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Distribution and Management of Herbicide-Resistant Palmer Amaranth in Arkansas

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Introduction

Palmer amaranth (pigweed) (*Amaranthus palmeri* S. Watson) is a highly competitive, annual broadleaf weed that has been listed as one of the most troublesome weeds to manage in multiple agricultural production systems in Arkansas (Van Wychen 2019). The prolific growth characteristics of Palmer amaranth are what make it one of the most adaptable and challenging weed species for farmers to manage.

Seeds are very small (1-2 mm diameter), black, and shiny (Figure 1) and are easily dispersed by wind, animals, livestock feed, and equipment (Legleiter and Johnson 2013, Ward et al. 2013). Upwards of 1,800,000 seeds have been produced by a single Palmer amaranth plant (Figure 2), which results in large concentrations of small seedlings when emerging (Figure 1). Palmer amaranth performs C4 photosynthesis, which allows for its increased growth rates (up to 2.5 inches per day) and efficiency in high-irradiance environments (Ward et al. 2013). Specifically, Palmer amaranth exhibits increased height, biomass, leaf area, and branching compared to other pigweed species leading to its superior invasiveness (Figure 3) (Horak and Loughin 2000). Palmer amaranth is also a dioecious weed species (separate male and female

Figure 2. Single female Palmer amaranth plant that produced 1.8 million seeds.

Figure 1. Seeds (left) and seedlings (right) of Palmer amaranth.

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Figure 3. Palmer amaranth stem size (left) and invasiveness in a soybean production field (right).

plants) (Steckel 2007), which ensures cross pollination and increases the likelihood that transfer of herbicide-resistant genes occurs. Viable Palmer amaranth pollen was identified as traveling up to 1,000 feet from its source plant (Ward et al. 2013). Additionally, Palmer amaranth has caused yield reductions of 91%, 60%, and 79%, in corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and soybean (*Glycine max* L. Merr.), respectively, if left uncontrolled (Bensch et al. 2003, MacRae et al. 2013, Massinga et al. 2001).

Herbicide Resistance in Arkansas

Palmer amaranth has been confirmed resistant to multiple sites-of-action in Arkansas that once provided excellent control (Table 1). A total of six sites-of-action have been rendered ineffective in certain areas of the state.

Site-of-action	Group number	Example herbicide trade names
ALS-inhibitor	2	Classic, Newpath, Scepter
Microtubule-inhibitor	3	Prowl, Treflan, Sonolan
EPSPS-inhibitor	9	Roundup
PPO-inhibitor	14	Flexstar, Sharpen, Valor
VLCFA-inhibitor	15	Dual Magnum, Warrant, Zidua
HPPD-inhibitor	27	Callisto, Laudis

Table 1. Confirmed herbicide resistance sites-of-action, WSSA Group numbers, and corresponding example herbicide trade names for Palmer amaranth (*Amaranthus palmeri*) populations in Arkansas.

Generally, all Palmer amaranth populations in Arkansas are assumed to be resistant to the EPSPS-inhibitor (glyphosate), ALS-inhibitors (Classic, Newpath, Scepter), and microtubule-inhibitors (yellow herbicides) (Prowl, Treflan, Sonolan). HPPD-inhibiting herbicides (bleaching herbicides) (Callisto, Laudis) have also seen a rise in suspected incidences of resistance in Palmer amaranth (Figure 4). Although not all populations represented in the map have been confirmed resistant, greenhouse screenings of populations from the blue shaded counties resulted in less than 60% control from a label rate of tembotrione (Laudis). Additionally, previous research in Arkansas revealed at least one-third of the screened Palmer amaranth populations exhibited reduced sensitivity to mesotrione (Callisto) (Singh et al. 2018).

PPO-inhibitor (Group 14) resistance has now become widespread throughout the row crop production area in Arkansas, and there have been confirmed instances of VLCFA-inhibitor (Group 15) resistance in Crittenden, Greene, and Lonoke counties (Figure 5). Although populations have been confirmed resistant, VLCFA-inhibitors such as *S*-metolachlor (Dual Magnum) are still a viable option in most environments for Palmer amaranth control. Care should be taken to use *S*-metolachlor and other Group 15 herbicides [acetochlor (Warrant), dimethenamid (Outlook), and pyroxasulfone (Zidua)] in conjunction with herbicides utilizing an alternative site-of-action, such as Photosystem II inhibitors like atrazine, metribuzin, or diuron, to prolong the life of these effective herbicides. For more information regarding *S*-metolachlor and the initial documented resistance in Arkansas, please see FSA2185 (http://bit.ly/FSA2185-Metolachlor), Metolachlor Herbicides: What are the Facts?

In order to manage herbicide-resistant Palmer amaranth and prevent further spread of resistance, the University of Arkansas System Division of Agriculture recommends the following resistance management strategies:

1. Rotate crops.
2. Plant a winter cover crop such as cereal rye. Allow the cover crop to grow as long as possible to keep the soil surface shaded; terminate from 2 weeks prior up to planting.
3. Use deep tillage (once every four years), cultivation, and other cultural practices for pigweed control where possible.

4. Rotate and mix herbicides with different sites-of-action at effective rates.
5. Avoid repetitive, sequential applications of the same herbicide or herbicides having the same site-of-action.
6. Control pigweeds on fallow or set-aside land and following harvest (Figure 6) to prevent seed from returning to the soil seedbank.
7. Clean tillage and harvest equipment thoroughly to remove pigweed seeds and reduce their transport from field-to-field.
8. **If you suspect resistance after a herbicide application:** attempt to eradicate escapes with alternative herbicides or cultural methods. **Do not let them go to seed!** In an instance of a suspected new case of herbicide resistance, collect seed samples from suspect plants and take them to your county Extension agent who will have them tested at the University of Arkansas or can let you know if resistant populations are known to exist.

Figure 6. Palmer amaranth emerging in Rohwer, AR on October 12, 2019. A seedhead is forming (circled in red) on a plant less than two inches tall.

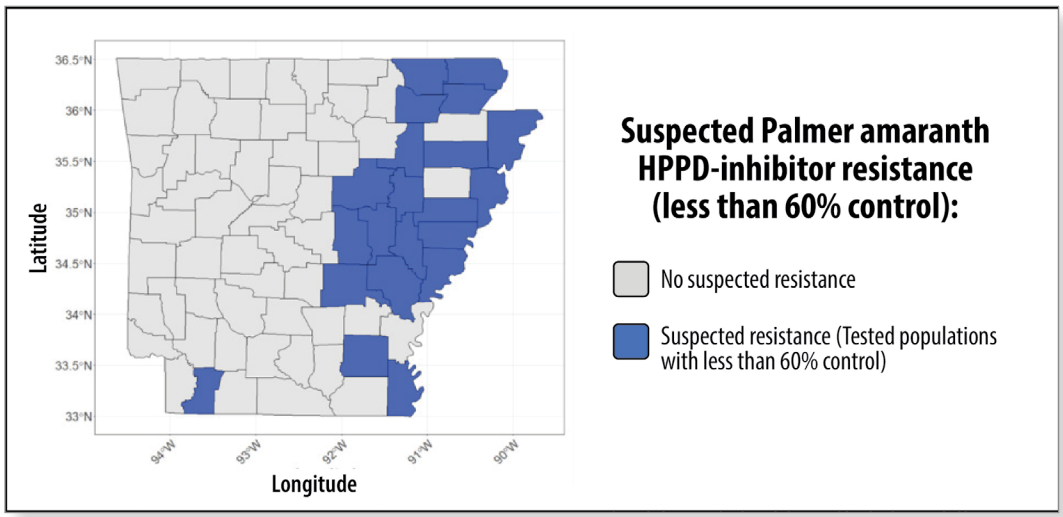

Figure 4. Map of Arkansas with suspected HPPD-inhibitor (Group 27) resistant Palmer amaranth populations by county. Although not all of these populations have been confirmed resistant, greenhouse screenings of populations from shaded counties resulted in less than 60% control from a label rate of tembotrione (Laudis).

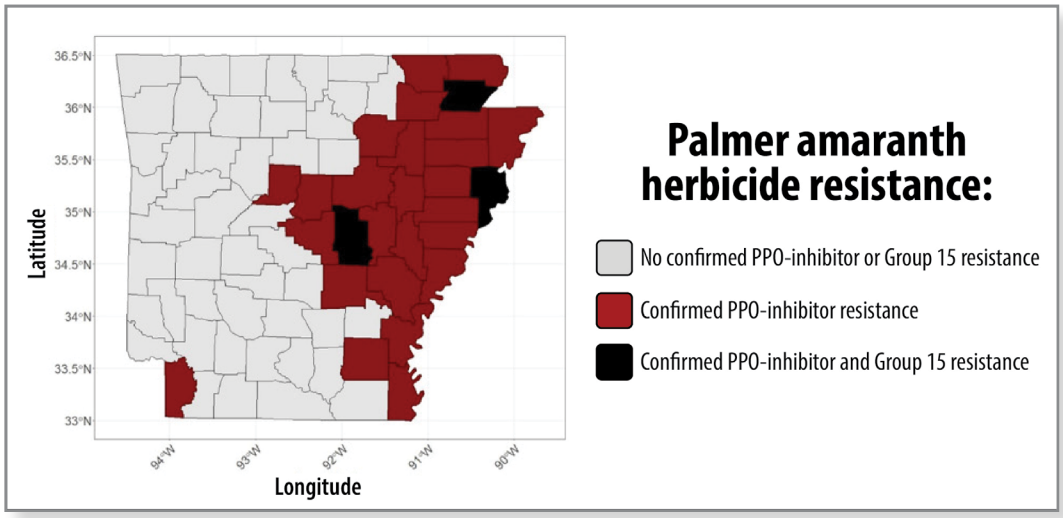

Figure 5. Map of Arkansas with confirmed PPO-inhibitor (Group 14) and VLCFA-inhibitor (Group 15) resistant Palmer amaranth populations by county.

General Management Recommendations for Herbicide-Resistant Palmer Amaranth

Several best practices for Palmer amaranth management should be followed regardless of cropping situation. These include:

1. **Start clean.** There are more options for management prior to crop emergence to remove the first flush of Palmer amaranth successfully.

2. **Plant early in narrow row widths.** This allows for the crop to gain a competitive advantage and reach canopy closure sooner, thereby increasing the effectiveness of a given herbicide program. In soybean production systems, at least 90% of total emerged Palmer amaranth plants occurred before canopy closure, and emergence was reduced by 73-76% compared to a treatment without soybean (Jha and Norsworthy 2009).

3. **Apply residual PRE herbicides with multiple sites-of-action at planting and overlap residuals.** The overlapping of residuals is key to eliminating early-season competition with pigweed (Figure 7) and puts less selection pressure on postemergence (POST) herbicides, as well as provides added flexibility to hit the proper application timing for POST herbicides.

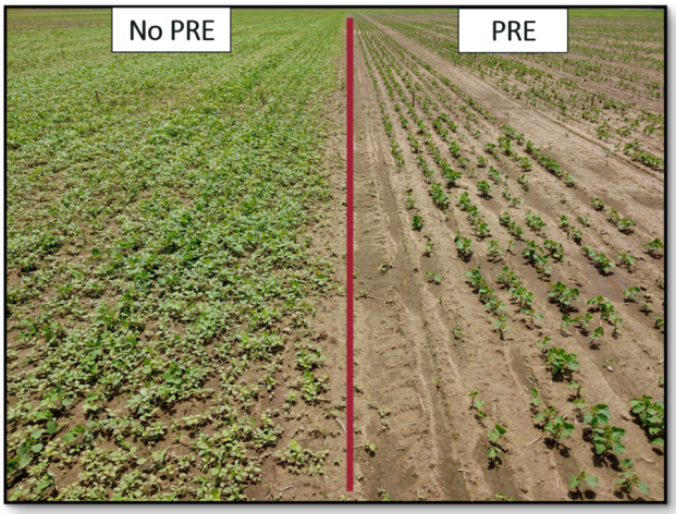

Figure 7. Illustration of the importance of starting clean and using a residual, preemergence herbicide. Soybean on the left received no burndown and preemergence (PRE) herbicide compared to soybean on the right starting clean from a burndown plus residual PRE.

4. **Setup herbicide application equipment correctly and effectively for each application.** Selecting an appropriate nozzle to produce an optimum droplet size will help with spray drift management and maintaining appropriate coverage. Increasing spray volumes provides a greater number of droplets for potential impaction and retention on a pigweed leaf surface. Adjuvants perform numerous roles within a spray application including: reducing surface tension of the spray solution resulting in fewer droplets that bounce and shatter, altering spray pH and tying up cations in spray water, breaking down the leaf cuticle to enhance absorption, or increasing droplet size to reduce drift potential.

5. **Monitor pigweed emergence closely and make timely POST applications that include a residual.** Pigweed is more easily controlled when it is four inches tall or less. In most instances, POST herbicides should be applied approximately 21 days following a preemergence (PRE) herbicide, and no later than 28 days. However, this can vary due to environmental conditions (i.e. air temperature, precipitation, etc.); therefore, diligent scouting is still required.

6. **Control or remove pigweed escapes prior to seed production, control plants that emerge after harvest (Figure 6), and/or utilize a harvest weed seed control strategy** to reduce the amount of pigweed seeds returning to the seedbank.

7. **Clean all equipment thoroughly to reduce the spread of seeds, and maintain turnrows, equipment yards, and ditches.**

8. **Use a program approach with diverse weed control tactics** including cultural practices and timely herbicide applications with multiple effective sites-of-action to successfully control Palmer amaranth (Norsworthy et al. 2012, Schwartz-Lazaro et al. 2017). More control efforts are better than one at successfully controlling Palmer amaranth. Some cultural practices most favorable for pigweed control are:

    a. Deep tillage (once every four years)
    b. Proper crop rotation
    c. Winter cover crop such as cereal rye
    d. Good seedbed preparation
    e. Establish good stands
    f. Plant in narrow row widths to hasten canopy closure
    g. Timely cultivation
    h. Harvest weed seed control

Crop-Specific Management Recommendations for Herbicide-Resistant Palmer Amaranth

The following recommendations are provided by University of Arkansas System Division of Agriculture weed scientists to specifically manage herbicide-resistant Palmer amaranth in the specific crops mentioned.

A direct mention of a specific product does not constitute endorsement but is based on data and observations from field research trials. Always read and follow the label when making a herbicide application.

Soybean:

1. **Start clean** with paraquat (Gramoxone), dicamba (Engenia, Xtendimax, FeXapan, Tavium) or 2,4-D (Enlist One) at planting depending on technology planted and current restrictions within the state.
2. **Plant soybean in narrow rows**; 15 inches or less if possible for quicker canopy.
3. **Plant a variety that is tolerant to metribuzin and a technology that can be used full season.** Tolerance ratings of tested commercial soybean varieties can be found at: http://bit.ly/2019-AR-soy-metribuzin. Xtend soybean will be available but due to dicamba cutoff dates, will likely not be a viable option where severe pigweed populations occur unless planting occurs in April. The Enlist technology, which enables both Enlist One plus glufosinate (Liberty/Interline) POST, has resulted in the best success of these multiple-resistant populations. LLGT27 varieties have tolerance to glufosinate and glyphosate POST, and a PRE HPPD-inhibiting herbicide (Alite 27), but Alite 27 is not available for use in most Arkansas counties.
4. **Use residual herbicides containing multiple sites-of-action at planting.** Metribuzin at 6 to 8 oz/A plus a Group 15 herbicide such as *S*-metolachlor, Zidua, or Outlook should be applied.
5. **Make timely POST applications regardless of herbicide used.**
6. **Overlap a residual herbicide** at 3 weeks after planting utilizing Outlook or Zidua with POST applications.
7. **Repeat residual and POST application 2 weeks following the first POST application** (may not be needed with a narrow-row width system).
8. **Control or remove escapes prior to seed production.**
9. **Utilize harvest weed seed control** like narrow-windrow burning if possible.

Cotton:

1. **Start clean** with paraquat (Gramoxone), dicamba (Engenia, FeXapan, Xtendimax) or 2,4-D (Enlist One) at planting depending on the technology planted and current restrictions within the state.
2. **Plant a variety that is resistant to glufosinate (Liberty/Interline) or Enlist** which enables both Enlist One (2,4-D) plus glufosinate POST which has resulted in the best success with these difficult-to-control populations. If Xtend varieties are planted, take note of current Plant Board regulations on dicamba applications.
3. **Use Brake plus Cotoran, Caparol, or Diuron PRE**, especially in heavily infested fields. Apply rates based on soil type. Poor results have been found with Brake applied to soils high in clay content.
4. **Overlap with a residual herbicide** at 3 to 4 weeks after planting utilizing Outlook, Dual Magnum, or Warrant with POST applications.
5. **Repeat residual with POST application** 2 weeks following the first POST application.
6. **Post-direct or layby with diuron (1 qrt/A) plus MSMA plus Anthem Flex or Zidua plus crop oil concentrate.**
7. **Control or remove escapes prior to seed production.**

Corn:

1. **Start clean and use a residual at planting** to control emergence until an early POST window (V3-V4).
2. **Make a timely POST application utilizing atrazine at 1.5-2 qrts/A with the POST program.** Atrazine has been found to synergize HPPD-inhibiting herbicides such as mesotrione (Halex GT), tembotrione (Capreno, Laudis), topramezone (Armezon), and tolpyralate (Shieldex) making them more effective. Remember a maximum of 2.5 lb ai/A/year of atrazine is permitted to be applied.
3. **Control escapes and new flushes following corn harvest.** Accomplish this with tillage or a non-selective herbicide like paraquat in combination with a Photosystem II inhibitor. If pigweed are large, it will likely take both tillage and the non-selective herbicide. If pigweed produce seed in the field, control will be more difficult the following season.

Peanut:

1. **Start clean and plant in narrow rows** (30 inches or less) if possible.
2. **Utilize Valor plus a labeled Group 15 PRE** such as Outlook at planting.
3. **Make timely POST applications** with Gramoxone + Storm + Zidua from cracking to early POST.
4. **Remove escapes** prior to harvest.

Rice:

1. **Apply Sharpen at 2-3 fl oz/A PRE** as this provides the best residual control of pigweed. However, control will be reduced in PPO-inhibitor-resistant populations.
2. **Apply Loyant POST at 8-10 fl oz/A** when pigweeds are less than 6 inches tall. Loyant provides excellent control of Palmer amaranth.
3. **Flood the field to prevent new flushes.**
4. **Make an extra POST application of Loyant or Grandstand + Propanil to levees and furrow-irrigated rice for late season control.**

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