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Optimizing pyroxasulfone-coated fertilizer in cotton

Brock A. Dean[1], Charles W. Cahoon[2], Guy D. Collins[2], David L. Jordan[3], Zachary R. Taylor[4], Jacob C. Forehand[1], Jose S. de Sanctis[1] and James H. Lee[1]

[1]Graduate Research Assistant, Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC, USA; [2]Associate Professor, Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC, USA; [3]William Neal Reynolds Professor, Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC, USA and [4]Research Specialist, Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC, USA

Research Article

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Corresponding author:
Brock A. Dean; Email: badean@ncsu.edu

Abstract

Two studies were conducted in 2022 and 2023 near Rocky Mount and Clayton, NC, to determine the optimal granular ammonium sulfate (AMS) rate and application timing for pyroxasulfone-coated AMS. In the rate study, AMS rates included 161, 214, 267, 321, 374, 428, and 481 kg ha^{-1}, equivalent to 34, 45, 56, 67, 79, 90, and 101 kg N ha^{-1}, respectively. All rates were coated with pyroxasulfone at 118 g ai ha^{-1} and topdressed onto 5- to 7-leaf cotton. In the timing study, pyroxasulfone (118 g ai ha^{-1}) was coated on AMS and topdressed at 321 kg ha^{-1} (67 kg N ha^{-1}) onto 5- to 7-leaf, 9- to 11-leaf, and first bloom cotton. In both studies, weed control and cotton tolerance to pyroxasulfone-coated AMS were compared to pyroxasulfone applied POST and POST-directed. The check in both studies received non-herbicide-treated AMS (321 kg ha^{-1}). Before treatment applications, all plots (including the check) were maintained weed-free with glyphosate and glufosinate. In both studies, pyroxasulfone applied POST was most injurious (8% to 16%), while pyroxasulfone-coated AMS resulted in ≤4% injury. Additionally, no differences in cotton lint yield were observed in either study. With the exception of the lowest rate of AMS (161 kg ha^{-1}; 79%), all AMS rates coated with pyroxasulfone controlled Palmer amaranth ≥83%, comparably to pyroxasulfone applied POST (92%) and POST-directed (89%). In the timing study, the application method did not affect Palmer amaranth control; however, applications made at the mid- and late timings outperformed early applications. These results indicate that pyroxasulfone-coated AMS can control Palmer amaranth comparably to pyroxasulfone applied POST and POST-directed, with minimal risk of cotton injury. However, the application timing could warrant additional treatment to achieve adequate late-season weed control.

Introduction

Palmer amaranth has become one of the most troublesome weeds across the southern U.S. cotton production region (Van Wychen 2022). If left unmanaged, Palmer amaranth at 3 and 8 plants m^{-1} can reduce cotton yield by as much as 28% and 92%, respectively (MacRae et al. 2013; Morgan et al. 2001; Rowland et al. 1998). In addition to adversely affecting cotton yield, Palmer amaranth densities of 1,300 weeds ha^{-1} can reduce harvest efficiency by as much as 2 hr ha^{-1} (Smith et al. 2000). The ability to control Palmer amaranth has steadily declined due to the rising prevalence of biotypes with resistance to many of the herbicides registered in cotton production (Heap 2024).

In tandem with rising weed management concerns, cotton producers have had to navigate high production costs, which increased by an estimated 31% from 2018 to 2023 (USDA-ERS 2023a). A portion of these expenses are attributed to the input costs of fertilizers, insecticides, and other agrichemicals for early-season cotton development and crop maintenance (Edmisten and Collins 2024). However, the development and spread of multiple herbicide-resistant (HR) weed biotypes like Palmer amaranth has rendered weed control one of the more costly components of cotton production (Washburn 2024). The need for expensive herbicide programs and advanced application technology, coupled with the continued rise in herbicide-tolerant cottonseed costs, has further highlighted the financial challenges of managing multiple HR weed biotypes (Korres et al. 2019; Ofosu et al. 2023; USDA-ERS 2023b). Timely pesticide and fertilizer applications are critical for maximizing cotton yield; however, this is often challenging due to the complexities of cotton weed management (Tariq et al. 2020). Given the importance of efficiency and the necessity of effectively managing multiple HR Palmer amaranth, there is a great need to incorporate alternative weed management strategies into cotton production.

In 2020, pyroxasulfone, a very-long-chain-fatty-acid inhibitor (Weed Science Society of America Group 15), received an amended label, allowing it to be coated on granular fertilizer and topdressed onto cotton (Anonymous 2024). Before the label amendment, pyroxasulfone could be only postemergence directed (POST-directed) in cotton. This posed challenges, as many growers are ill equipped or hesitant to apply herbicides POST-directed. Such applications are time and labor intensive and require a height difference between the cotton and the targeted weeds, which is often difficult to achieve (Askew et al. 2002; Wilcut et al. 1995). However, pyroxasulfone-coated fertilizer offers growers an alternative to POST-directed applications, with the potential to conserve inputs. Previous research has shown that simultaneously applying herbicide and granular fertilizer can reduce fuel and labor costs and soil compaction (Buhler 1987).

While herbicide-coated fertilizer can improve efficiency, pyroxasulfone has been reported to effectively control Palmer amaranth, with some studies reporting ≥90% control 21 d after treatment (DAT) (Janak and Grichar 2016; Steele et al. 2005). Aside from Palmer amaranth, pyroxasulfone has also demonstrated activity on troublesome grasses in cotton, including Texas millet [*Urochloa texana* (Buckley) R. Webster.], goosegrass [*Eleusine indica* (L.) Gaertn.], and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] (Kharel et al. 2022; Steele et al. 2005; Stephenson et al. 2017; Van Wychen 2022). Although research on pyroxasulfone-coated fertilizer is limited, other studies have demonstrated effective weed control in row crop production systems using herbicide-coated fertilizer (Grey and Webster 2013; Grey et al. 2008; Rabaey and Harvey 1994). One study, conducted by Yelverton (1998), reported that effective weed control with herbicide-coated fertilizer depended on particle coverage and the timing of application.

Currently pyroxasulfone is registered to be coated on non-nitrate-based fertilizers and applied at rates ranging from 225 to 785 kg ha^{-1}. Applications can be made on cotton from 5-leaf to the beginning bloom stage (Anonymous 2024). However, recommended fertilizer rates and application timings vary by location, soil texture, and estimated yield potential. On deep, sandy-textured soils, typical of the southeastern cotton production region, many growers apply a split or replacement application of nitrogen due to leaching potential (Hons et al. 2004). These applications generally result in small amounts of nitrogen being applied early in the growing season, with the remainder applied at the beginning of boll development (Gatiboni and Hardy 2024). Depending on the timing of application, pyroxasulfone-coated fertilizer may be well suited for these situations, as it could provide necessary late-season residual following residuals applied at earlier growth stages (M. Inman, BASF Corporation, personal communication). However, there are concerns that if pyroxasulfone is applied and coated with a low rate of fertilizer, the lack of distribution of the herbicide may jeopardize weed control (Anonymous 2024). Owing to frequent applications of low fertilizer rates and variability in application timing, it is imperative to optimize pyroxasulfone-coated fertilizer in cotton production.

The objectives of this research were to determine (1) the optimal granular ammonium sulfate (AMS) rate for applying pyroxasulfone-coated AMS and (2) the optimal application timing for pyroxasulfone-coated AMS to effectively control Palmer amaranth in cotton.

Materials and Methods

Shared Methodology

Two field studies were conducted in 2022 and 2023 at the Upper Coastal Plains Research Station near Rocky Mount, NC (35.89°N, 77.68°W), and the Central Crops Research Station near Clayton, NC (35.67°N, 78.51°W). The soil at Rocky Mount consisted of an Aycock very fine sandy loam (Fine-silty, siliceous, subactive, thermic Typic Paleudults) with 0.3% to 0.4% humic matter and pH 6.0 to 6.1. The soil at Clayton consisted of a Dothan loamy sand (Loamy, kaolinitic, thermic Arenic Kandiudults) with 0.3% to 0.4% humic matter and pH 5.5 to 6.0 (Mehlich 1984).

Fields at both locations were prepared using conventional tillage and then bedded into 91- and 97-cm rows at Rocky Mount and Clayton, respectively. In both years and at both locations, plots were 4 rows × 9.1 m. Deltapine® cotton cultivar 'DP 2115 B3XF' (Bayer Crop Science, Research Triangle Park, NC, USA) was planted on May 11, 2022, at Rocky Mount and May 12, 2022, at Clayton. In 2023, 'DP 2115 B3XF' cotton cultivar was planted at Rocky Mount on May 9, whereas Deltapine® ThryvOn® cotton cultivar 'DP 2211 B3TXF' was planted at Clayton on May 11. Cotton was seeded at approximately 107,637 seeds ha^{-1} to a depth of 2 to 2.5 cm. All pesticide and fertilizer applications required for crop maintenance were applied in accordance with recommendations from North Carolina Cooperative Extension (Edmisten et al. 2024).

In both studies, pyroxasulfone (Zidua® SC herbicide, BASF, Research Triangle Park, NC, USA) was applied at 118 g ai ha^{-1} across all treatments. Pyroxasulfone-coated AMS (21-0-0-24, FCI Agri Service, Raeford, NC, USA) was prepared by mixing the desired rate of herbicide, water, and 1 ml of blue dye in an electric-powered concrete mixer that contained the appropriate rate of granular AMS. The proportion of water to AMS was 473 ml water to 113 kg AMS, which was suggested as the optimal ratio for preparing pyroxasulfone-coated AMS (M. Inman, personal communication, January 23, 2024). The blue dye (1 ml) was included in the mixture to provide a means for visually estimating coverage throughout the mixing process. In both studies, the check received 321 kg ha^{-1} of non-herbicide-treated AMS as a grower standard for comparison. All fertilizer treatments were evenly topdressed across the soil surface within three cotton row middles using 1.89-L plastic containers (ULINE, Pleasant Prairie, WI, USA) with lids that had equally spaced and sized holes (4 mm). In both years, topdress applications were made in the morning when dew was present. In addition to a check, both studies included pyroxasulfone applied POST and POST-directed for comparison. Plots treated with pyroxasulfone POST and POST-directed also received 321 kg ha^{-1} of non-herbicide-treated AMS. All spray applications were applied using a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 207 kPa. Backpack sprayers were outfitted with AIXR11002 flat-fan nozzles (TeeJet® Air Induction XR Flat Spray Tips, TeeJet® Technologies, Wheaton, IL, USA) to apply POST applications, and POST-directed applications were applied with a single-flood nozzle (TK-VS2 wide-angle FloodJet®, TeeJet® Technologies).

Prior to treatment applications, all plots (including the check) were treated with glyphosate (Roundup PowerMAX® 3 Herbicide, Bayer Crop Science) at 1,345 g ae ha^{-1} and glufosinate (Liberty® 280 SL Herbicide, BASF) at 656 g ai ha^{-1} to control previously emerged weeds. No residual herbicides were used prior to treatment applications. All study locations were naturally infested with Palmer amaranth. Residual Palmer amaranth control was estimated using a scale of 0 to 100, where 0 indicated no control and 100 indicated complete absence of Palmer amaranth (Frans et al. 1986). Cotton injury was similarly evaluated on a scale of 0 to 100, with 0 representing no visible injury and 100 signifying complete plant death (Frans et al. 1986). Visual assessments of cotton injury were a collective measure of plant necrosis, chlorosis, and stunting.

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Table 1. Treatment dates and accumulated rainfall, rate study.[a]

			Rainfall			
Location	Year	Date	0–8 DAT	9–16 DAT	17–24 DAT	25–32 DAT
			cm			
Clayton	2022	17 Jun	0.66	0.59	7.54	0.97
	2023	21 Jun	3.21	4.52	5.96	0.08
Rocky Mount	2022	17 Jun	1.60	0.05	6.10	0.46
	2023	21 Jun	4.52	1.48	8.03	0.23

[a]Abbreviation: DAT, days after treatment.

All data were subject to analysis of variance using the GLIMMIX procedure of SAS (version 9.4; SAS Institute, Cary, NC, USA) ($\alpha = 0.05$). The weedy check was excluded from the statistical analyses for cotton lint yield and weed control in both studies. Treatment means were separated using Tukey's honestly significant difference test ($P \leq 0.05$) where appropriate. In both studies, location, year, replication, and their interactions were considered random effects to allow inferences to be made across broader environmental conditions and locations (Blouin et al. 2011; Moore and Dixon 2015).

Rate Study

Pyroxasulfone (118 g ai ha^{-1}) was coated on granular AMS at rates of 161, 214, 267, 321, 374, 428, and 481 kg ha^{-1}, equivalent to 34, 45, 56, 67, 79, 90, and 101 kg N ha^{-1}, respectively. Weed control and cotton tolerance to pyroxasulfone-coated AMS were compared to pyroxasulfone applied POST and POST-directed. All applications were made on 5- to 7-leaf cotton on June 17, 2022, and June 21, 2023. Treatments were arranged in a randomized complete-block design (RCBD) with four replicates. Weed control and cotton injury were visually estimated biweekly until 70 DAT, and late-season Palmer amaranth density was recorded prior to cotton defoliation. At the conclusion of the season, the center two rows of each plot were mechanically harvested and weighed to determine lint yield. For statistical analyses, treatment was considered a fixed effect. Accumulated rainfall received for herbicide activation in both years and at both locations is reported in Table 1.

Timing Study

Treatment structure was a 4 × 3 factorial including three application methods plus a check at three application timings. Treatments were arranged in a RCBD with four replicates. For application methods, pyroxasulfone was applied via coated AMS (321 kg ha^{-1}), POST over the top, and POST-directed. Application timings were categorized as early (5- to 7-leaf), mid- (9- to 11-leaf), and late (first bloom). For each timing, visual estimates of cotton injury were collected 3 and 7 DAT. At 14 d after late application (DALA), visual estimates of weed control and cotton injury were collected for each timing and were continued on a biweekly schedule until 70 DALA. In addition to cotton injury and weed control, late-season Palmer amaranth density was collected prior to cotton defoliation, and the center two rows of each plot were mechanically harvested and weighed to determine cotton lint yield at the conclusion of the season. For statistical analyses, application method, application timing, and their interaction were considered fixed effects. A significant interaction between application method and timing was observed for cotton response data; the results are presented accordingly. Application dates and accumulated rainfall in both years and at both locations are reported in Table 2.

Table 2. Treatment dates for each application timing and accumulated rainfall, timing study.[a,b]

				Rainfall			
Timing	Location	Year	Date	0–8 DAT	9–16 DAT	17–24 DAT	25–32 DAT
				cm			
Early	Clayton	2022	10 Jun	0.71	0.46	0.97	7.17
		2023	21 Jun	3.21	4.52	5.96	0.08
	Rocky Mount	2022	10 Jun	4.09	0.56	0.05	7.21
		2023	21 Jun	4.52	1.48	8.03	0.23
Mid-	Clayton	2022	24 Jun	0.59	7.55	0.97	0.08
		2023	3 Jul	6.27	4.65	0.08	0.13
	Rocky Mount	2022	24 Jun	0.05	7.21	0.47	1.12
		2023	3 Jul	4.53	5.06	1.12	0.28
Late	Clayton	2022	6 Jul	7.20	0.94	2.57	0.81
		2023	17 Jul	0.08	0.13	2.42	4.39
	Rocky Mount	2022	6 Jul	7.24	0.44	5.11	2.57
		2023	17 Jul	1.15	0	0.61	3.26

[a]Abbreviation: DAT, days after treatment.
[b]Application timings were early, 5- to 7-leaf; mid-, 9- to 11-leaf; late, first bloom.

Results and Discussion

Rate Study

Palmer Amaranth Control

In both years and locations, adequate rainfall was received for herbicide activation (Table 1). No differences in control were observed between pyroxasulfone applied POST (92%) and POST-directed (89%) (Table 3). Additionally, every treatment controlled Palmer amaranth comparably to pyroxasulfone applied POST-directed (89%). Despite no differences, it is notable that there was a 10% difference in control between pyroxasulfone applied POST-directed (89%) and coated on 161 kg ha^{-1} of AMS (79%) (Table 3). Given the competitive nature of Palmer amaranth and its ability to produce immense amounts of seed (Bensch et al. 2003; Schwartz et al. 2016), this difference may warrant the use of higher rates of pyroxasulfone-coated fertilizer.

With the exception of the lowest rate of AMS (161 kg ha^{-1}), all treatments provided Palmer amaranth control comparably to pyroxasulfone applied POST (Table 3). These results are consistent with earlier research by Skoglund and Gandrud (1984) that demonstrated that herbicide-coated fertilizer can provide weed control equivalent to standard spray applications when applied at appropriate fertilizer rates. Although pyroxasulfone coated on 161 kg ha^{-1} of AMS was less effective than pyroxasulfone applied POST, it performed comparably to all other AMS rates coated with pyroxasulfone (Table 3). No differences in Palmer amaranth density were observed across all treatments, with each treatment reducing plant density by 63% to 88% compared to the non-herbicide-treated check (Table 3).

Cotton Response

As anticipated, pyroxasulfone applied POST was the most injurious treatment, resulting in 8% to 12% cotton injury (Table 4). Although these results demonstrate minimal injury with pyroxasulfone applied POST, research on cotton tolerance to

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Table 3. Palmer amaranth control and density as influenced by pyroxasulfone applied POST, POST-directed, and coated at differing rates of granular ammonium sulfate fertilizer.[a,b,c,d,e,f]

Herbicide	Treatment	AMS rate	Control 42 DAT	Density
		kg ha^{-1}	%	plants m^{-2}
None	AMS	321	—	8 a
Pyroxasulfone	AMS	161	79 b	2 b
	AMS	214	83 ab	1 b
	AMS	267	84 ab	2 b
	AMS	321	85 ab	3 b
	AMS	374	88 ab	2 b
	AMS	428	88 ab	1 b
	AMS	481	88 ab	2 b
	POST	321	92 a	2 b
	POST-directed	321	89 ab	2 b

[a]Abbreviations: AMS, granular ammonium sulfate; DAT, days after treatment.
[b]Means followed by the same letter are not different according to Tukey's honestly significant difference (α = 0.05).
[c]Pyroxasulfone was applied at 118 g ai ha^{-1}.
[d]Applications were made on 5- to- 7-leaf cotton.
[e]Non-herbicide-treated AMS was applied at 321 kg ha^{-1} in the check and where pyroxasulfone was applied POST and POST-directed.
[f]Prior to applications, all plots (including the check) were treated with glyphosate at 1,345 g ae ha^{-1} and glufosinate at 656 g ai ha^{-1}.

Table 4. Cotton injury and yield as influenced by pyroxasulfone applied POST, POST-directed, and coated at differing rates of granular ammonium sulfate fertilizer.[a,b,c,d,e,f]

Herbicide	Treatment	AMS rate	Cotton injury 3 DAT	Cotton injury 14 DAT	Lint yield
		kg ha^{-1}	%	%	kg ha^{-1}
None	AMS	321	2 c	3 c	—
Pyroxasulfone	AMS	161	1 c	2 c	1,100 a
	AMS	214	1 c	3 c	1,080 a
	AMS	267	1 c	3 c	1,200 a
	AMS	321	3 c	3 c	1,040 a
	AMS	374	2 c	3 c	1,100 a
	AMS	428	2 c	3 c	1,040 a
	AMS	481	2 c	4 bc	1,130 a
	POST	321	12 a	8 a	1,070 a
	POST-directed	321	7 b	5 b	1,060 a

[a]Abbreviations: AMS, granular ammonium sulfate; DAT, days after treatment.
[b]Means followed by the same letter are not different according to Tukey's honestly significant difference (α = 0.05).
[c]Pyroxasulfone was applied at 118 g ai ha^{-1}.
[d]Applications were made on 5- to- 7-leaf cotton.
[e]Non-herbicide-treated AMS was applied at 321 kg ha^{-1} in the check and where pyroxasulfone was applied POST and POST-directed.
[f]Prior to applications, all plots (including the check) were treated with glyphosate at 1,345 g ae ha^{-1} and glufosinate at 656 g ai ha^{-1}.

pyroxasulfone has widely varied. For instance, Eure et al. (2013) observed significant cotton injury and 19% to 35% yield loss after pyroxasulfone was applied POST, whereas Kroger et al. (2008) observed no yield loss and only 13% to 17% cotton injury when pyroxasulfone was applied to 4-leaf cotton.

For treatments containing AMS, all injury was in the form of cotton necrotic leaf speckling and mostly caused by AMS granules adhering to damp foliage at time of application. Regardless of the AMS rate coated with pyroxasulfone, all injury was ≤4% and comparable to injury observed from non-herbicide-treated AMS (321 kg ha^{-1}) applied to the check (3%) (Table 4). These results are further supported by research from Tennessee that also reported minimal cotton injury with the use of pyroxasulfone-coated fertilizer in cotton (Steckel 2021). At 3 DAT, pyroxasulfone applied POST-directed (7%) was more injurious than every AMS rate coated with pyroxasulfone (≤2%). At 14 DAT, pyroxasulfone POST-directed (5%) remained more injurious than pyroxasulfone coated on 161 to 320 kg ha^{-1} (≤3%) of AMS but was comparable to pyroxasulfone coated on 374 to 481 kg ha^{-1} (4%) of AMS (Table 4). These findings suggest that regardless of the AMS rate, pyroxasulfone-coated AMS can likely result in cotton injury that is less than or comparable to pyroxasulfone applied POST-directed. Except for pyroxasulfone applied POST (3%), cotton injury was transient by 28 DAT (data not shown). No differences in cotton lint yield were observed, with yield ranging from 1,040 to 1,210 kg lint ha^{-1} (Table 4).

Table 5. Analysis of variance for the main effects of application method and timing on cotton injury and Palmer amaranth control.[a,b]

Source of variation	Cotton injury 3 DAT	Cotton injury 14 DALA	Control, 42 DAT	Density	Lint yield
Method (M)	<0.001	<0.001	0.916	0.001	0.488
Timing (T)	<0.001	<0.001	<0.001	0.062	0.573
M × T	0.002	<0.001	0.795	0.023	0.931

[a]Abbreviations: DALA, days after late applications; DAT, days after treatment.
[b]Data are P-values.

Table 6. Palmer amaranth control and density as influenced by pyroxasulfone applied POST, POST-directed, and coated on granular ammonium sulfate.[a,b,c,d,e]

Herbicide	Method	Control, 42 DAT	Density
		%	plants m^{-2}
None	AMS	—	16 a
Pyroxasulfone	Coated	90	2 b
	POST	91	2 b
	POST-directed	90	2 b

[a]Abbreviations: AMS, granular ammonium sulfate; DAT, days after treatment.
[b]Data are averaged over application timings. Means followed by the same letter are not different according to Tukey's HSD (α = 0.05).
[c]Pyroxasulfone was applied at 118 g ai ha^{-1}.
[d]Non-herbicide-treated AMS was applied at 321 kg ha^{-1} in the check and where pyroxasulfone was applied POST and POST-directed.
[e]Prior to treatment applications, all plots (including the check) were treated with glyphosate at 1,345 g ae ha^{-1} and glufosinate at 656 g ai ha^{-1}.

Timing Study

Palmer Amaranth Control

The main effect of application timing was significant for Palmer amaranth control (Table 5). The main effect of application method and the two-way interaction of application timing and application method was not significant (Table 5). However, it is important to understand Palmer amaranth control across application methods. Therefore data for Palmer amaranth control are presented for application methods averaged over application timings (Table 6) and application timings averaged over application methods (Table 7). Data for Palmer amaranth density are averaged over application timings (Table 6).

Averaged over application timings, there were no differences in visual estimates of Palmer amaranth control across application

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Table 7. Influence of application timing on Palmer amaranth control.[a,b,c,d]

Timing	Control, 42 DALA
	%
Early (70 DAT)	83 b
Mid- (56 DAT)	93 a
Late (42 DAT)	95 a

[a]Abbreviations: DALA, days after late application; DAT, days after treatment.
[b]Data are averaged over application methods. Means followed by the same letter are not different according to Tukey's HSD (α = 0.05).
[c]Application timings were early, 5- to 7-leaf; mid-, 9- to 11-leaf; late, first bloom.
[d]Pyroxasulfone (118 g ai ha^{-1}) was applied POST, POST-directed, and coated on granular ammonium sulfate fertilizer (321 kg ha^{-1}) at each timing.

Table 8. Cotton injury and yield as influenced by pyroxasulfone applied POST, POST directed, and coated on granular ammonium sulfate at different application timings.[a,b,c,d,e,f]

Timing	Herbicide	Method	Cotton injury		Lint yield
			3 DAT	14 DALA	
					kg ha^{-1}
Early	None	AMS	3 ef	0 c	—
	Pyroxasulfone	Coated	3 ef	0 c	1,000 a
		POST	16 a	0 c	1,000 a
		POST-directed	9 b	0 c	1,070 a
Mid-	None	AMS	4 de	0 c	—
	Pyroxasulfone	Coated	4 de	0 c	1,060 a
		POST	14 a	0 c	1,050 a
		POST-directed	6 cd	0 c	1,100 a
Late	None	AMS	1 f	1 b	—
	Pyroxasulfone	Coated	1 f	1 b	1,130 a
		POST	8 bc	9 a	1,020 a
		POST-directed	3 ef	1 b	1,110 a

[a]Abbreviations: AMS, granular ammonium sulfate; DALA, days after late application; DAT, days after treatment.
[b]Means followed by the same letter are not different according to Tukey's HSD (α = 0.05).
[c]Pyroxasulfone was applied at 118 g ai ha^{-1}.
[d]Application timings were early, 5- to 7-leaf; mid-, 9- to 11-leaf; late, first bloom.
[e]Non-herbicide-treated AMS was applied at 321 kg ha^{-1} in the check and where pyroxasulfone was applied POST and POST-directed.
[f]Prior to applications, all plots (including the check) were treated with glyphosate at 1,345 g ae ha^{-1} and glufosinate at 656 g ai ha^{-1}.

methods, with each method providing ≥90% control 42 DAT (Table 6). Reductions in Palmer amaranth density follow similar trends as visual control estimates, with all treatments resulting in 88% fewer plants compared to the check (Table 6). These findings further suggest that pyroxasulfone-coated AMS (321 kg ha^{-1}) (90%) has potential to control Palmer amaranth similarly to pyroxasulfone applied POST (91%) and POST-directed (90%). Excellent control of Palmer amaranth with pyroxasulfone is expected, as many other studies also reported ≥90% control (Cahoon et al. 2015; Doherty et al. 2014; Geier et al. 2006).

At 42 DALA, pyroxasulfone applied at the mid- timing (93%) controlled Palmer amaranth similarly to pyroxasulfone applied at the late timing (95%) (Table 7). However, at the same time, early applications (83%) were less effective than both the mid- (93%) and late (95%) applications (Table 7). It is important to note that at 42 DALA, 70 and 56 d had elapsed since the early and mid- timing applications of pyroxasulfone, respectively. Dissipation studies estimate the residual half-life (DT_{50}) of pyroxasulfone at between 8 and 71 d, which may explain the reduced control observed by early timing applications compared to later applications (Mueller 2017; Mueller and Steckel 2011; Westra 2012). Following pyroxasulfone applied at the early timing, an additional POST application, including another residual herbicide, would be needed to ensure adequate late-season weed control (Cahoon and York 2024; Culpepper and Vance 2021, 2023). It is important to note that glyphosate and glufosinate were applied POST before treatments at each timing. When considering this, a POST application followed by pyroxasulfone-coated AMS at the mid- timing (9- to 11-leaf cotton) could potentially achieve adequate late-season control of Palmer amaranth, especially if used in combination with a strong PRE herbicide program.

Cotton Response

As expected, pyroxasulfone applied POST was the most injurious treatment at each timing. However, pyroxasulfone applied POST at the early (16%) and mid- (14%) timings was more injurious than when applied at the late timing (8%) (Table 8). Between the early (9%), mid- (6%), and late (3%) applications, cotton injury from pyroxasulfone POST-directed followed a consistent trend, with total injury decreasing the later applications were made (Table 8). This is likely attributed to cotton maturity, as taller plants generally receive less herbicide contact during POST-directed lay-by applications (Altom et al. 2000; Ferrell et al. 2007). Pyroxasulfone-coated AMS (3%) caused less injury compared to pyroxasulfone applied POST-directed (9%) at the early timing, thus suggesting that it may be a safer alternative for growers considering 5- to 7-leaf POST-directed lay-by applications.

In addition, pyroxasulfone-coated AMS (321 kg ha^{-1}) caused greater injury when applied at the mid- timing (4%) compared to the late timing (1%) (Table 8). However, regardless of the timing at which pyroxasulfone-coated AMS (321 kg ha^{-1}) was applied, all injury was ≤4% and comparable to the injury observed with non-herbicide-treated AMS (321 kg ha^{-1}) applied in the check (≤4%). At 14 DALA, no cotton injury was observed from applications made at the early or mid- timings (Table 8). It is important to note that by 14 DALA, 42 and 28 d had elapsed since the early and mid-timing applications of pyroxasulfone, respectively. These results suggest that there is no adverse cotton response due to these applications being made at different timings. This is further supported by cotton lint yield data, which indicate no differences across all application timings and methods (Table 8).

Practical Implications

Given the complexities of cotton weed management and the continued rise in weed control costs, there is great need for alternative weed management strategies in cotton production. Since pyroxasulfone-coated fertilizer was registered in cotton in 2020, limited research has been conducted to optimize pyroxasulfone-coated fertilizer in cotton production systems. This research provides evidence that pyroxasulfone-coated AMS (≥214 kg ha^{-1}) has the potential to control Palmer amaranth comparably to pyroxasulfone applied POST and POST-directed, with minimal risk of cotton injury. When applied onto 5- to 7-leaf cotton, pyroxasulfone-coated AMS was less injurious than pyroxasulfone POST-directed, suggesting that it may be a safer option for growers considering early-season POST-directed lay-by applications. This research also indicates that when pyroxasulfone is applied to 5- to 7-leaf cotton, an additional POST application may be necessary to achieve season-long control of Palmer amaranth, regardless of the application method. Aside from the results in these studies, it is important that pyroxasulfone-coated

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AMS be applied in compliance with current label recommendations (Anonymous 2024), as additional research is warranted to further explore the efficacy and usability of pyroxasulfone-coated fertilizer in cotton production. Evaluating its use in the early season may be beneficial, as increased weed pressure at this time could affect weed control.

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