LATE HERBICIDE APPLICATIONS FOR PALMER AMARANTH: CAN WE PREVENT A TRAIN WRECK

Report to the Delaware Soybean Board

Organization:
College of Agriculture and Natural Resources
University of Delaware
Newark, DE 19716

Principal Investigators:
Mark VanGessel, Extension Specialist and Professor
Kurt Vollmer, Post-Doctoral Researcher

University of Delaware
Research and Education Center
16483 County Seat Highway
Georgetown, DE 19947
302/856-7303 (phone) 302/856-1845 (fax)
mjv@udel.edu

Contributors:

Barbara Scott, Research Associate

Quintin Johnson, Extension Associate

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Palmer amaranth is a recent species to the region and has become one of the "driver weeds", a species that needs control strategies targeted specifically for it. Palmer amaranth originated in the deserts of the southwestern United States and northern Mexico. As a result, it is well adapted to stressful conditions. Palmer amaranth tolerates drought and heat better than other weeds. Palmer amaranth is capable of continuing to photosynthesize at temperatures higher than soybeans or corn, allowing it to grow while these crops have "shut down". This allows Palmer amaranth to grow rapidly throughout the summer and outcompete soybeans. Fields infested with Palmer amaranth are found throughout Delaware as well as eastern shore of Maryland, southeastern Pennsylvania, and New Jersey. This species is related to our common pigweed, but it is much more aggressive. It is common for this plant to grow as tall as 6 feet, and a single plant will produce a tremendous number of seeds. Palmer amaranth has a prolonged germination period that requires the use of postemergence herbicides.

In addition, most postemergence herbicides are not effective on larger Palmer amaranth plants. UD research has demonstrated that herbicide applications made to 6 to 8 inch tall Palmer amaranth has not provided consistent control. This results in a short time period that Palmer amaranth can be effectively controlled with postemergence herbicides. If weather is not conducive to spraying during this time or if a sprayer is not available, farmers are looking for guidance on strategies to deal with larger plants.

Complicating Palmer amaranth control in DE is the widespread resistance to glyphosate and ALS-inhibiting herbicides (Group 2) such as Classic, Raptor, and Pursuit. Farmers are relying on PPO-inhibiting herbicides (Group 14) such as Reflex, Cobra, or Flexstar or Liberty (Group 10) for postemergence Palmer amaranth control. Previous research, some funded by DSB, has demonstrated that increasing the use of adjuvants has only minimal effect on improving Palmer amaranth control.

Limited research has been done with dicamba or 2,4-D for control of larger Palmer amaranth plants. A preliminary trial in 2017 at UD's Research and Education Center found similar levels of control when dicamba, Liberty or Reflex was applied to 14-inch tall Palmer amaranth plants (all less than 70% control). However, control improved if a second herbicide application was made 7 days later. In addition to improved control, Palmer amaranth seed production appeared to be reduced with the second herbicide application. Most farmers realize the challenges they face if Palmer amaranth plants are large, but it is difficult to make decisions on the best way to minimize Palmer amaranth's impact on yield and contribution to the seedbank.

Herbicide resistance is increasing in DE as new infestations of Palmer amaranth are discovered and new weed-resistant biotypes are reported (i.e. common ragweed). With no new herbicide sites-of-action available for the near future, integrated weed management strategies need to be evaluated and implemented. Cover crops are one tactic that UD Weed Science has been investigating and has shown considerable amount of potential for both winter annual weeds such as horseweed as well as Palmer amaranth. One concern with integrating cover crops is its impact on soil-applied herbicides. Information is lacking on the potential effect of cover crop to intercept the herbicide spray. In addition, famers need to know if herbicides are washing off the plant residue to reach the soil surface. While cover crop systems are reducing weed emergence and early-season weed growth, many situations still require the use of residual herbicides. Information is needed on how best to recommend the use of residual herbicides in fields with cover crops.

The **research objectives** are to evaluate the effectiveness of various approaches for control of Palmer amaranth and other problem weed species.

Specific objectives are:

- Evaluate various options for management of large Palmer amaranth plants (initial year);
- and determine interaction of rye cover crop with soil-applied herbicide applications (2nd year).

This proposal was developed based on the priorities outlined by the DSB in their request for proposals, as well as conversations with soybean farmers, ag businesses, and DE Department of Agriculture's Noxious Weed Program. The first objective was a new project and the second objective was a continuation of previous research. This research will benefit Delaware's soybean growers and the soybean industry by identifying potential options for controlling large Palmer amaranth plants. These projects are designed to address weed control in terms of effectiveness, adaptability to Delaware's specific needs, as well as resistance management.

Procedures

The **first objective** examined the effectiveness of strategies to control Palmer amaranth when larger than recommended sizes. This experiment used soybeans with the following herbicide-tolerance traits: Liberty Link (Enlist E3); 2,4-D-resistant (Enlist E3); dicamba-resistant (Xtend) and Roundup Ready (Xtend). Large Palmer amaranth plants, 12 to 14-inches tall, were treated with Engenia (dicamba) plus glyphosate, Enlist Duo (2,4-D choline+glypohsate), Reflex plus glyphosate and Liberty as single as well as sequential applications. Engenia and Reflex were applied as a tankmixture with glyphosate. Flexstar GT is a prepackaged mixture of fomesafen and glyphosate with proprietary adjuvants. Sequential applications were made 7 days apart. In addition, the sequential treatments included Cobra (lactofen) to assess the potential benefit of including herbicides with additional modes-of-action. Fomesafen label does not allow more than one application so it was not used as part of a sequential application. This objective also examined if the order in which herbicides are applied influenced control. Treatments are listed in Table 1.

Soybeans were drilled no-till on June 18. The research area was sprayed with glyphosate plus Liberty before planting to eliminate any emerged weeds. Outlook was applied after planting at 12 fl oz to provided limited control of annual weeds.

All herbicides were applied at 20 g/A; with appropriate spay tips (coarse droplets for dicamba and 2,4-D; medium droplets for Liberty and Reflex); at maximum allowable rates; and with appropriate adjuvants. The first application was made on July 20.

Plots were evaluated for Palmer amaranth control. At harvest, five female Palmer amaranth plants were measured for height, clipped at the ground level for recording biomass, and threshed to determine seed production. Plots were harvested to determine impact of treated Palmer amaranth plants on yield. However, using multiple varieties did not allow comparison of yields across the various herbicide programs.

Results

Palmer amaranth control with a single POST application did not provide acceptable control, with 83% control from Enlist Duo being the highest (Table 1). Liberty plus Enlist One provided only 75% control at 5 weeks after treatment, yet no Palmer amaranth plants were present at harvest. In this trial, Reflex plus glyphosate provided better control than Flexstar GT.

Sequential applications of Engenia plus glyphosate, Enlist Duo, and Liberty provided 97% control or better when rated 4 weeks after treatment (Table 1). Sequential applications of PPO herbicides Reflex, Cobra, or Flexstar provided similar level of Palmer amaranth control as a single application. Adding Cobra with sequential applications of Engenia, Enlist Duo or Liberty did not improve control; tankmixtures with Enlist Duo resulted in less control than Enlist Duo by itself.

Weed seeds per plant were quite variable and ranged from 4,748 to 38,584 (Table 1). The nontreated plants had the highest number of seeds, yet it was lower than what is often reported. The soybeans were drilled in 7-inch rows presumably increasing soybean competitiveness and helping to limit Palmer amaranth seed production.

There were no yield differences among treatments with the same soybean variety (data not presented). Herbicide treatments that caused soybean leaf burn (Cobra) did not impact soybean yield, nor did they delay soybean maturity.

Based on preliminary results from one year, sequential applications of dicamba, 2,4-D choline or Liberty are needed to control larger Palmer amaranth plants. Provided Palmer amaranth plants are not taller than 17 inches, excellent control can be achieved with sequential applications of dicamba, 2,4-D choline or Liberty. Sequential applications of PPO herbicides, or including Cobra with sequential applications did not improve control.

Table 1. Treatments for controlling large Palmer amaranth.

Trt No.	First Application[a]	Second Application[a]	P.amaranth 8/7/2018 Control %		P.amaranth 10/10/2018 Total Count #/plot		P.amaranth Dry Weight per plant		P. amaranth Num seeds / female plant	
1	Engenia[b]+glyphosate	None	70	e	0.3	de	8	cd	--[c]	
2	Enlist Duo[d]	None	83	c	0.3	de	9	cd	--	
3	Liberty	None	70	e	2.3	bcd	34	b	27,353	a
4	Reflex+glyphosate	None	82	c	0.7	cde	28	bc	--	
5	Flexstar GT	None	73	e	2.3	bcd	19	bcd	7,562	a
6	Engenia+glyphosate	Engenia+glyphosate	100	a	0	e	0	d		
7	Enlist Duo	Enlist Duo	97	ab	0	e	0	d		
8	Liberty	Liberty	99	a	0	e	0	d		
9	Reflex+glyphosate	glyphosate	99	a	0	e	0	d		
10	Flexstar GT	glyphosate	70	e	3	b	30	bc	9,908	a
11	Engenia+glyphosate	Engenia+glyphosate +Cobra	98	ab	0	e	0	d		
12	Enlist Duo	Enlist Duo +Cobra	85	c	0	e	0	d		
13	Liberty	Liberty+Cobra	99	a	0	e	0	d		
14	Reflex+glyphosate	glyphosate+Cobra	80	cd	0.3	de	8	cd	12,760	a
15	Flexstar GT	glyphosate+Cobra	80	cd	2.7	bc	10	bcd	4,748	a
16	None[e]	None	0	f	10.7	a	107	a	38,584	a
17	Liberty+Enlist One[d]	None	75	de	0	e	0	d		
18	Authority Elite followed by Reflex+glyphosate		93	b	0.3	de	13	bcd	10,893	a
19	Engenia+Cobra	Engenia+glyphosate	100	a	0	e	0	d		
20	Cobra+glyphosate	FlexstarGT	75	de	0.3	de	14	bcd	16,993	a
LSD P=.05			5.21		2.08		24.612		40,021.97	
CV			3.8		107.74		106.02		95.67	
Treatment Prob(F)			0.0001		0.0001		0.0001		0.3690	

[a]Initial (or first) herbicide application was when Palmer amaranth was 12 to 14 inch tall; sequential applications had a second application made 7 days later.
[b]dicamba formulation was Engenia; UD research has not shown any difference in Palmer amaranth control among the various dicamba formulations.
[c]"—" indicates only male plants were present at harvest time.
[d] Enlist Duo is 2,4-D choline plus glyphosate; Enlist One is only 2,4-D choline
[e]Multiple untreated checks were used, one for each variety (dicamba + RR resistance; 2,4-D resistance; Liberty Link).

Procedures

The **second objective** examined the potential impact of cereal rye cover crop on application of soil-applied residual herbicides. One concern growers have voiced is the potential of cover crops to intercept residual herbicides, preventing them from reaching the soil. On-going research has demonstrated that weed control is generally acceptable in these situations, but it is difficult to know if this is due to herbicides or cover crop.

This study examined level of rye biomass and herbicide. Rye cover was either 1) none, 2) fall-seeded rye terminated in boot stage, or 3) fall-seeded and not sprayed before planting. Herbicide treatments were 1) none, 2) Dual Magnum, and 3) Valor. Valor and Dual Magnum represent the range of herbicide properties for washing off cover crop residue. Valor has low water solubility and does not easily wash off plant residue, while Dual Magnum has high water solubility and readily washes off plant residue. This study was conducted in a field naturally infested with pigweed species. Valor and Dual Magnum are both effective on pigweed species, which served as a good indicator species for treatment effectiveness.

Water sensitive papers were used to determine the amount of spray solution reaching the soil surface at time of application. Cards were analyzed using the SnapCard mobile app. One day after herbicide application, a 0.5 m^2 quadrat of cereal rye was removed. Removing the rye also resulted in removal of the herbicide that was potentially intercepted by the rye.

Cereal rye was planted on October 12, 2017 and terminated on May 29, 2018. Soybeans were planted on June 8, and preemergence herbicides applied within 24 hours. Rye plots not treated before planting were sprayed with glyphosate 2 days after planting.

Results

The presence and level of a cereal rye cover crop did not influence preemergence herbicide activity. Although rye biomass was higher for rye not terminated until after planting (1,981 lbs/A) compared to rye terminated 10 days before planting (1,303 lbs/A) (Table 2). However, there was no difference in spray card coverage regardless of the amount rye or no rye treatments.

At 2 WAP there were no observable treatment differences in weed control. At 4 WAP, only the main effect of herbicide was significant for weed control. When averaged over the presence or absence of cereal rye, Valor provided better Palmer amaranth control (85%), compared to Dual Magnum (38%), and no herbicide (12%) (Table 3). The lack of interaction between herbicides and cereal rye in this study demonstrates that cereal rye did not supplement weed control. This may have been the result of lower cereal rye biomasses in this study compared to other cover crop studies. Normal target biomass for weed suppression with cereal rye is 5,000 to 7,000 lbs/A.

In the microplots, where rye was removed one day after the Dual Magnum or Valor application, weed control for Palmer amaranth was similar to the whole plots. Indicating that a sufficient amount of herbicide reached the soil surface.

Due to severe deer-feeding on the soybeans, as well as water damage to the

plots, late-season weed control and yields were not collected.

Table 2. Rye biomass and spray coverage using different levels of cereal rye.

Treatment	Cereal rye		Spray coverage	
	---lbs A^{-1}---		---%---	
No rye	----	----	25	a
10 DPP	1,303	a	16	a
Plant Green	1,981	b	16	a
LSD P=0.05	68.5		9.1	
CV	16.5		21.2	
Treatment Prob(F)	0.0389		0.089	

Table 3. Weed control with Dual Magnum or Valor at 4 weeks after planting. Control is averaged over different levels of cereal rye.

Treatment	Rate	Unit	P.amaranth whole plot %control 4 WAP		P.amaranth micro-plot[a] %control 4 WAP	
No herbicide			12	b	23	b
Dual Magnum	1.25	pt/A	38	b	40	ab
Valor SX	2	oz wt/A	85	a	71	a
LSD P=0.05			43.9		58.8	
CV			78.5		86.6	
Treatment Prob(F)			0.005		0.0399	

[a]Microplot is the 0.5 m^2 area that had the cereal rye removed one day after Dual or Valor was applied.