

## Managing PPO-Resistant Weeds in Soybeans

Protoporphyrinogen oxidase (PPO) inhibitor herbicides are widely used for postemergence and residual weed control and the management of glyphosate-resistant weeds in soybeans. Tall waterhemp, common ragweed, and Palmer amaranth have evolved as PPO-resistant weeds in many parts of the country.<sup>1</sup> Best management practices are needed to manage resistant weeds and preserve the effectiveness of PPO herbicides for use in soybeans.

### PPO Herbicides

PPO inhibitors belong to various chemical families and are classified as group 14 site-of-action herbicides (Table 1). The primary site-of-action of these herbicides is inhibition of the PPO enzyme which leads to the disruption or leaking of cell membranes. These herbicides are effective against broadleaf weeds, but some have activity on grasses. Many are contact-type, postemergence herbicides with limited translocation in plants. Visual symptoms are generally leaves that become chlorotic (yellowing) followed by necrosis (browning) and desiccation within 1 to 3 days. PPO inhibitors that are soil-active generally have short to moderate residual activity lasting about 4 to 6 weeks. These herbicides applied alone or in mixtures with other herbicides are widely used for residual weed control in soybeans. PPO herbicides are also important in soybeans for the management of glyphosate-resistant weeds to include Palmer amaranth and waterhemp.

### PPO-Resistant Weeds

Resistance to PPO herbicides has been confirmed in thirteen weed species globally.<sup>1</sup> Three weed species are reported to be PPO-resistant in the United States. Tall waterhemp (*Amaranthus tuberculatus*) was the first weed to evolve PPO-resistance and was reported in Kansas in 2001

Table 1. Common names of selected PPO herbicides used in soybeans.		
Chemical Family	Active Ingredient	Product Name
Diphenylethers	acifluorfen	Ultra Blazer® Herbicide
	fomesafen	Reflex® Herbicide, Flexstar® Herbicide
	lactofen	Cobra® Herbicide, Phoenix™ Herbicide
N-phenylphthalimides	flumiclorac	Resource® Herbicide
	flumioxazin	Valor® Brand Herbicide
Pyrimidinedione	saflufenacil	Sharpen® Herbicide
Triazinones	carfentrazone	Aim® EC Herbicide
	fluthiacet	Cadet® Herbicide
	sulfentrazone	Authority® brand Herbicide

(Figure 1).<sup>1</sup> Waterhemp currently has the most widespread resistance to PPO herbicides occurring in the states of KS, NE, MO, IA, IL, IN, MN, and WI. PPO-resistant common ragweed (*Ambrosia artemisiifolia*) was first reported in Delaware in 2005, and is now also occurring in NJ, MD, NC, OH, and MI (Figure 2).<sup>1</sup> PPO-resistant Palmer amaranth (*Amaranthus palmeri*) was first reported in 2011 in Arkansas, and is now also occurring in Tennessee and Illinois (Figure 3).<sup>1</sup> It is believed to be only a matter of time before PPO-resistant Palmer amaranth spreads throughout the South and Midwest. Resistance to PPO herbicides in weedy species has been attributed to mutations in the PPO gene.<sup>2</sup> The intensive use of PPO herbicides can exert high selection pressure leading to the evolution of resistant weed populations within a short period of time. In addition, weed populations with multiple resistance to PPO and ALS inhibitors as well as to glyphosate have evolved.

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*As of September 4, 2020, no dicamba formulations are currently registered by the U.S. EPA for in-crop use with seed in the Roundup Ready® Xtend Crop System in the 2021 season, and current stocks of low-volatility dicamba herbicides XtendiMax® herbicide, Engenia® herbicide and Fexapan® herbicide previously approved for in-crop use with seed in the Roundup Ready® Xtend Crop System may not be used after July 31, 2020.*

## Best Management Practices

Best management practices for the control of PPO-resistant weeds involves the use of herbicides along with mechanical and cultural practices.

- **Crop rotation.** In a corn/soybean rotation, proactively manage broadleaf weeds with effective herbicide options available in corn to reduce the soil seed-bank when in soybeans where PPO-resistant weeds can be more difficult to manage.
- **Tillage.** Deep tillage can help on less erosive fields with a history of high weed densities.
- **Cover crops.** Dense cover crop systems can impede spring weed emergence.
- **Narrow rows and increased seeding rates.** Planting soybeans in narrow or drilled rows and at higher seeding rates encourages canopy closure which can suppress weed emergence.
- **Start clean** using a herbicide burndown application or tillage. Using an effective residual herbicide in the burndown application helps to maintain a clean field prior to planting.
- **Scout fields** to determine herbicide burndown or tillage effectiveness. It is also important to scout fields for seedling weeds where preemergence herbicides were applied at planting as soil residual activity of herbicides fade away. Scouting also helps to recognize if weeds might be displaying resistance. A broadleaf weed is susceptible to an applied PPO herbicide if the top leaves burn and fall off. However, it is likely showing resistance if the tops only mottle and the plant continues to grow.
- **Spray early** to kill weeds before they reach 4 inches in height. Smaller weeds are easier to control.
- **Use overlapping residuals** to maintain bare soil and control later germinating weeds. Include postemergence herbicides when necessary to control emerged weeds. Overlapping residual herbicides can help from a resistance management standpoint and provide more flexibility with timely postemergence herbicide applications.
- **Employ multiple sites of action** to reduce selection pressure on any one given herbicide and slow the spread of resistant weeds.
- **XtendFlex® soybean** allow the use of glufosinate as an additional mode of action for broad-spectrum weed control including PPO-resistant weeds.
- **Hand weeding.** Hand removal of weeds may be necessary to prevent resistant weeds from dropping seed and adding to the soil seed-bank.
- **Clean equipment.** Minimize field-to-field weed seed movement by cleaning of tillage and harvesting equipment.

Using new herbicide trait packages, postemergence and preemergence herbicides, multiple sites-of-action, overlapping residual herbicide applications, and a diversified program that includes cultural practices will help in the management of PPO-resistant weeds and preserve the effectiveness of PPO herbicides for use in soybeans. Continue to monitor weed resistance issues in your fields and manage accordingly.

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Figure 1. Waterhemp seedlings.



Figure 2. Common ragweed in early growth stage.



Figure 3. Top image: Palmer Amaranth seedlings. Bottom image: Young Palmer Amaranth plant

## Sources (verified 3/23/20)

<sup>1</sup>Heap, I. The International Survey of Herbicide Resistant Weeds. Online. Internet. Tuesday, March 17, 2020. [www.weedscience.org](http://www.weedscience.org).

<sup>2</sup>Salas, R., Burgos, N., Tranel, P., Singh, S., Glasgow, L., Scott, R., and Nichols, R. 2016. Resistance to PPO-inhibiting herbicide in Palmer amaranth from Arkansas. *Pest Management Science*. Wiley Online Library. [www.wileyonlinelibrary.com](http://www.wileyonlinelibrary.com).

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## Legal Statements

**As of September 4, 2020, no dicamba formulations are currently registered by the U.S. EPA for in-crop use with seed in the Roundup Ready® Xtend Crop System in the 2021 season, and current stocks of low-volatility dicamba herbicides XtendiMax® herbicide, Engenia® herbicide and Fexapan® herbicide previously approved for in-crop use with seed in the Roundup Ready® Xtend Crop System may not be used after July 31, 2020.**

\*This product is not currently available for commercial sale or commercial planting. Commercialization is dependent on multiple factors, including successful conclusion of the regulatory process. The information presented herein is provided for educational purposes only, and is not and shall not be construed as an offer to sell.

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XtendFlex® soybeans have received full approval for planting in the United States but, as of the date this material was published, are pending approval in certain export markets. Commercial availability in 2021 is dependent upon regulatory approval.

**ALWAYS READ AND FOLLOW PESTICIDE LABEL DIRECTIONS.** It is a violation of federal and state law to use any pesticide product other than in accordance with its labeling. NOT ALL formulations of dicamba, glyphosate or glufosinate are approved for in-crop use with products with XtendFlex® Technology. ONLY USE FORMULATIONS THAT ARE SPECIFICALLY LABELED FOR SUCH USES AND APPROVED FOR SUCH USE IN THE STATE OF APPLICATION. Contact the U.S. EPA and your state pesticide regulatory agency with any questions about the approval status of dicamba herbicide products for in-crop use with Roundup Ready 2 Xtend® soybeans or products with XtendFlex® Technology.

Performance may vary, from location to location and from year to year, as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible and should consider the impacts of these conditions on the grower's fields.

Products with XtendFlex® Technology contains genes that confer tolerance to glyphosate, glufosinate and dicamba. Glyphosate will kill crops that are not tolerant to glyphosate. Dicamba will kill crops that are not tolerant to dicamba. Glufosinate will kill crops that are not tolerant to glufosinate. Contact your seed brand dealer or refer to the Bayer Technology Use Guide for recommended weed control programs.

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