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Evaluation of residual palmer amaranth control with herbicides coated on fertilizer

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Herbicide-coated fertilizers have the potential to provide lasting control of problematic weeds while simultaneously reducing the risk of injury to cotton, thus reducing yield penalties. Therefore, research was conducted in Fayetteville and Marianna, AR, to evaluate which herbicides coated on fertilizer provide lasting control of Palmer amaranth without increased risk of cotton injury. Eight herbicides were coated onto a blend of 196 kg ha^{-1} of urea and 112 kg ha^{-1} of muriate of potash and applied at the 6- to 8-leaf growth stage over the top of cotton. In Marianna, florpyrauxifen-benzyl provided the lowest control, which was 73% averaged over 14 and 28 d after treatment (DAT). The level of control provided by florpyrauxifen-benzyl did not differ from the other treatments in Fayetteville. While some herbicide treatments did have decreased control by 28 DAT, they were still effective, providing no less than 93% control. Palmer amaranth density differed among herbicides only in Marianna, where florpyrauxifen-benzyl-treated plots had a higher weed density. None of the herbicide treatments in either of the experiments caused any adverse effects on the crop as measured by visual injury, seedcotton yield, and crop groundcover. Most of the coated fertilizer treatments provided high levels of Palmer amaranth control and demonstrated the weed management potential of this herbicide application method. These results highlight the potential of implementing herbicides that are not labeled for over-the-top postemergence applications in cotton as coated fertilizers, as this method reduces the risk of injury and yield penalties.

KEYWORDS

cotton, herbicide-coated fertilizer, muriate of potash, residual control, residual herbicide, urea

1 Introduction

Palmer amaranth (*Amaranthus palmeri* S. Wats.) is one of the most problematic weeds in cotton (*Gossypium hirsutum* L.) production. Prolonged seed viability even when the weed germinates late into the season, proliferous seed production (up to 600,000 seeds plant^{-1}), and the ability to reach up to 2 meters in height are among the characteristics that enable this plant to be highly competitive in adverse conditions (Keeley et al., 1987; Morgan et al., 2001; Norsworthy et al., 2016). Cotton yield can be drastically decreased without proper weed control, and ten Palmer amaranth plants per nine meters of cotton row may reduce lint yield by up to 57% (MacRae et al., 2013; Morgan et al., 2001). Furthermore, Palmer amaranth can decrease cotton canopy volume and biomass by 45% and 50%, respectively, and it should be controlled up to the 12-node growth stage to minimize potential yield loss (MacRae et al., 2013).

Cotton producers depend on effective season-long weed management programs to alleviate or mitigate competition pressure and achieve optimum yield (Burke et al., 2005; Culpepper and York, 1998). Residual herbicides can be applied at preemergence (PRE) and postemergence (POST) and are essential to weed control, especially with an aggressive species such as Palmer amaranth. Historically common in cotton production, post-directed and layby spray applications are described as a postemergence, directed herbicide application that may be utilized late into the season, extending beyond the 12-node growth stage (Koger et al., 2007). These applications provide more robust weed management further into the season by controlling emerged weeds or extending residual activity (Culpepper and York, 1997). However, hooded equipment is often required to avoid crop injury depending on the herbicide or growth stage.

Like post-directed or layby applications, nitrogen (N) and potassium (K) are applied late in the season, usually at the squaring and early bloom growth stages (Wells and Green, 1991). In cotton, producers typically apply both N and K at the peak requirement of the plant, which is when the bolls begin to develop (squaring or 6- to 8-leaf growth stage), as well as at early bloom (10- to 12-node growth stage) (Kerby and Adams, 1985; Robertson et al., 2007). At squaring, both N and K are required, while at early bloom, only N is again recommended (Kerby and Adams, 1985; Robertson et al., 2007). Potassium is often applied as granular muriate of potash and N as granular urea (Maguire et al., 2019). If the fertilizers being blended are of similar granule size and are required by the crop at similar growth stages, bulk blending can allow producers to apply those nutrients simultaneously (Maguire et al., 2019; Wells and Green, 1991). Due to their similar application timings and granule size, urea and muriate of potash make a compatible fertilizer blend (Maguire et al., 2019).

As urea and muriate of potash need to be applied at squaring, a bulk blend of this fertilizer can potentially be a compatible carrier for POST-applied herbicides. The application of herbicides coated onto granular fertilizer is a concept that has been used in many production systems, including rice (*Oryza sativa* L.), turfgrass, and even ornamental container production (Braverman, 1995; Crossan et al., 1997; Yelverton, 1998). Using herbicide-coated fertilizers in a cotton production setting would allow producers to simultaneously apply POST herbicides and fertilizer, providing sought-after practical implications. For instance, herbicides that are typically applied post-directed could potentially be spread over the top of cotton without causing injury. In addition, there is potential for increased tolerance to herbicides already labeled for over-the-top POST use. Furthermore, if producers already apply fertilizer, the simultaneous herbicide application may prevent extra equipment changes. On the other hand, herbicide-coated fertilizers may not provide the same level of control as spray applications for all products due to decreased foliar contact (Braverman, 1995).

In cotton, residual herbicides can be applied preplant, PRE, POST, and POST-directed. Application timing and method will vary even among labeled herbicides due to the risk of crop injury. For instance, fluridone and pyroxasulfone are only labeled for PRE and post-directed applications, respectively, while *S*-metolachlor is considered safe to be used for over-the-top applications (Everman et al., 2009; Grichar et al., 2020; Price et al., 2008; Webb et al., 2019). Potentially, any herbicide that provides residual or POST weed control could be integrated into late-season programs as herbicide-coated fertilizers. Florpyrauxifen-benzyl is a POST herbicide that provides control of Palmer amaranth (Anonymous, 2023). Although not labeled for use in cotton, prior research has tested the potential of using florpyrauxifen-benzyl as a post-directed spray application at the 8-node growth stage (Doherty et al., 2020). While effective, this spray application can reduce seedcotton yield. Therefore, coating this herbicide onto fertilizer might decrease the risk of yield penalties compared to the post-directed spray application.

Residual Palmer amaranth control with increased cotton tolerance to herbicides that are often phytotoxic to the crop might be achieved by integrating herbicide-coated fertilizers into cotton production systems and existing weed control programs. Research into herbicide-coated fertilizers has been conducted in crops such as rice (Cotter, 2023). If this method could be utilized in cotton, producers could maximize weed control while minimizing injury to the crop. Therefore, research was conducted to evaluate which herbicides coated on fertilizer provide lasting control of Palmer amaranth over time without substantial risk of cotton injury.

2 Materials and methods

A field experiment was conducted at two sites in the summer of 2023 to evaluate residual Palmer amaranth control and crop tolerance in response to herbicides coated onto urea and muriate of potash and applied over the top of cotton. One trial was established at the Milo J. Shult Agricultural Research and Extension Center in Fayetteville, AR (36°05’43”N 94°10’22”W), and the other at the Lon Mann Cotton Research Station near Marianna, AR (34°41’40”N 90°46’08”W). The elevation of the site in Fayetteville was 390.88 m and was 70.18 m in Marianna. In Fayetteville, the experimental site was composed of a Leaf silt loam soil, and in Marianna the soil was a Zachary silt-loam soil (Table 1).

All fields were prepared with a disk, which was then followed by a hipper. The plots consisted of four rows and were 7.6 m long by 3.9 m wide in Marianna and 3.6 m wide in Fayetteville. Rows were

TABLE 1 Soil information for both Fayetteville and Marianna, AR in 2023.

Location	Soil type	Taxonomic class	Sand (%)	Silt (%)	Clay (%)	pH	Organic matter (%)
Fayetteville	Silt loam	Leaf silt-loam (fine, mixed, active, thermic Typic Albaquults)	27.1	54.4	18.5	7.2	2
Marianna	Silt loam	Zachary silt-loam (Fine-silty, mixed, active, thermic Typic Albaqualfs)	16.2	68.8	15	7.3	1.25

97 cm and 91 cm wide in Marianna and Fayetteville, respectively. The experiment was planted with a four-row vacuum planter (John Deere Max Emerge, Moline, IL, 61625) at a 1.3-cm depth and 106,000 seeds ha^{-1} to a three-gene *Bt* variety with resistance to glyphosate, glufosinate, and dicamba [Bollgard® 3 XtendFlex (DP2020B3XF) Bayer Crop Science LP, St. Louis, MO]. Crop maintenance consisted of applying plant growth regulators, herbicides, insecticides, and irrigation, each discussed below. Throughout the season, both sites received two applications of mepiquat chloride (Pix® Ultra Plant Regulator, BASF Corp, Research Triangle Park, NC) at 49 g ai ha^{-1}, using ground spray equipment. A plant growth regulator was utilized to focus energy and nutrient resources into reproductive growth. Insecticide was applied as necessary to maintain a healthy crop. The experiment was overhead irrigated in Fayetteville and furrow-irrigated when less than 2.5 cm of rainfall was present in a week in Marianna (Figure 1). Broadcast applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 4.8 km hr^{-1} with four AIXR 110015 flat fan nozzles (Teejet Technologies, Springfield, IL).

Following planting, paraquat (Gramoxone®, Syngenta Crop Protection, LLC, Greensboro, NC) at 700 g ai ha^{-1} and fluometuron (Cotoran®, ADAMA, Raleigh, NC) at 560 g ai ha^{-1} were applied in Marianna. Only fluometuron was applied at 560 g ai ha^{-1} in Fayetteville since the field was tilled immediately before planting. Additionally, clethodim (Select Max®, Valent, San Ramon, CA) at 85 g ai ha^{-1} was applied to control grasses in Fayetteville. A mixture of glyphosate (Roundup PowerMax3®, Bayer Crop Science LP, St. Louis, MO) at 1260 g ae ha^{-1} and glufosinate-ammonium (Interline®, UPL NA Inc., King of Prussia, PA) at 656 g ae ha^{-1} were applied at the 2-to 3-leaf and 6- to 8-leaf growth stages at both locations.

The experiment was designed as a randomized complete block with nine treatments and four replications. The nine treatments consisted of one nontreated check and eight herbicide treatments. Herbicide treatments were as follows: pyroxasulfone at 128 g ai ha^{-1}, *S*-metolachlor at 1388 g ai ha^{-1}, florpyrauxifen-benzyl at 29 g ai ha^{-1}, fluridone at 168 g ai ha^{-1}, fluometuron at 1120 g ai ha^{-1}, a combination of pyroxasulfone at 128 g ai ha^{-1} plus fluridone at 168 g ai ha^{-1}, a combination of pyroxasulfone at 128 g ai ha^{-1} plus fluometuron at 1120 g ai ha^{-1}, and a combination of fluometuron at 1120 g ai ha^{-1} plus fluridone 168 g ai ha^{-1} (Table 2).

All herbicide treatments were applied on a dry, granular fertilizer blend consisting of urea at 196 kg ha^{-1} and muriate of potash at 112 kg ha^{-1}. Urea contains 46% N, and muriate of potash contains 60% K_2O. The nontreated check also received an application of the fertilizer blend, which was not treated with herbicide. The herbicides were mixed with BullsEye Blue Spray Pattern Indicator (SPI) (Milliken Chemical, Spartanburg, SC) at 0.112 L ha^{-1} to ensure the herbicide was evenly coated onto the fertilizer. The fertilizer and herbicide were combined in a concrete mixer that was 1.3 m tall by 0.64 m wide by 1.09 m long (Central Machinery, Camarillo, CA). After air drying, each herbicide-coated fertilizer treatment was weighed out for each plot considering the target application rate of the fertilizer mixture (308 kg ha^{-1}). The herbicide-coated fertilizer was applied using a 2.7 kg, 5-setting GroundWork hand spreader (Tractor Supply Co, Brentwood, TN) set on the third setting. The person applying the herbicide-coated fertilizer with the hand-spreader walked at 4.8 km hour^{-1} through the furrows of each plot, making two passes through each furrow. The experiments were irrigated no more than 3 d after the herbicide-coated fertilizer application.

Residual Palmer amaranth control was evaluated on a scale of 0 to 100, with 0 representing no control and 100 representing no visible Palmer amaranth plants present (Frans et al., 1986). Ratings were taken at 14 and 28 d after treatment (DAT). Additionally, two 1 m^2 quadrants were established in each plot, and Palmer amaranth counts were taken weekly from 7 to 28 DAT. These counts were used to calculate relative density, where the number of Palmer amaranth plants counted in each plot was divided by the number of plants in the nontreated check. Injury was also rated at 14 and 28 DAT on a scale of 0 to 100, with 0 representing no injury and 100 representing complete plant death (Frans et al., 1986). Aerial images were taken using a DJI Mavic Mini Drone (SZ DJI Technology Co. Ltd, Nanshan, Shenzhen, China) at 14 DAT, and the percent cotton groundcover was determined using FieldAnalyzer (Green Research Services LLC, Fayetteville, AR). To obtain seedcotton yield, the two middle rows of each four-row plot were harvested by hand in Fayetteville, and yield was calculated (kg ha^{-1}). The experiment in Marianna was accidentally mowed before harvest; therefore, no yield data were available for this experimental site.

2.1 Statistical analysis

Cotton injury and Palmer amaranth control data were subjected to an analysis of variance (ANOVA) with repeated measures to determine the difference between treatments and evaluation timing using PROC GLIMMIX in SAS 9.4 (SAS Institute, Cary, NC). Data were analyzed by location, as location often interacted with herbicide treatment. All distributions were checked using the JMP Pro V. 17 distribution platform (SAS Institute, Cary, NC). The weed control and injury data did not fit a normal distribution via the Shapiro-Wilk test, and a beta distribution was used to analyze the

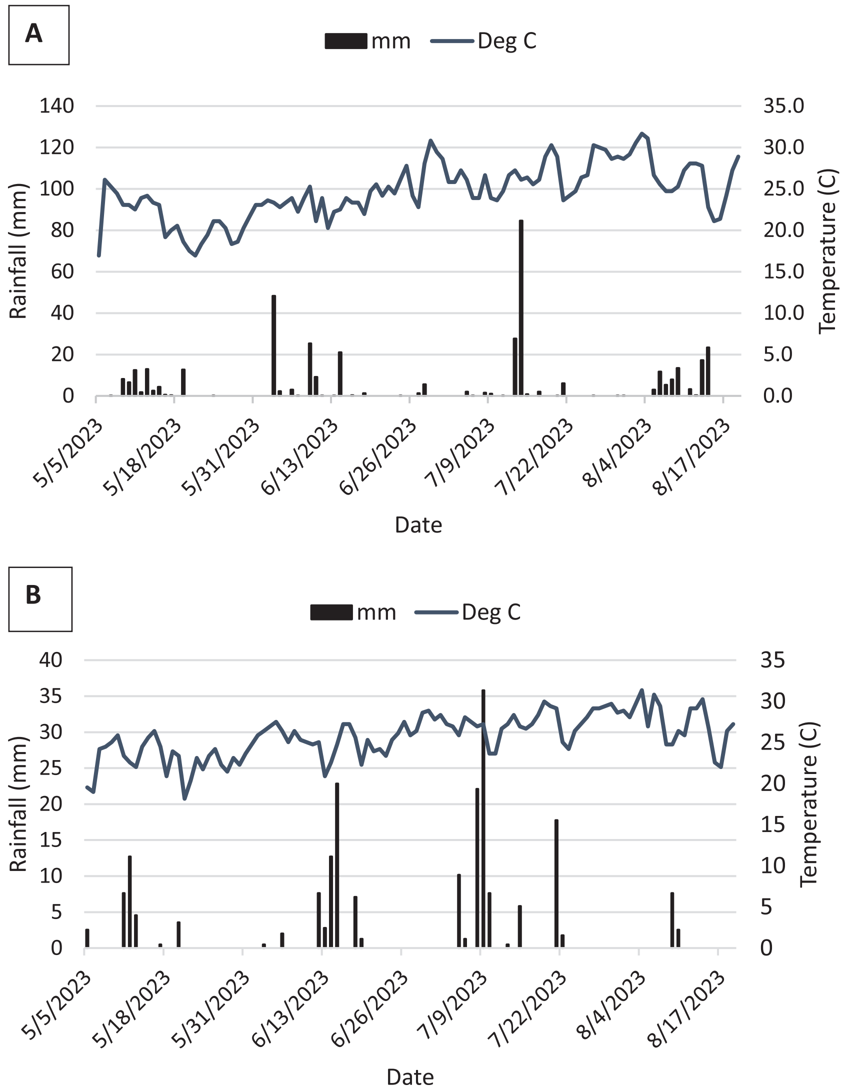

FIGURE 1
Rainfall and temperature data over the growing season in 2023 at **(A)** the Milo J. Shult Agricultural Research and Extension Center in Fayetteville, AR, and **(B)** the Lon Mann Cotton Research Station 2023. The gray vertical arrows represent herbicide-coated fertilizer application. Application dates for experiments were the same within location. When rainfall was insufficient, supplemental irrigation was provided via overhead (Fayetteville) or furrow (Marianna) irrigation.

responses. An unstructured covariance was selected for repeated measures analysis based on the model of best fit (Gbur et al., 2012). Denominator degrees of freedom were adjusted using the Kenward and Roger (1997) approximation. Seedcotton yield and cotton groundcover data were analyzed using a gamma distribution, while relative Palmer amaranth densities were analyzed using a beta distribution. Seedcotton yield, cotton groundcover, and relative density data were subjected to an ANOVA with the PROC GLIMMIX procedure. Means were separated using Tukey's HSD *post-hoc* analysis (α= 0.05).

TABLE 2 Herbicide information and rates used in the experiments.

Common name	Product name	Rate (g ai ha^{-1})	Group number	Manufacturer	Address
Florpyrauxifen-benzyl	Loyant ®	29	4	Corteva Agriscience LLC	Indianapolis, IN
Fluridone	Brake ®	168	12	SePRO Corp.	Carmel, IN
Fluometuron	Cotoran®	1120	5	ADAMA	Raleigh, NC
Pyroxasulfone	Zidua SC®	128	15	BASF Corp.	Research Triangle Park, NC
S-metolachlor	Dual Magnum®	1388	15	Syngenta Crop Protection LLC	Greensboro, NC

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TABLE 3 Cotton injury, residual Palmer amaranth control, and Palmer amaranth density in response to herbicide-coated fertilizers applied at the 6- to 8-leaf stage of cotton in Fayetteville and Marianna, AR, in 2023.

Herbicide	Rate	Injury		Palmer amaranth control			Palmer amaranth density	
		Fayetteville	Marianna	Fayetteville		Marianna	Fayetteville	Marianna
		14 & 28 DAT[a] averaged		14 DAT	28 DAT	14 & 28 DAT averaged	28 DAT	
	g ai ha^{-1}	——————%—————		—————————%————————			% of the nontreated check	
Florpyrauxifen-benzyl	29	3 ab[b]	6	94 ab[c]	89 b	73 b	41	39 a
Fluridone	168	4 ab	4	97 ab	94 ab	88 a	22	11 ab
Fluometuron	1120	2 b	2	99 a	93 b	91 a	32	25 ab
Fluometuron + fluridone	840 + 168	3 ab	6	97 ab	94 ab	92 a	22	8 ab
Pyroxasulfone	128	3 ab	4	94 ab	95 ab	94 a	36	4 ab
Pyroxasulfone + fluridone	128 + 168	8 a	8	98 ab	95 ab	93 a	9	3 b
Pyroxasulfone + fluometuron	128 + 1120	4 ab	3	99 a	93 b	98 a	15	2 b
S-metolachlor	1388	3 ab	4	94 ab	93 b	86 ab	35	24 ab
P-value		0.0103[d]	0.0782	0.2464	0.828	0.0013	0.2226	0.0010
RM *P*-value[e]		0.9333	0.4207	<.0001		0.6476	————	———

[a]DAT, d after treatment.
[b]Means within a column for each location not containing the same lowercase letter are significantly different according to Tukey's HSD (α=0.05).
[c]Means within a location for each herbicide, stretching from 14 to 28 DAT not containing the same lowercase letter are significantly different according to Tukey's HSD (α=0.05).
[d]P-values were generated using the GLIMMIX procedure without repeated measures SAS 9.4 with a beta distribution
[e]P-values were generated as repeated measures using the GLIMMIX procedure in SAS 9.4 with a beta distribution.

3 Results

3.1 Palmer amaranth control

In Fayetteville, Palmer amaranth control varied among herbicide treatments, with differences evident across two evaluation dates (14 and 28 DAT), indicating that the control level differed (Table 3). In Marianna, Palmer amaranth control differed only among the herbicides but not over the 14 and 28 DAT evaluations. The lack of differences across evaluation dates would suggest that the level of Palmer amaranth control did not differ over time for any of the herbicide treatments for the periods evaluated in Marianna. Florpyrauxifen-benzyl was generally one of the least effective herbicides in providing residual Palmer amaranth control at both locations. In Fayetteville, control did not differ between 14 and 28 DAT, where control was 94 and 89%, respectively. In Marianna, florpyrauxifen-benzyl provided an average of 73% Palmer amaranth control (across 14 and 28 DAT).

Palmer amaranth control decreased over time when fluometuron was applied alone. In Fayetteville, the fluometuron coated on fertilizer provided 99% control 14 DAT, but by 28 DAT, control had diminished to 93% (Table 3). Likewise, in Marianna, Palmer amaranth control was 91% averaged over the 14 and 28 DAT evaluations with this treatment Fluometuron plus pyroxasulfone provided similar levels of Palmer amaranth control compared to fluometuron alone. The addition of pyroxasulfone to fluometuron treatment exhibited a 6% decrease in control from the 14 to 28 DAT evaluation dates in Fayetteville, from 99 to 93%. In Marianna, on average, the pyroxasulfone plus fluometuron treatment provided strong residual Palmer amaranth control (98%), which did not deviate from that of the other herbicides, aside from the florpyrauxifen-benzyl treatment.

In Fayetteville, *S*-metolachlor provided the same level of Palmer amaranth control from 14 DAT to 28 DAT, at 93 and 94%, respectively (Table 3). In Marianna, there was an average of 86% control, which did not differ from the other herbicide treatments.

The remaining four herbicide treatments provided similar levels of control at 14 and 28 DAT in Fayetteville and Marianna (Table 3). These four treatments were as follows: fluridone, fluridone plus fluometuron, fluridone plus pyroxasulfone, and pyroxasulfone alone. In Fayetteville, these treatments provided 94 to 98% control at 14 and 28 DAT, respectively, which did not differ between the evaluation dates. In Marianna, control ranged from 88% to 94% when considering the 14 and 28 DAT averages.

Differences in relative Palmer amaranth density were observed only in Marianna (Table 3). Compared to florpyrauxifen-benzyl, pyroxasulfone plus fluridone and pyroxasulfone plus fluometuron treatments had lower densities. Considering both sites, relative density did not exceed 41% compared to the nontreated check.

3.2 Cotton injury, yield, and groundcover reduction

Cotton injury from herbicide-coated fertilizers differed only in Fayetteville. The average injury across 14 and 28 DAT ranged from 2 to 8% (Table 3). Injury to cotton caused by pyroxasulfone plus fluridone averaged 8% and manifested as necrotic blotches or lesions on leaves (Figure 2). The level of injury to cotton caused by most of these herbicides is less than what would be expected, considering that most of the herbicides are not labeled for over-the-top applications, except for S-metolachlor and pyroxasulfone. This method of application safened an application of a herbicide not labeled in cotton, florpyrauxifen-benzyl. Seedcotton yield was not affected by any treatment in either location, regardless of Palmer amaranth presence or cotton injury (Table 4). Aerial imagery displayed that the weed pressure or crop injury did not affect the cotton groundcover for any herbicide-coated fertilizer treatment (Table 4).

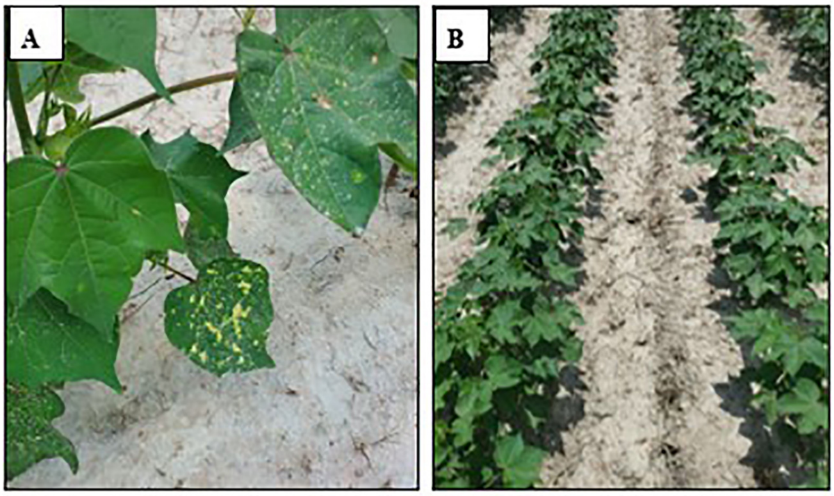

FIGURE 2
Circular blotches on cotton leaves (7 d after treatment) caused by fluridone plus pyroxasulfone. **(A)** Individual leaf. **(B)** Plot picture.

TABLE 4 Percentage groundcover 14 d after treatment response to herbicide-coated fertilizers in both Fayetteville and Marianna and seedcotton yield in Fayetteville in 2023.

Herbicide	Rate (g ai ha^{-1})	Groundcover		Seedcotton yield
		Fayetteville	Marianna	Fayetteville
		14 DAT[a]		
		—————————————%—————————————		kg ha^{-1}
Nontreated check				2990
Florpyrauxifen-benzyl	29	94	99	3150
Fluridone	168	95	93	3750
Fluometuron	1120	98	96	3920
Fluometuron + fluridone	840 + 168	91	93	4230
Pyroxasulfone	128	99	91	3300
Pyroxasulfone + fluridone	128 + 168	99	87	3320
Pyroxasulfone + fluometuron	128 + 1120	98	92	3750
S-metolachlor	1388	95	93	3250
P-value[b]		0.8160	0.6317	0.3156

[a]DAT, d after treatment.
[b]*P*-values were generated using the GLIMMIX procedure in SAS 9.4 with a gamma distribution.

4 Discussion

4.1 Palmer amaranth control

In other research when florpyrauxifen-benzyl was sprayed POST-directed to 8-node cotton, Palmer amaranth control averaged 99% at 28 DAT (Doherty et al., 2020). The results from the POST-directed application by Doherty et al. (2020) versus those presented here indicate that less control may occur when the herbicide is coated on fertilizer. Still, experiments comparing the two application methods would be needed. In a study comparing spray versus coated applications of florpyrauxifen-benzyl, a spray application generally provided superior weed control in rice (Cotter, 2023). In a study conducted by Barnett et al. (2013), fluometuron mixed with glufosinate and applied as a foliar spray provided 92% Palmer amaranth control through 35 DAT. The control provided by this foliar treatment is similar to that of the fluometuron-coated-fertilizer application.

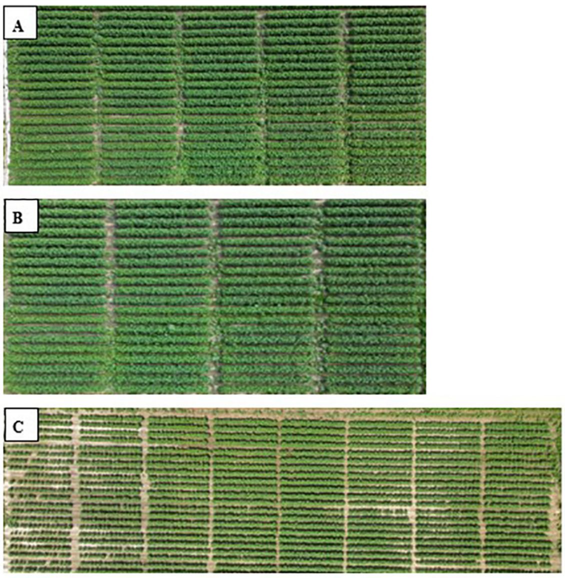

FIGURE 3
Aerial images of both Fayetteville **(A, B)** and Marianna **(C)** 21 d after treatment. **(A)** displays tiers one through four of the Fayetteville trial, and **(B)** displays tiers five through eight.

Like that of the herbicide-coated fertilizer treatment, when *S*-metolachlor was sprayed POST and mixed with glyphosate, Palmer amaranth control averaged 73% at a late-season evaluation (Clewis et al., 2006). Similar to these results, Palmer amaranth control can range from 85 to 99% when *S*-metolachlor is mixed and sprayed with glyphosate, with at least a 3 percentage-point decrease in control 13 d after treatment (Webb et al., 2019). Though this herbicide could provide residual control of Palmer amaranth as a coated fertilizer, it is important to consider that resistance to *S*-metolachlor has been previously confirmed in Palmer amaranth populations, which may limit the areas where *S*-metolachlor would be an effective option (Brabham et al., 2019).

A study by Grichar et al. (2020) evaluating the broadcast spraying of fluridone at PRE found that Palmer amaranth control ranged from 82% to 100% when fluridone was applied PRE, followed by POST glyphosate applications. Therefore, the level of control provided by the treatments containing fluridone coated onto fertilizer is similar to when the herbicide was broadcast. Since these four treatments offer control comparable to spray applications, using these as herbicide-coated fertilizers presents an optimal strategy for producers, especially the ones targeting Palmer amaranth.

4.2 Cotton injury and yield

If florpyrauxifen-benzyl is applied POST-directed to 8-node cotton, up to 11% epinasty can occur (Doherty et al., 2020). Although only 8% injury to cotton occurred following the pyroxasulfone plus fluridone treatment when coated on fertilizer, an over-the-top spray application of pyroxasulfone mixed with glyphosate and applied POST caused up to 23% injury to cotton in other research (Webb et al., 2019). The injury did not differ from 14 to 28 DAT for any treatment in either experimental site concerning the herbicide-coated fertilizer application.

It is unlikely that sufficient Palmer amaranth was present in the plots to affect seedcotton yield because the weeds were removed with POST applications of glyphosate plus glufosinate through the 6- to 8-leaf stage of cotton. Weed suppression in this period is critical since Palmer amaranth plants can grow unimpeded and compete with the crop for essential resources, such as light and nutrients, potentially leading to reduced yield (MacRae et al., 2013). In fact, the presence of just ten Palmer amaranth plants per nine meters of cotton row has the ability to decrease lint yield by up to 57% (MacRae et al., 2013; Morgan et al., 2001). Therefore, ensuring that interference from Palmer amaranth is minimized until at least the 12-node growth stage (early bloom) is vital because, beyond this developmental stage, cotton yield is less susceptible to the detrimental effects due to competition. Additionally, all treatments caused minimal crop injury, attributed to less herbicide retention on leaves and reduced phytotoxicity compared to a smaller droplet (McKinlay et al., 1972; Prasad and Cadogan, 1992).

Regardless of any injury caused to the cotton plants by any treatment, it did not translate into crop groundcover reduction. In addition, Palmer amaranth plants present in the plots did not cause severe interference that would result in reduced cotton plant or canopy size, which could be attributed to limited Palmer amaranth presence before the first bloom growth stage and the size of the weedy plants (MacRae et al., 2013). If large Palmer amaranth were present in the plots, reduction in the crop's canopy volume could have reached up to 50% (MacRae et al., 2013). A comparison of the two locations displays the injury, weed control, and canopy size using aerial images (Figure 3).

5 Conclusions

Applying residual herbicides late in the season is a valuable tool to reduce Palmer amaranth interference. Although numerous herbicides are available for POST-directed application in cotton, options for over-the-top postemergence control are limited. Optimal Palmer amaranth control with minimal crop injury was obtained with most of the treatments tested in this study, accentuating the potential of these herbicides to be safely used on fertilizer over the top of cotton in late-season applications. No herbicide at either location provided less than 73% Palmer amaranth control at any evaluation timing. Concerning injury to cotton, no herbicide caused more than 8% injury to the crop at either location. Additionally, seedcotton yield and cotton groundcover were not affected by any of the treatments tested, further corroborating that no herbicide treatment adversely affected the crop. These preliminary results strongly support the use of herbicides coated with fertilizer for late-season weed management in cotton. Further research is needed into cotton tolerance, the extent of weed control with other species, and different herbicidal options.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

SL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JN: Conceptualization, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. TB: Conceptualization, Methodology, Supervision, Visualization, Writing – review & editing. BT: Methodology, Supervision, Writing – review & editing. TR: Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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