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WEED SCIENCE

Integrating Fluridone into a Glufosinate-based Program for Palmer Amaranth Control in Cotton

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ABSTRACT

Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* S Wats.) has increased the need for effective preemergence (PRE) herbicides in cotton (*Gossypium hirsutum* L.). Fluridone, a carotenoid biosynthesis inhibitor, has a mechanism of action currently not used in crops. Field research focused on Palmer amaranth control by fluridone (224 g a.i. ha^{-1}) applied PRE alone and in combination with acetochlor, diuron, pendimethalin, and half and full rates of fomesafen (1260, 560, 1063, 140, and 280 g a.i. ha^{-1}, respectively). Also evaluated were fluridone (112 and 168 g ha^{-1}) plus fomesafen 140 g ha^{-1}, diuron 560 g ha^{-1} plus fomesafen 140 or 280 g ha^{-1}, and acetochlor 1260 g ha^{-1}plus fomesafen 140 or 280 g ha^{-1}. PRE herbicides were followed by glufosinate applied twice postemergence (POST) and diuron plus MSMA at layby. Fluridone injured cotton 3% or less and did not increase injury when combined with other herbicides. Palmer amaranth was controlled 97% by fluridone at 224 g ha^{-1} prior to glufosinate application compared with 87 to 95% control by acetochlor, diuron, fomesafen, or pendimethalin. Fluridone alone controlled Palmer amaranth as well as acetochlor plus fomesafen and better than diuron plus fomesafen. Similar control was obtained with fluridone at 112, 168, and 224 g ha^{-1}, acetochlor, or diuron plus fomesafen at 140 g ha^{-1}. Glufosinate controlled emerged weeds but continued emergence was noted in the absence of residual herbicides. PRE herbicides increased control prior to layby but did not increase cotton yield. This research demonstrated that fluridone can be used in a glufosinate-based system for proactive resistance management.

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Palmer amaranth (*Amaranthus palmeri* S Wats.) is the most troublesome weed in cotton production in the southeastern U.S. (Culpepper et al., 2010; Webster, 2013). It has a number of characteristics, such as high photosynthetic capacity, drought tolerance mechanisms, and adaptation to shading, which allow it to grow rapidly and compete with crops (Ehleringer, 1983; Horak and Loughin, 2000; Jha et al., 2008; Monks and Oliver, 1988; Place et al., 2008; Sellers et al., 2003; Wright et al., 1999). Cotton yield has been reduced 6 to 15% with one Palmer amaranth per 10 m of row and up to 92% with eight weeds per m of row (MacRae et al., 2013; Morgan et al., 2001; Rowland et al., 1999). Palmer amaranth also interferes with cotton harvest (Smith et al., 2000) and sometimes makes mechanical harvest impractical (Morgan et al., 2001).

Prior to commercialization of glyphosate-resistant (GR) cotton, growers relied on multiple applications of residual herbicides applied preplant incorporated, preemergence (PRE), and postemergence (POST) directed to effectively control weeds (Wilcut et al., 1995). These programs were effective if rainfall occurred shortly after application of PRE herbicides and weeds were small during POST-directed applications (Culpepper and York, 1997). Pyrithiobac, an acetolactate synthase (ALS)-inhibiting herbicide applied PRE or POST, controls Palmer amaranth with minimal injury to cotton (Branson et al., 2005; Jordan et al., 1993a, b). However, ALS-resistant Palmer amaranth is now common throughout the southern U.S., thus reducing the utility of pyrithiobac as a control option (Bond et al., 2006; Nandula et al., 2012; Poirier et al., 2014; Sosnoskie et al., 2011).

Cotton resistant to glyphosate was commercialized in 1997 and was quickly adopted by growers (Gianessi, 2005). Weed control programs using only glyphosate effectively controlled most weeds while allowing greater flexibility in application timing and reducing potential herbicide carryover (Culpepper and York, 1998, 1999; Faircloth et al., 2001). Glyphosate once controlled Palmer amaranth

(Corbett et al., 2004; Culpepper and York, 1998; Parker et al., 2005), but a GR biotype was confirmed in Georgia in 2005 (Culpepper et al., 2006). Since then, GR in Palmer amaranth has been confirmed in 25 states (Heap, 2016). Additionally, Palmer amaranth populations in several states express resistance to both ALS-inhibiting herbicides and glyphosate (Heap, 2016; Nandula et al., 2012; Poirier et al., 2014; Sosnoskie et al., 2011).

Residual herbicides commonly used prior to GR cotton have again become necessary to control GR Palmer amaranth (Burgos et al., 2006; Whitaker et al., 2011). Current Cooperative Extension Service recommendations for controlling GR Palmer amaranth in cotton include a residual preplant or preplant incorporated herbicide followed by additional residual herbicides applied PRE. These soil-applied herbicides are followed by timely POST applications of glufosinate, in many cases mixed with acetochlor or *S*-metolachlor, and a POST-directed layby application of another residual herbicide such as diuron (Culpepper, 2015; York, 2016). Use of residual herbicides is an effective herbicide resistance management strategy because of the ability to overlap (in time) residual herbicides to minimize emergence of weeds throughout the growing season and thus reduce selection pressure from POST herbicides (Duke and Powles, 2008; Norsworthy et al., 2012; York, 2016).

Among the most effective and most widely used residual herbicides for controlling GR Palmer amaranth are flumioxazin and fomesafen (Cahoon et al., 2014; Whitaker et al., 2011), both of which inhibit protoporphyrinogen oxidase (PPO) in sensitive plants (Beale and Weinstein, 1990; Matringe et al., 1989). However, widespread use of these herbicides in cotton, along with extensive use in other crops, has increased concern over potential to select for PPO-resistant biotypes (Cahoon et al., 2014; Riggins and Tranel, 2012). Resistance to PPO-inhibiting herbicides was reported in Palmer amaranth in Arkansas in 2011 (Heap, 2016), and resistant populations are now known to exist in at least five states (Scott et al., 2016).

Fluridone controls weeds by inhibiting phytoene desaturase and thus preventing carotenoid biosynthesis (Bartels and Watson, 1978; Kowalczyk-Schroder and Sandmann, 1992). Fluridone was first investigated for possible use in cotton in the 1970s. Banks and Merkle (1979) and Waldrep and Taylor (1976) reported good control of *Amaranthus* species by fluridone. However, potential carryover of fluridone to subsequent crops was a concern (Banks et al., 1979; Banks and Merkle, 1979; Schroeder and Banks, 1986).

Research with fluridone during the 1970s was conducted with rates of 300 to 900 g a.i. ha^{-1}(Banks and Merkle, 1979; Waldrep and Taylor, 1976). More recently, research with fluridone for control of GR Palmer amaranth has focused on lower use rates. Fluridone at 200 to 224 g ha^{-1} controlled Palmer amaranth greater than 90% (Crow et al., 2014; Hill et al., 2016). No more than 7 and 13% visible injury to corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], rice (*Oryza sativa* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], and sunflower (*Helianthusannuus* L.) was noted in the season following fluridone applied at 224 and 900 g ha^{-1}, respectively, on silt loam and silty clay soils in Arkansas (Hill et al., 2014). Research on sandy soils in North Carolina with fluridone applied the preceding year at rates up to 1120 g ha^{-1} showed less than 10% visible injury to soybean, grain sorghum, peanut (*Arachis hypogaea* L.), and corn and no effect on plant height 4 wk after planting or yield (Cahoon et al., 2015b).

The objective of our research was to determine the effectiveness of fluridone in cotton when applied alone or mixed with other commonly used residual herbicides to control GR Palmer amaranth. The research also aimed to understand the effect of those herbicide mixtures on cotton growth and yield on coarse-textured soils typical of cotton production in the southeastern U.S.

MATERIALS AND METHODS

The experiment was conducted at seven sites in North Carolina during 2013 and 2014. During both years, the experiment was conducted in two fields on the Central Crops Research Station at Clayton (referred to as Clayton-1 and Clayton-2; 35.67° N, 78.51° W) and on a private farm in Mount Olive (35.20° N, 77.96° W). Adjacent areas within the same fields were used during the second year. The experiment also was conducted in 2014 on the Upper Coastal Plain Research Station at Rocky Mount (35.90° N, 77.68° W).

Soil in both fields at Clayton was Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) with humic matter of 0.2% in Clayton-1 and 0.51% in Clayton-2 and pH of 5.5. Soil at Mount Olive was a Wagram loamy sand (loamy, kaolinitic, thermic Arenic Kandiudults) with humic matter of

0.4% and a pH of 5.1. Soil at Rocky Mount was an Aycock sandy loam (fine-silty, siliceous, subactive, thermic Typic Paleudults) with humic matter of 0.3% and pH of 5.9. Soil humic matter content was determined by the North Carolina Department of Agriculture and Consumer Services, Agronomic Section, according to Melich (1984). Palmer amaranth densities were naturally occurring at greater than 100 plants m^{-2} at all locations.

Stoneville® cotton cultivar ST 4946GLB2 (Bayer CropScience, Research Triangle Park, NC) was planted at each site on dates listed in Table 1. Tillage systems at each location are also listed in Table 1. Conventional tillage consisted of disking and bed formation. Strip-tillage was according to Meijer et al. (2016). At sites with no-till and strip-tillage systems, cotton was planted into residue from a preceding cotton crop. Plot size was 4 rows by 9 m. Row width was 91 cm at Rocky Mount and 97 cm at Clayton and Mount Olive.

Herbicide application dates are listed in Table 1 and sources of herbicides are listed in Table 2. All plots at strip-tilled and no-till locations received a burndown application of 2,4-D dimethylamine salt at 766 g a.e. ha^{-1} plus glyphosate potassium salt at 866 g a.e. ha^{-1} approximately 3 wk prior to planting and paraquat dichloride at 840 g a.i. ha^{-1} a few hours ahead of planting. Treatments consisted of a factorial arrangement of fluridone at two rates (0 and 224 g a.i. ha^{-1}) and the following six tank-mix herbicides: none, acetochlor 1260 g a.i. ha^{-1}, diuron 560 g a.i. ha^{-1}, fomesafen 140 and 280 g a.i. ha^{-1} (hereafter referred to as fomesafen-low and fomesafen-high, respectively), and pendimethalin 1063 g a.i. ha^{-1}. Fluridone and the tank-mix herbicides were applied as broadcast sprays within 2 hr after planting. Four additional treatments in 2013 and 2014 represented grower standards and included diuron 560 g ha^{-1} plus fomesafen-low or fomesafen-high and acetochlor 1260 g ha^{-1} plus fomesafen-low or fomesafen-high. In 2014 only, two additional treatments included fluridone at 112 and 168 g ha^{-1}mixed with fomesafen-low.

Table 1. Tillage systems, planting dates, herbicide application dates, and rainfall in first 15 d following planting

Location	Year	Tillage system	Planting date	Herbicide application date				Rainfall Days after planting		
				PRE	EPOST	MPOST	Layby	0-5	6-10	11-15
								cm		
Clayton-1	2013	Conventional	13 May	13 May	4 June	10 June	16 July	1.0	9.3	0.2
Clayton-2	2013	No-till	14 May	14 May	10 June	28 June	15 July	2.7	7.6	0.3
Mount Olive	2013	Strip-till	8 May	8 May	31 May	17 June	2 July	0	0	4.9
Clayton-1	2014	No-till	12 May	12 May	3 June	17 June	2 July	9.8	0	0
Clayton-2	2014	Conventional	12 May	12 May	30 May	17 June	2 July	9.8	0	0
Mount Olive	2014	Strip-till	3 May	3 May	15 May	28 May	27 June	0	0	5.3
Rocky Mount	2014	Strip-till	6 May	6 May	27 May	13 June	1 July	0	6.6	0

Table 2. Herbicides used in experiment[z]

Herbicide	Trade name	Formulation concentration	Manufacturer
acetochlor	Warrant®	359 g ai L^{-1}	Monsanto Co., St. Louis, MO
2,4-D dimethylamine salt	Weedar®64	456 g ae L^{-1}	Nufarm Inc., Morrisville, NC
diuron	Direx®4L	480 g ai L^{-1}	ADAMA Agricultural Solutions Ltd., Morrisville, NC
fluridone	experimental	240 g ai L^{-1}	SePRO Corp., Carmel, IN
fomesafen	Reflex®	240 g ai L^{-1}	Syngenta Crop Protection, Greensboro, NC
glufosinate-ammonium	Liberty® 280 SL	280 g ai L^{-1}	Bayer CropScience, Research Triangle Park, NC
glyphosate potassium salt	Roundup PowerMAX®	540 g ae L^{-1}	Monsanto Co., St. Louis, MO
MSMA	MSMA 6	720 g ai L^{-1}	Drexel Chemical Co., Memphis, TN
paraquat dichloride	Parazone® 3SL	360 g ae L^{-1}	ADAMA Agricultural Solutions Ltd., Morrisville, NC
pendimethalin	Prowl® H_2O	455 g ai L^{-1}	BASF Ag Products, Research Triangle Park, NC

[z] Labels available from CDMS, Marysville, CA at http://www.cdms.com.

All plots except the nontreated checks received glufosinate-ammonium at 594 g a.i. ha^{-1} applied early postemergence (EPOST) to 1- to 2-leaf cotton and mid-postemergence (MPOST) 14 to 19 d later to 6- to 8-leaf cotton. A POST-directed layby application of diuron at 1120 g ha^{-1}plus MSMA at 2240 g a.i. $ha^{-1}$was applied 14 to 26 d after MPOST when cotton was approximately 40 to 50 cm in height. All POST and layby applications were targeted at 5- to 10-cm Palmer amaranth.

Preplant burndown herbicides and paraquat were applied with a tractor-mounted sprayer equipped with flat-fan nozzles (DG11002 TeeJet® Drift Guard flat-spray nozzles, TeeJet Technologies, Wheaton, IL) delivering 140 L ha^{-1} at 165 kPa. The PRE and POST herbicides were applied using a CO_2-pressurized backpack sprayer equipped with flat-fan nozzles (AIXR 11002 TeeJet® air induction flat-spray nozzles, TeeJet Technologies) delivering 140 L ha^{-1} at 165 kPa. Layby herbicides were applied with a single flood nozzle (TK-VS2 FloodJet® wide-angle flat-spray nozzles, TeeJet Technologies) per row middle delivering 140 L ha^{-1} at 210 kPa.

In each year, weed control and crop injury were visually estimated using a scale of 0 to 100%, with 0 equal to no control or injury and 100 equal to complete control or crop death (Frans et al., 1986). Weed control and crop injury were estimated just prior to EPOST, MPOST, and layby applications, 14 d after layby application, and in mid-September. Above-ground fresh biomass of Palmer amaranth was determined in mid-September from three row middles (25 to 26 m^{-2}) in treated plots and from 1 m^{-2} in nontreated checks. Treated plots were mechanically harvested in October or November. Nontreated checks were not harvested due to severe weed infestations, and yields were assumed to be zero.

The experimental design was a randomized complete block with treatments replicated four times. Data, excluding nontreated checks, were subjected to analysis of variance appropriate for the factorial treatment arrangement of fluridone rates by tank-mix herbicides. Data for visual estimates of Palmer amaranth control and cotton injury were arcsine square-root transformed prior to analysis. Nontransformed data are presented with statistical interpretation based upon transformed data. The PROC GLIMMIX procedure of SAS (Version 9.3; SAS Institute Inc., Cary, NC) was used. Herbicide treatments were considered as fixed factors, whereas locations and replications were treated as random. Means for interactions or main effects were separated using Fisher's Protected LSD Test at $p = 0.05$. A second analysis compared the factorial arrangement of acetochlor, fluridone (224 g ha^{-1}), and diuron by rates of fomesafen (0 and 280 g ha^{-1}). A third analysis compared fomesafen-low alone and mixed with acetochlor, diuron, or fluridone at 112, 168, and 224 g ha^{-1} in 2014. Fresh biomass of Palmer amaranth in all herbicide treatments was compared to biomass in the nontreated checks using Dunnett's procedure (Dunnett, 1955).

RESULTS AND DISCUSSION

Clayton locations received 9.8- to 10.3-cm rainfall during the first 10 d after planting and the Rocky Mount location received 6.6 cm during this period (Table 1). No rainfall occurred during the first 10 d after planting at Mount Olive, but 4.9 to 5.3 cm were received during the period of 11 to 15 d after planting. Few Palmer amaranth emerged before the first rainfall at Mount Olive.

Fluridone Mixtures. No cotton injury at EPOST was noted at Rocky Mount in 2014, in either year at Mount Olive, and at Clayton in 2014. Only the main effect of tank-mix herbicides was significant at Clayton-1 in 2013. Averaged over fluridone rates, diuron and fomesafen at both rates injured cotton only 2 to 4% (data not shown). Acetochlor and pendimethalin injured cotton 10 and 23%, respectively. Acetochlor injury was expressed as stunting. Pendimethalin caused greatly enlarged cotyledons and malformation of the true leaves. Similar symptoms have been reported previously (Cahoon et al., 2015a). Only the main effect of fluridone rates was significant at Clayton-2 in 2013, where cotton was injured 0 and 3% by fluridone at 0 and 224 g ha^{-1}, respectively. Injury was transient; little to no injury was observed at MPOST or later in the season (data not shown).

A treatment-by-location interaction was not observed for Palmer amaranth control at time of EPOST or MPOST application. However, fluridone by tank-mix herbicide interactions were present. Among the tank-mix herbicides applied alone, greatest Palmer amaranth control at time of EPOST application was obtained with acetochlor and fomesafen-high (Table 3). Pendimethalin was least effective and controlled Palmer amaranth 82% compared with 87% control by diuron and fomesafen-low and 94 to 95% control by acetochlor and fomesafen-high. Fluridone applied alone controlled Palmer amaranth 97% at EPOST. Control by fluridone alone was similar to control by all the fluridone-containing tank mixtures. Hill et al. (2016) reported 100 and 96% control of Palmer amaranth at 4 and 6 wk after application, respectively, by fluridone PRE at 224 g ha^{-1}on silt loam soils.

Glufosinate applied EPOST controlled all emerged Palmer amaranth across all treatments. However, due to continued emergence, control declined to 88% at time of MPOST in the absence of PRE herbicides (Table 3). All PRE herbicides and herbicide combinations increased control. Similar to observations at time of EPOST, control at MPOST by tank-mix herbicides in the absence of fluridone was greatest with acetochlor and fomesafen-high. However, they were only 2 to 3% more effective than diuron, fomesafen-low, or pendimethalin. Fluridone alone or mixed with other herbicides controlled Palmer amaranth 98 to 99%.

At time of layby application, following two POST applications of glufosinate, a treatment-by-location interaction was observed, but the fluridone by tank-mix herbicide interaction within locations and the main effect of tank-mix herbicide were not significant. At 6 of 7 locations, the main effect of fluridone was significant. Averaged over tank-mix herbicides, Palmer amaranth control by fluridone at 0 and 224 g ha^{-1} was 96 and 98%, respectively, at Clayton-1 in 2013, 88 and 97% at Mount Olive in 2013, 93 and 100% at Clayton-1 in 2014, 99 and 100% at Clayton-2 in 2014, 96 and 99% at Mount Olive in 2014, and 98 and 100% at Rocky Mount in 2014 (data not shown). The main effect of tank-mix herbicides also was not significant at 14 d after layby, although a small but significant main effect of fluridone was observed. Averaged over locations and tank-mix herbicides, Palmer amaranth was controlled 99 and 100% in the presence of 0 and 224 g ha^{-1} fluridone, respectively (data not shown). Palmer amaranth was controlled 98 to 100% late in the season, with no differences among treatments (data not shown).

Averaged over locations, Palmer amaranth fresh biomass in nontreated plots late in the season averaged 18,320 kg ha^{-1} (data not shown). No differences in Palmer amaranth biomass were observed among herbicide treatments. Fresh biomass in treated plots, which ranged from 10 to 160 kg ha^{-1}, was reduced at least 99% compared with the nontreated check. Seed cotton yields, averaged over locations, ranged from 1930 to 2100 kg ha^{-1}, with no differences detected among treatments (data not shown).

Table 3. Interaction of fluridone and tank-mix herbicides applied PRE on Palmer amaranth control[z]

PRE herbicides	Application rate	Control	
		At EPOST[y]	At MPOST[x]
	g ha^{-1}	%	
none		0 f	88 e
acetochlor	1260	95 bc	97 bc
diuron	560	87 d	94 d
fomesafen-low	140	87 d	94 d
fomesafen-high	280	94 c	96 c
pendimethalin	1063	82 e	94 d
fluridone	224	97 abc	98 ab
fluridone + acetochlor	224 + 1250	99 a	99 a
fluridone + diuron	224 + 560	98 ab	98 ab
fluridone + fomesafen-low	224 + 140	97 abc	98 ab
fluridone + fomesafen-high	224 + 280	98 ab	99 a
fluridone + pendimethalin	224 + 1063	98 ab	98 ab

[z] Data averaged over seven locations in 2013 and 2014. Means within a column followed by the same letter are not different according to Fisher's Protected LSD Test at $p = 0.05$.

[y] Data recorded 12 to 27 d after PRE application.

[x] Glufosinate was applied at 594 g ha^{-1} EPOST to all plots. Data recorded 13 to 18 d after EPOST application.

Fluridone Plus Fomesafen Compared with Grower Standards. In the analysis for the factorial arrangement of acetochlor, fluridone (224 g ha^{-1}), and diuron by rates of fomesafen (140 and 280 g ha^{-1}), there were no treatment-by-location interactions. Averaged over locations, only the main effect of acetochlor, diuron, and fluridone was significant at EPOST, MPOST, and layby. Palmer amaranth control by acetochlor and fluridone was similar (97 to 99%) and greater than control by diuron (92 to 96%) at each evaluation (Table 4). Palmer amaranth was controlled completely 14 d after layby and late in the season (data not shown). Compared to the nontreated check, all treatments reduced Palmer amaranth fresh biomass at least 99.75% (data not shown). There were no differences among these treatments for cotton injury at any evaluation, and there were no differences in seed cotton yield (data not shown).

Effect of Fluridone Rates. No differences in Palmer amaranth control due to fluridone rates were noted with the fluridone plus fomesafen-low mixtures (Table 5). Regardless of fluridone rate, mixtures of fluridone plus fomesafen-low controlled Palmer amaranth 13 to 16%, 4 to 6%, 2 to 3%, and 2% greater than fomesafen-low alone at EPOST, MPOST, layby, and 14 d after layby, respectively. Except for fluridone 112 g ha^{-1} at MPOST, control by fluridone plus fomesafen-low mixtures was similar to control by acetochlor plus fomesafen-low at all evaluations. Control by fluridone plus fomesafen-low mixtures was as good as or better than control by diuron plus fomesafen. No differences in late-season Palmer amaranth control or biomass were noted with any of these treatments; all treatments controlled Palmer amaranth 99 to 100% late in the season and reduced Palmer amaranth biomass at least 99.9% (data not shown). Crop injury was 5% or less with all treatments at early POST (data not shown), and no differences in cotton yield were noted among these treatments. Seed cotton yields ranged from 2070 to 2210 kg ha^{-1} (Table 5).

Table 4. Palmer amaranth control by fluridone plus fomesafen compared with grower standards of acetochlor plus fomesafen and diuron plus fomesafen[z]

Herbicides[y]	Control		
	At EPOST	At MPOST	At layby
	%		
acetochlor	98 a	98 a	98 a
diuron	92 b	95 b	96 b
fluridone	97 a	98 a	99 a

[z] Data averaged over seven locations and two rates of fomesafen (140 and 280 g ha^{-1}). Means within a column followed by the same letter are not different according to Fisher's Protected LSD at p = 0.05.

[y] Acetochlor, diuron, and fluridone applied at 1260, 560, and 224 g ha^{-1}, respectively.

Table 5. Palmer amaranth control and cotton yield with varying rates of fluridone plus fomesafen-low[z,y]

Residual herbicides[x]	Application rate	Palmer amaranth control				Seed cotton yield
		At EPOST	At MPOST	At layby	14 d after layby	
	g ha^{-1}	%				kg ha^{-1}
fomesafen-low	140	80 c	93 c	97 c	98 b	2150 a
fluridone + fomesafen-low	112 + 140	93 ab	97 b	99 ab	100 a	2170 a
fluridone + fomesafen-low	168 + 140	96 ab	98 a	100 a	100 a	2090 a
fluridone + fomesafen-low	224 + 140	96 ab	99 a	100 a	100 a	2110 a
diuron + fomesafen-low	560 + 140	90 bc	95 bc	98 bc	100 a	2210 a
acetochlor + fomesafen-low	1260 + 140	97 a	99 a	100 a	100 a	2070 a

[z] Means within a column followed by the same letter are not different according to Fisher's Protected LSD Test at p = 0.05.

[y] Data averaged over four locations in 2014.

[x] Residual herbicides applied preemergence. All treatments included glufosinate applied at 594 g ha^{-1}EPOST (18 to 27 d after planting) and MPOST (34 to 40 d after planting). Diuron + MSMA were applied at 1120+ 2240 g ha^{-1}, respectively, 51 to 64 d after planting.

This research demonstrated excellent cotton tolerance and excellent Palmer amaranth control by fluridone alone or in combination with acetochlor, diuron, fomesafen, or pendimethalin. Fluridone's mechanism of action is unique in the agronomic crop herbicide market. Use of fluridone in cotton could reduce selection pressure from herbicides with other mechanisms of action, especially PPO inhibitors that are widely used in cotton and several other crops. Fluridone is currently available in the southeastern U.S. only as a prepackaged mixture with fomesafen (Anonymous, 2016). Our research shows that combinations of fluridone plus diuron or fluridone plus acetochlor are as effective as the commercial formulation containing fluridone plus fomesafen and thus might be better options to reduce further selection for PPO inhibitor-resistant Palmer amaranth.

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