
3			
6			
7			
15			
12			
14			
27			
14			
22			
5			
8			
15			
18			
17			

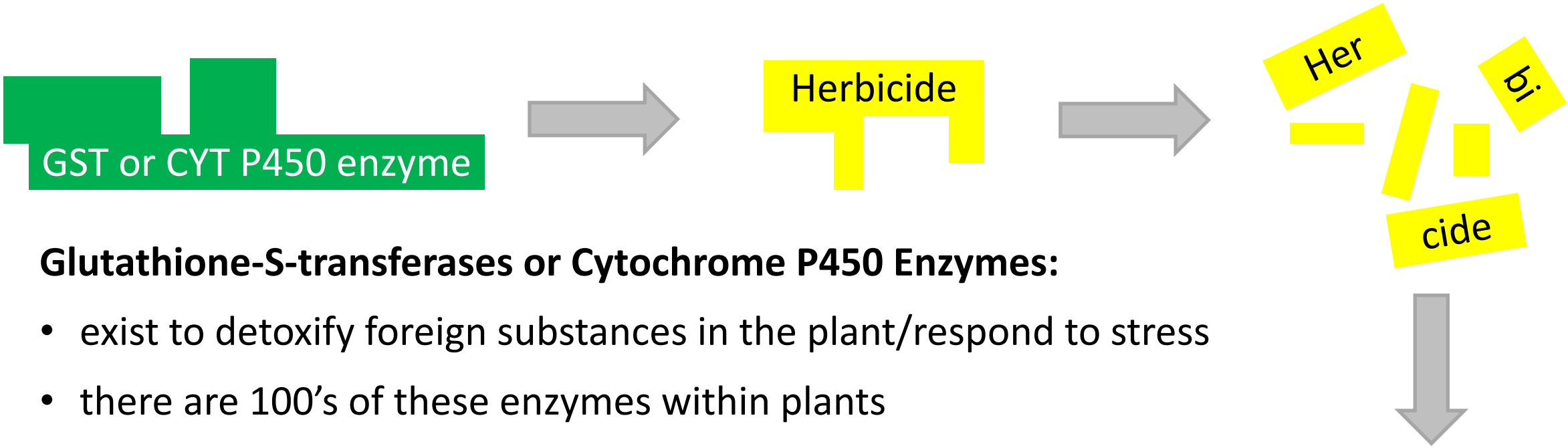
PREMIX	ACTIVE INGREDIENT	TRADE NAME(S)	SITE OF ACTION GROUP

PREMIX	ACTIVE INGREDIENT	TRADE NAME(S)	SITE OF ACTION GROUP

For more information and links to additional resources, visit www.IWillTakeAction.com

TAKE ACTION IS ENDORSED BY THE FOLLOWING ORGANIZATIONS:

"New" Types of Resistance Mechanisms in Pigweeds:
Metabolic Resistance



Glutathione-S-transferases or Cytochrome P450 Enzymes:

- exist to detoxify foreign substances in the plant/respond to stress
- there are 100's of these enzymes within plants
- these enzymes are the reason we can use many herbicides without injury to the crop (e.g., atrazine and corn)
- metabolic resistance occurs when one of these enzymes become mutated or "overproduced"

For more info, see Dr. Pat Tranel's "Why Care About Metabolic Herbicide Resistance" video on YouTube

"New" Types of Resistance Mechanisms in Pigweeds:

Metabolic Resistance

- Plant is able to break down the herbicide at an increased rate
- Group 2 (ALS), 5 (triazine), 14 (PPO), 9 (glyphosate), 27 (HPPD), 15 (VLCFA), 4 (auxins)
- Can confer resistance to other herbicides within the same group and possibly to herbicides in other groups
- Common 2010 - today

What is our recommendation for the control of these “new types” of resistant weeds?

Some Thoughts on Weed Management in 2023 and Beyond

M ORE COMPLEX herbicide labels, registrations, requirements, etc.

I NTEGRATED APPROACHES that don't just rely on herbicides alone will become more and more important.

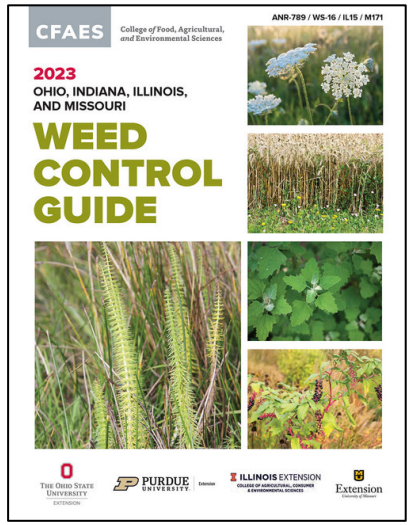
Z ERO TOLERANCE for resistant weeds. Because these "new" resistant weeds aren't like what mom used to make.

Mizzou® weed science

weedscience.missouri.edu

Email: bradleyke@missouri.edu

Phone: 573-882-4039



id weeds

App: ID Weeds (free download)

facebook

Facebook: Mizzou Weed Science

twitter

Twitter: @ShowMeWeeds