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Short title: Herbicide-Coated Fertilizer

Residual Weed Control in Cotton Utilizing Herbicide-Coated Fertilizer

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Abstract

An experiment was conducted in 2022 and 2023 near Rocky Mount and Clayton, NC, to evaluate residual herbicide-coated fertilizer for cotton tolerance and Palmer amaranth control. Treatments included acetochlor; atrazine; dimethenamid-*P*; diuron; flumioxazin; fluometuron; fluridone; fomesafen; linuron; metribuzin; pendimethalin; pyroxasulfone; pyroxasulfone + carfentrazone; *S*-metolachlor; and sulfentrazone. Each herbicide was individually coated on granular ammonium sulfate (AMS) and top-dressed at 321 kg ha^{-1} (67 kg N ha^{-1}) onto 5- to 7-leaf cotton. The check received the equivalent rate of non-herbicide-treated AMS. Before top-dress, all plots (including the check) were treated with glyphosate and glufosinate to control previously emerged weeds. All herbicides resulted in transient cotton injury, except metribuzin. Cotton response to metribuzin varied by year and location. In 2022, metribuzin caused 11 to 39% and 8 to 17% injury at Clayton and Rocky Mount, respectively. In 2023, metribuzin caused 13 to 32% injury at Clayton and 73 to 84% injury at Rocky Mount. Pyroxasulfone (91%), pyroxasulfone + carfentrazone (89%), fomesafen (87%), fluridone (86%), flumioxazin (86%), and atrazine (85%) controlled Palmer amaranth ≥ 85%. Pendimethalin and fluometuron were the least effective treatments, resulting in 58% and 62% control, respectively. As anticipated, early season metribuzin injury translated into yield loss; plots treated with metribuzin yielded 640 kg ha^{-1} and were only comparable to linuron (790 kg ha^{-1}). These findings research suggest, with the exception of metribuzin, residual herbicides coated on AMS may be suitable and effective in cotton production, providing growers with additional modes of action for late-season control of multiple herbicide-resistant Palmer amaranth.

Nomenclature: acetochlor; atrazine; dimethenamid-*P*; diuron; flumioxazin; fluometuron; fluridone; fomesafen; glufosinate, glyphosate; linuron; metribuzin; pendimethalin; pyroxasulfone; pyroxasulfone + carfentrazone; *S*-metolachlor; sulfentrazone; Palmer amaranth, *Amaranthus palmeri* S. Watson. AMAPA; cotton, *Gossypium hirsutum* L.

Keywords: cotton tolerance; impregnated fertilizer

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Introduction

In recent years, cotton producers have had to navigate high production costs, which increased by an estimated \$459 ha^{-1} between 2018 and 2022 (USDA-ERS 2023a). This rise in expense is partly due to the prevalence of multiple herbicide-resistant (HR) weed species, like Palmer amaranth. 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). Historically, growers could simply and cost-effectively manage Palmer amaranth by concurrently using postemergence (POST) herbicides and herbicide-tolerant cultivars (Duke and Powles 2008). However, Palmer amaranth biotypes have evolved resistance to many of the POST herbicides available in cotton (Foster and Steckel 2022; Jones, 2022), thus necessitating more focus on alternative weed control strategies.

Before herbicide-resistant cotton cultivars, it was commonplace to layer residual herbicides with multiple effective modes of actions (MOAs) (Culpepper et al. 2010; Prostko et al. 2001). A standard recommendation of this time would have included pendimethalin or trifluralin applied pre-plant incorporated (PPI), followed by a photosystem II (PSII)-inhibitor, such as diuron or fluometuron, applied preemergence (PRE). If warranted, a postemergence-directed (POST-directed) application, including cyanazine, diuron, fluometuron, or prometryn plus MSMA or DSMA, would follow to ensure adequate late-season weed control (Wilcut et al. 1995). Like the aforementioned strategy, similar programs are currently advised by extension weed specialists to effectively manage multiple HR Palmer amaranth and to further delay the evolution of herbicide-resistance (Busi et al. 2020; Cahoon and York 2024; Neve et al. 2011). Soil residual herbicides routinely applied PRE to control Palmer amaranth in cotton include the protoporphyrinogen oxidase (PPO)-inhibitor fomesafen, the very-long-chain-fatty-acid (VLCFA)-inhibitor acetochlor, and the photosystem II (PSII)-inhibitors diuron and fluometuron (Whitaker et al. 2011). However, diuron (carcinogenic effects) and fluometuron (groundwater concerns) are under review by the United States Environmental Protection Agency, bringing into question the longevity of these herbicides for managing Palmer amaranth (U.S. EPA 2022). In the potential absence of diuron and fluometuron, alternative options remain available, including the phytoene desaturase-inhibitor fluridone and the microtubule-inhibitor pendimethalin.

Residual herbicides registered for POST over-the-top (OTT) use in cotton are relatively limited; the VLCFA-inhibitors, including acetochlor, dimethenamid-*P*, and *S*-metolachlor, are the predominate options. These herbicides provide effective residual control of Palmer amaranth but do not control emerged weeds (Hay 2017; Riar et al. 2012). In 2024, transgenic cotton cultivars tolerant to the herbicide isoxaflutole were commercially launched. Isoxaflutole, a 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting herbicide, will offer growers an additional tool for managing Palmer amaranth PRE and/or early POST, following the official release of the cotton formulation (Farr et al. 2022; Joyner et al. 2022). Like the VLCFA-inhibitors, isoxaflutole does not effectively control emerged Palmer amaranth (Joyner 2021). The ALS-inhibiting herbicides, including trifloxysulfuron and pyrithiobac, provide additional POST residual options in cotton. However, Palmer amaranth biotypes resistant to ALS-inhibiting herbicides are widespread, ultimately hindering their use (Nakka et al. 2017; Norsworthy et al. 2008). Beyond the aforementioned herbicides, no other POST-OTT residual herbicides are available in cotton production.

Despite limited POST-OTT residual herbicides, additional options exist for controlling Palmer amaranth using POST-directed lay-by and hooded sprayer applications. These applications direct and/or shield the spray beneath the cotton foliage to avoid the risk of injury. In cotton, the available herbicide options include the PSII-inhibitors diuron, fluometuron, and prometryn; the VLCFA-inhibitors acetochlor, *S*-metolachlor, and pyroxasulfone; and the PPO-inhibitors fomesafen and flumioxazin (Cahoon and York 2024, Wilcut et al. 1995). Although many residual herbicides are registered for POST-directed use in cotton, these products are seldom used in this capacity. This is partly because applying herbicides POST-directed is time- and labor-intensive, and following the commercialization of glyphosate-tolerant cotton, many growers replaced such methods of weed control for simple and cost-effective POST-only programs (Webster and Sosonskie 2010). Additionally, POST-directed applications require a height difference between the cotton and targeted weeds to prevent injury, which is difficult to obtain due to the robust growth of Palmer amaranth (Askew et al. 2002).

Due to the infrequent use of POST-directed herbicides, greater dependence and, consequently, greater selection pressure for resistance have been imposed on the few remaining POST-OTT residual options. Currently, Palmer amaranth biotypes resistant to HPPD- and VLCFA inhibitors have been discovered, bringing to question the longevity of these important

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MOAs (Brabham et al. 2019; Mahoney et al. 2020). With weed control costs continuing to rise and the rate of herbicide discovery at a near standstill (Beckie and Harker 2017; Washburn 2023), there is a pressing need for alternative weed control strategies that have the potential to integrate additional herbicide MOAs into cotton weed management.

Given that growers frequently apply fertilizer within a growing season (Edmisten and Collins 2024), especially on the sandy soils of the southern U.S. cotton production region (Gatiboni and Hardy 2024), one potential weed management strategy is residual herbicide-coated fertilizer. Buhler (1987) reported that herbicide-coated fertilizer could reduce time, labor costs, and soil compaction. In turfgrass and container nurseries, herbicide-coated fertilizer is commonly used to prevent herbicide volatility and to reduce the risk of injury (Derr 1994; Yelverton 1998). Since herbicide-coated granules are more likely to fall to the ground than adhere to crop foliage, less crop injury could be expected compared to spray applications. As a result, herbicide-coated fertilizer may have the potential to integrate additional herbicide MOAs into cotton with minimal risk of injury. Additionally, herbicide-coated fertilizer could provide cotton growers with an alternative to applying herbicides POST-directed (Steckel 2021).

Currently, pendimethalin and pyroxasulfone are the only herbicides registered to be applied coated on granular fertilizer in cotton (Anonymous 2024a, 2024c). Pendimethalin-coated fertilizer has been shown to control Texas millet (*Urochloa texana* R. Webster) similarly to pendimethalin sprayed at planting (Grey et al. 2008). Research in North Carolina found pyroxasulfone-coated granular ammonium sulfate (AMS) controlled Palmer amaranth comparable to pyroxasulfone applied POST and POST-directed (Dean et al. 2023). Although some studies have evaluated herbicide-coated fertilizer in cotton, there is need to further investigate the efficacy and utility of additional herbicide MOAs applied coated on AMS fertilizer in cotton. The objectives of this research were to evaluate cotton tolerance to top-dress applications of various herbicides applied coated on granular AMS fertilizer and to evaluate their efficacy in controlling Palmer amaranth.

Materials and Methods

An experiment was conducted in 2022 and 2023 at the Upper Coastal Plains Research Station near Rocky Mount, NC (35.89, 77.68), and the Central Crops Research Station near Clayton, NC (35.67, 78.51). The soil at Rocky Mount consisted of an Aycock very fine sandy

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loam (Fine-silty, siliceous, subactive, thermic Typic Paleudults) with 0.3 to 0.4% humic matter and pH of 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 of 5.5 to 6.0 (Mehlich 1984).

Fields at both locations were prepared using conventional tillage and then bedded into 91-cm rows at Rocky Mount and 97-cm rows at Clayton. Plots were 4 rows wide by 9.1-m long. Deltapine® cotton cultivar 'DP 2115 B3XF' (Bayer CropScience, Research Triangle Park, NC) 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 2- to 2.5-cm depth. All pesticide and fertilizer applications required for crop maintenance were applied following recommendations from North Carolina Cooperative Extension (Edmisten et al. 2024).

Treatments included 15 residual herbicides plus a check. Herbicides and application rates are reported in Table 1. Treatments were arranged in a randomized complete block design with four replications. Each herbicide was coated on granular AMS (21-0-0-24; FCI Agri Service Company, Raeford, NC) and applied at 321 kg ha^{-1} (67 kg N ha^{-1}) onto 5- to 7-leaf cotton. This timing matches when a typical fertilizer application would be made to fulfill peak fertility demand during cotton squaring. The check received the equivalent rate of non-herbicide-treated AMS for comparison. Herbicide-coated AMS was prepared by mixing the desired rate of herbicide, water, and 1 ml of blue dye (45 ml of the total solution) in an electric-powered concrete mixer (Sears, Roebuck and Co, USA.) that contained the appropriate rate of granular AMS. The blue dye (1 ml) was included in the mixture to provide a means for visually estimating coverage throughout the mixing process. All treatments were evenly top-dressed within three cotton row middles using 1.89 L plastic containers (ULINE Company, U.S.A.) with lids that had equally spaced and sized (approximately 4 mm) holes. Prior to applications, all plots (including the check) were treated with glyphosate (Roundup PowerMAX® 3 Herbicide, Bayer CropScience, St. Louis, MO) at 1,345 g ae ha^{-1} and glufosinate (Liberty® 280 SL Herbicide, BASF Corporation, Research Triangle Park, NC) at 656 g ai ha^{-1} to control previously emerged weeds. No residual herbicides were used prior to treatment applications. Spray applications were made using a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 207 kPa. Backpack sprayers were equipped with AIXR 11002 flat-fan nozzles (TeeJet® Air Induction

Extended Range spray nozzles; TeeJet Technologies, Wheaton, IL). Application dates and accumulated rainfall at both locations in both years are reported in Table 2.

All locations were naturally infested with Palmer amaranth. Percentage of cotton injury and weed control were estimated visually according to Frans et al. (1986) until 70 days after treatment (DAT). Additionally, late-season Palmer amaranth density was measured before cotton defoliation by randomly placing two 0.25 m^2 quadrats per plot and counting the number of individuals within each quadrat. At the conclusion of the season, the center two rows of each plot were mechanically harvested and weighed to determine cotton lint yield. All data were subject to analysis of variance using the GLM procedure of SAS software (version 9.4; SAS Institute Inc., Cary, NC) ($\alpha = 0.05$) (Saville 2015). Treatment means were separated using Fisher's protected LSD ($P \leq 0.05$) where appropriate. For all analyses, treatment, year, location, and their interactions were considered fixed effects, while replication was considered a random effect.

Results and Discussion

Cotton Response

Main effects of treatment, year, and location were significant for cotton injury. The three-way interaction of the main effects was significant; thus, data for cotton injury are presented by location. Most injury was in the form of cotton necrotic leaf specking and resulted from AMS granules adhering to damp foliage at time of application. However, interveinal and marginal leaf chlorosis was characteristic of the PSII-inhibitors, including diuron, fluometuron, linuron, atrazine, and metribuzin. These herbicides are apoplastically translocated (moving upward through the plant from the soil) throughout the plant and can be absorbed through foliage or roots (Ross and Childs 1996). When soil-applied, plant roots can readily absorb these herbicides, causing chlorophyll synthesis inhibition and degradation of cell membranes (Neal et al. 2015).

At 7 DAT in 2022, sulfentrazone was the most injurious at both locations, resulting in 18 and 11% cotton injury at Clayton and Rocky Mount, respectively (Table 3). Similar to sulfentrazone, metribuzin and fomesafen had a greater cotton response at Clayton than Rocky Mount. At Clayton, metribuzin and fomesafen resulted in 11 and 12% cotton injury, respectively. Meanwhile, both caused 8% injury at Rocky Mount (Table 3). In addition to sulfentrazone (18%), fomesafen (12%), and metribuzin (11%), acetochlor (7%), pyroxasulfone + carfentrazone (7%), flumioxazin (6%), and linuron (6%) all caused injury statistically greater than non-

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herbicide treated AMS at Clayton 7 DAT (Table 3). Except for sulfentrazone (11%), metribuzin (8%), and fomesafen (8%), pyroxasulfone + carfentrazone (6%) was the only other treatment that caused injury greater than the non-herbicide treated AMS (4%) at Rocky Mount (Table 3). Notably, atrazine (1%), acetochlor (2%), diuron (2%), fluometuron (1%), and pendimethalin (2%) resulted in statistically less injury than the non-herbicide treated AMS (4%) at this location (Table 3). Differences in cotton injury between the two locations were likely attributed to rainfall, with Clayton and Rocky Mount accumulating 0.66 and 2.44 cm between 0 and 8 DAT, respectively (Table 2). Due to lower rainfall at Clayton, AMS granules likely remained on cotton foliage for an extended period after top-dress, thus causing slightly greater injury.

By 28 DAT in 2022, all treatments, except metribuzin, resulted in cotton injury statistically comparable to the injury observed with non-herbicide-treated AMS (3%) at both locations. Once again, cotton response to metribuzin was greater at Clayton (18%) than Rocky Mount (12%; Table 3). This was further evident 42 DAT, where metribuzin caused 39 and 17% cotton injury at Clayton and Rocky Mount in 2022, respectively (Table 3). Differences between locations were likely due to rainfall and soil texture. Soil texture at Clayton is a loamy sand, while Rocky Mount is a very-fine sandy loam. Between 17 and 40 DAT, Clayton received 1.95 cm more precipitation than Rocky Mount (Table 2). Given the higher sand content at Clayton plus the additional rainfall, metribuzin could have leached into the cotton root zone, thus causing greater root absorption and injury (Kleemann and Gill 2008; Moomaw and Martin, 1978). These findings are further supported by Coble and Schrader (1973), who reported greater soybean (*Glycine max* L. Merr) sensitivity to metribuzin after rainfall was received on coarse-textured soil with low organic matter. In general, these results are expected, as metribuzin cannot be applied to soybeans or many other crops on coarse-textured soil with less than 2% organic matter (Anonymous 2024b). Aside from metribuzin, no other herbicide injured cotton 42 DAT at either location (Table 3).

Similar to 2022, relatively minor cotton injury was observed at Rocky Mount and Clayton in 2023, except for metribuzin (Table 4). However, cotton tolerance to metribuzin differed in 2023, particularly at Rocky Mount. At 7 DAT, metribuzin accounted for 32 and 73% cotton injury at Clayton and Rocky Mount, respectively (Table 4). This response was likely influenced by extensive rainfall received at Clayton (2.67 cm) and Rocky Mount (2.74 cm) the first two days following top-dress. By 28 and 42 DAT at Rocky Mount, metribuzin caused 84

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and 81% injury, respectively, whereas at Clayton, 15 and 13% injuries were observed, respectively (Table 4). Between 9 and 24 DAT, Clayton accumulated 1.74 cm greater rainfall than Rocky Mount (Table 2). Similar to 2022, rainfall likely triggered a cotton response to metribuzin in 2023; however, the heavier rainfall earlier in the season at Clayton, combined with the coarser-textured soil, may have leached metribuzin below the root zone, reducing the amount of herbicide bioavailable for root absorption (Shaner 2014). Similar thoughts were reported by VanGessel et al. (2017), suggesting substantial rainfall on coarse-textured soil may have increased wheat (*Triticum aestivum* L.) tolerance to metribuzin.

Aside from metribuzin, there was overall less cotton injury in 2023 (Table 4). At Clayton, acetochlor, atrazine, dimethenamid-*P*, diuron, fluometuron, pendimethalin, pyroxasulfone, *S*-metolachlor, and the non-herbicide treated AMS caused no injury 7 DAT (Table 4). This is contrary to results observed in 2022, where these treatments caused 4 to 7% cotton injury at that timing (Table 3). Similar to 2022, pyroxasulfone (0%), *S*-metolachlor (1%), acetochlor (2%), atrazine (0%), fluometuron (1%), pendimethalin (1%), and dimethenamid-*P* (2%) all caused cotton injury comparable to the non-herbicide treated AMS at Rocky Mount 7 DAT (Table 4).

Over two growing seasons, cotton response to diuron and fluridone was consistent across locations 7 DAT, accounting for 1 to 3% and 3 to 4% cotton injury, respectively (Tables 3 and 4). However, cotton response to flumioxazin varied by year. In 2022, flumioxazin caused 6 and 4% injury at Clayton and Rocky Mount, respectively (Table 3). Meanwhile, in 2023, flumioxazin resulted in 13% injury at Clayton and 11% at Rocky Mount (Table 4). At Clayton, sulfentrazone resulted in less injury in 2023 (11%) than in 2022 (18%) (Tables 3 and 4). At Rocky Mount, cotton response to sulfentrazone remained consistent, with 11% cotton injury observed both years. Contrary to 2022, no treatment injured cotton 28 DAT in 2023, except metribuzin (Table 4). At both locations, cotton response to metribuzin remained evident 42 DAT (Table 4).

Acetochlor, *S*-metolachlor, and pyroxasulfone applied POST OTT of cotton are reported to cause ≥ 19% cotton injury (Cahoon et al. 2014; Collie et al. 2014; Eure et al. 2013). However, when coated on granular AMS and applied OTT of 5- to 7-leaf cotton, these herbicides injured cotton ≤ 7%. Previous research from Tennessee also reported minimal injury when pyroxasulfone-coated fertilizer was top-dressed in cotton (Steckel 2021). Fluometuron applied POST OTT to cotyledon and 2- to 4-leaf cotton has been reported to cause 40% cotton injury (Kendig et al. 2007). However, when applied on granular AMS, fluometuron only accounted for

1 to 4% injury. Likewise, low doses of flumioxazin applied POST OTT to simulate spray drift causes 69 to 97% cotton injury (Stephenson IV et al. 2019). However, flumioxazin-coated AMS caused no greater than 13% cotton injury. Research by Morgan et al. (2011a, 2011b) found that POST-directed lay-by applications of diuron, linuron, and fomesafen effectively controlled volunteer cotton. These same herbicides applied coated on AMS fertilizer in this study resulted in ≤ 12% cotton injury.

Palmer amaranth Control

The main effect of treatment was significant for Palmer amaranth control and density; the main effects of year and location were not significant. Furthermore, interactions among main effects were not detected; therefore, Palmer amaranth control and density data were averaged over years and locations (Table 5). Adequate rainfall was received for herbicide activation in both years at both locations (Table 2).

At 42 DAT, all treatments controlled Palmer amaranth ≥ 73%, except for pendimethalin and fluometuron, which recorded 58 and 62% control, respectively (Table 5). These results are expected, as pendimethalin and fluometuron have historically provided inconsistent control of Palmer amaranth (Culpepper and York 2000; Grichar 2008). Conversely, pyroxasulfone (91%) was more efficacious than every other treatment, except pyroxasulfone + carfentrazone (89%), fomesafen (87%), fluridone (86%), flumioxazin (86%), and atrazine (85%) (Table 5). Exceptional Palmer amaranth control with pyroxasulfone is unsurprising, given that many studies have also observed > 90% control (Cahoon et al. 2015; Janak and Grichar 2016). Apart from fluridone (56%), all the aforementioned herbicides reduced late-season Palmer amaranth density by at least 78% compared with the non-herbicide treated check (Table 5).

Pyroxasulfone + carfentrazone (89%), fomesafen (87%), fluridone (86%), and flumioxazin (86%) were more efficacious than metribuzin (78%), linuron (77%), diuron (76%), sulfentrazone (74%), *S*-metolachlor (73%), and dimethenamid-*P* (73%) (Table 5). Earlier work by Whitaker et al. (2011) reported that fomesafen generally provides more effective control of Palmer amaranth than diuron. In general, reductions in Palmer amaranth density followed similar trends as estimates of visual control, with plots treated with diuron containing 56% fewer plants than the nontreated check. In contrast, plots treated with fomesafen had 89% less plants (Table 5). Additionally, atrazine (85%) proved more effective in controlling Palmer amaranth than sulfentrazone (74%), *S*-metolachlor (73%), and dimethenamid-*P* (73%) (Table 5). However,

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sulfentrazone (74%), *S*-metolachlor (73%), and dimethenamid-*P* (73%) controlled Palmer amaranth comparable with acetochlor (80%), metribuzin (78%), linuron (77%), and diuron (76%) (Table 5). Houston et al. (2019) reported similar Palmer amaranth control with *S*-metolachlor, acetochlor, diuron, sulfentrazone, and metribuzin.

Cotton Yield

Main effect of treatment was significant for cotton yield; main effects were not significant for year and location. No significant interactions were detected; therefore, data for cotton yield are presented averaged over years and locations (Table 5). Numerically, cotton treated with diuron (960 kg ha^{-1}) and fomesafen (950 kg ha^{-1}) produced the greatest yield (Table 5). All remaining treatments, except metribuzin, linuron, and *S*-metolachlor, produced similar yield to plots treated with diuron or fomesafen. Although plots treated with *S*-metolachlor yielded less than those treated with diuron and fomesafen, the yield was statistically greater than that of metribuzin and comparable to all remaining treatments (Table 5). As expected, due to early season visual injury, cotton treated with metribuzin (640 kg ha^{-1}) yielded the lowest and was only comparable with linuron (790 kg ha^{-1}) (Table 5). Despite yielding similarly to cotton treated with metribuzin, linuron was comparable in yield to all other treatments. It should be noted that the objectives of this research were to evaluate cotton tolerance and weed control with various herbicides applied top-dress, coated on granular AMS fertilizer. Conducting this experiment under weed-free conditions may be more appropriate to evaluate treatment effects on cotton yield. However, yield reductions in response to metribuzin were expected as significant visual injury was observed earlier in the season.

Practical Implications

Due to the increasing prevalence of multiple HR Palmer amaranth and the continuous rise in weed control costs, alternative weed management strategies are needed in cotton production. Our results provide evidence that herbicide-coated AMS may allow the integration of additional residual herbicides for late-season weed control in cotton with minimal injury risk. This is important, considering that POST residual options in cotton are limited. The integration of additional residual herbicides using this application technique may reduce selection pressure on Group 15 herbicides, a mode of action on which cotton producers have long depended. Furthermore, considering many growers are ill-equipped or hesitant to apply herbicides POST-

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directed, residual herbicide-coated AMS may provide farmers with a more efficient avenue for applying late season residual herbicides. Simultaneously applying a residual herbicide and fertilizer in a single pass has potential to reduce time, labor, and fuel costs. Although this research proves many herbicides not currently labeled for OTT use in cotton can be safely used when coated on AMS fertilizer, additional research is warranted to further quantify cotton tolerance and potential yield effects under weed-free conditions.

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Competing Interests

The author(s) declare none.

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Table 1. Residual herbicide treatments applied top-dress, coated on granular ammonium sulfate fertilizer.[a]

Herbicides[b]	Trade names	Formulation concentration	Application Rate	Manufacturer
		g ai L^{-1}	g ai ha^{-1}	
acetochlor	Warrant®	360	1,260	Bayer CropScience
atrazine	Atrazine® 4L	480	1,120	Adama US
dimethenamid-*P*	Outlook®	719	630	BASF Corporation
diuron	Direx®	480	840	Makhteshim Agan of North America
flumioxazin	Valor® EZ	480	52	Valent U.S.A
fluometuron	Cotoran® 4L	480	1,120	Adama US
fluridone	Brake®	144	221	SePRO Corporation
fomesafen sodium salt	Reflex®	240	280	Syngenta Crop Protection
linuron	Linex® 4L	480	840	NovaSource, Inc
metribuzin	TriCor®	75%	420	UPL NA, Inc
pendimethalin	Prowl® H20	455	1,064	BASF Corporation
pyroxasulfone	Zidua® SC	500	118	BASF Corporation
pyrox + carfen-ethyl	Anthem® Flex	447 + 32	118 + 9	FMC Corporation
S-metolachlor	Dual Magnum®	913	1,067	Syngenta Crop Protection
sulfentrazone	Spartan®	480	210	FMC Corporation

[a]Specimen labels for each product and mailing addresses and website of each manufacturer can be found at www.cdms.net.

[b]Abbreviations: Pyrox + carfen-ethyl, pyroxasulfone + carfentrazone-ethyl.

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Table 2. Top-dress application dates and accumulated rainfall after applications.

Locations	Years	Application dates	Days following application					
			0-8	9-16	17-24	25-32	33-40	40-48
			——————————cm——————————					
Rocky Mount	2022	June 16	2.44	0.02	6.1	0.46	0.08	6.55
	2023	June 21	4.52	1.48	8.03	0.23	0.97	0.36
Clayton	2022	June 17	0.66	0.58	7.54	0.97	0.08	3.3
	2023	June 21	3.21	5.29	5.96	0.08	0.06	1.84

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Table 3. Cotton injury as affected by residual herbicide-coated granular ammonium sulfate fertilizer, 2022.[a]

Herbicides[b,c,d,e]	Cotton injury											
	Clayton						Rocky Mount					
	7 DAT		28 DAT		42 DAT		7 DAT		28 DAT		42 DAT	
	%											
none	4	ef	3	b	0	b	4	d	3	bc	0	b
acetochlor	7	c	4	b	0	b	2	gh	3	bc	0	b
atrazine	3	f	3	b	0	b	1	h	3	bc	0	b
dimethenamid-*P*	5	de	5	b	0	b	3	d-g	3	bc	0	b
diuron	3	f	3	b	0	b	2	gh	3	bc	0	b
flumioxazin	6	cd	4	b	0	b	4	de	3	bc	0	b
fluometuron	3	f	4	b	0	b	1	h	2	c	0	b
fluridone	4	ef	4	b	0	b	3	d-g	2	c	0	b
fomesafen	12	b	7	b	0	b	8	b	5	b	0	b
linuron	6	cd	7	b	0	b	4	d	5	bc	0	b
metribuzin	11	b	18	a	39	a	8	b	12	a	17	a
pendimethalin	5	cde	3	b	0	b	2	gh	3	bc	0	b
pyroxasulfone	4	ef	3	b	0	b	4	d	3	bc	0	b
pyrox + carfen	7	cd	4	b	0	b	6	c	4	bc	0	b
S-metolachlor	5	cde	4	b	0	b	4	def	2	c	0	b
sulfentrazone	18	a	7	b	0	b	11	a	5	bc	0	b

[a]Data are presented by year and location. Means within a column followed by the same letter are not statistically different according to Fisher's protected LSD ($P \leq 0.05$).
[b]Abbreviations: DAT, days after treatment; pyrox + carfen, pyroxasulfone + carfentrazone.

[c]Each herbicide was coated on granular AMS and top-dressed at 321 kg ha^{-1} onto 5- to 7-leaf cotton.
[d]The check received non-herbicide treated granular AMS at 321 kg ha^{-1}.

[e]Prior to top-dress, all plots (including the check) were treated with glyphosate at 1,345 g ae ha^{-1} and glufosinate at 656 g ai ha^{-1}

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Table 4. Cotton injury as affected by residual herbicide-coated granular ammonium sulfate fertilizer, 2023.[a]

	Cotton injury											
	Clayton						Rocky Mount					
Herbicides[b,c,d,e]	7 DAT		28 DAT		42 DAT		7 DAT		28 DAT		42 DAT	
	%											
none	0	d	0	b	0	b	0	g	0	b	0	b
acetochlor	0	d	0	b	0	b	2	efg	0	b	0	b
atrazine	0	d	0	b	0	b	0	g	0	b	0	b
dimethenamid-*P*	1	d	0	b	0	b	2	efg	0	b	0	b
diuron	1	d	0	b	0	b	3	e	0	b	0	b
flumioxazin	13	b	0	b	0	b	11	bc	0	b	0	b
fluometuron	0	d	0	b	0	b	1	efg	0	b	0	b
fluridone	3	cd	0	b	0	b	3	ef	0	b	0	b
fomesafen	9	bc	0	b	0	b	9	cd	0	b	0	b
linuron	8	bc	0	b	0	b	9	cd	0	b	0	b
metribuzin	32	a	15	a	13	a	73	a	84	a	81	a
pendimethalin	0	d	0	b	0	b	1	efg	0	b	0	b
pyroxasulfone	0	d	0	b	0	b	0	g	0	b	0	b
pyrox + carfen	8	bc	0	b	0	b	7	d	0	b	0	b
S-metolachlor	0	d	0	b	0	b	1	efg	0	b	0	b
sulfentrazone	11	b	0	b	0	b	11	bc	0	b	0	b

[a]Data are presented by year and location. Means within a column followed by the same letter are not statistically different according to Fisher's protected LSD ($P \leq 0.05$).
[b]Abbreviations: DAT, days after treatment; pyrox + carfen, pyroxasulfone + carfentrazone.

[c]Each herbicide was coated on granular AMS and top-dressed at 321 kg ha^{-1} onto 5- to 7-leaf cotton.
[d]The check received non-herbicide treated granular AMS at 321 kg ha^{-1}.

[e]Prior to top-dress, all plots (including the check) were treated with glyphosate at 1,345 g ae ha^{-1} and glufosinate at 656 g ai ha^{-1}

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Table 5. Influence of residual herbicide-coated granular ammonium sulfate fertilizer on Palmer amaranth control and density, and cotton lint yield.[a]

Herbicides[b,c,d,e]	Control 42 DAT		Density[f]		Cotton lint yield	
	%		plants m^{-2}		kg ha^{-1}	
none	–		9	a	860	ab
acetochlor	80	b-e	1	e	860	ab
atrazine	85	a-d	2	de	820	ab
dimethenamid-*P*	73	e	2	de	910	ab
diuron	76	de	4	bcd	960	a
flumioxazin	86	abc	1	e	840	ab
fluometuron	62	f	6	ab	880	ab
fluridone	86	abc	4	bcd	830	ab
fomesafen	87	abc	1	e	950	a
linuron	77	cde	2	de	790	bc
metribuzin	78	cde	2	de	640	c
pendimethalin	58	f	5	bc	850	ab
pyroxasulfone	91	a	1	e	850	ab
pyrox + carfen	89	ab	1	e	930	ab
S-metolachlor	73	e	3	b-e	800	b
sulfentrazone	74	e	3	b-e	820	ab

[a]Data are averaged over years and locations. Means within a column followed by the same letter are not statistically different according to Fisher's protected LSD ($P \leq 0.05$).

[b]Abbreviations: DAT, days after treatment; pyrox + carfen, pyroxasulfone + carfentrazone.

[c]Each herbicide was coated on granular AMS and top-dressed at 321 kg ha^{-1} onto 5- to 7-leaf cotton.

[d]The check received non-herbicide treated granular AMS at 321 kg ha^{-1}.

[e]Prior to top-dress, all plots (including the check) were treated with glyphosate at 1,345 g ae ha^{-1} and glufosinate at 656 g ai ha^{-1}.

[f]Density was measured approximately 70 DAT.

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