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DOI: 10.1017/wet.2024.106

Tolerance of Cotton to Herbicide-Coated Fertilizers

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Abstract

Cotton producers need residual herbicides that can safely and practically be applied postemergence (POST). Herbicide-coated fertilizers could allow for simultaneous application of residual herbicides and a bulk fertilizer blend. Therefore, a study was conducted in 2022 and 2023 in Fayetteville, AR, to evaluate cotton tolerance to 12 herbicide treatments coated onto a fertilizer blend and applied over cotton. Herbicides and rates evaluated included: diuron at 840 g ai ha^{-1}, florpyrauxifen-benzyl at 29 g ai ha^{-1}, flumioxazin at 105 g ai ha^{-1}, flumioxazin plus pyroxasulfone at 70 + 90 g ai ha^{-1}, fluridone at 168 g ai ha^{-1}, fluometuron at 840 g ai ha^{-1}, fomesafen at 280 g ai ha^{-1}, pyroxasulfone at 128 g ai ha^{-1}, saflufenacil at 66 g ai ha^{-1}, saflufenacil plus dimethenamid-P at 25 + 219 g ai ha^{-1}, saflufenacil plus pyroxasulfone at 44 + 91 g ai ha^{-1}, and *S*-metolachlor at 1388 g ai ha^{-1}. In both years, fluridone, fluometuron, diuron, and *S*-metolachlor caused less than 10% injury at 7 d after treatment (DAT). Higher injury levels were observed in 2022 (19 to 30%) compared to 2023 (4 to 12%) for flumioxazin, fomesafen, saflufenacil, saflufenacil plus dimethenamid-P, and saflufenacil plus pyroxasulfone. The elevated injury in one of two years was attributed to the presence of dew when the herbicide-coated fertilizer was applied. The initial injury was transient, as the cotton generally had recovered by 28 DAT for all herbicides. No differences in seed cotton yield or groundcover among the herbicide treatments occurred either year. These results highlight the potential of using several POST-applied, residual herbicides coated on fertilizer that are not currently registered for over-the-top use in cotton.

Nomenclature: Dimethenamid-P; diuron; florpyrauxifen-benzyl; fluometuron; flumioxazin; fluridone; fomesafen; pyroxasulfone; saflufenacil; *S*-metolachlor; cotton, *Gossypium hirsutum* L.

https://doi.org/10.1017/wet.2024.106 Published online by Cambridge University Press

Introduction

Cotton producers rely on residual herbicides for season-long control of problematic weeds such as Palmer amaranth (*Amaranthus palmeri* S. Wats.) and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] (Burke et al. 2005; Culpepper and York 1998). Without adequate control of these weeds, yields can be compromised. For instance, ten Palmer amaranth plants per 9 meters of cotton row can decrease lint yield by up to 57% (MacRae et al. 2013; Morgan et al. 2001). Historically, mid- to late-season applications of residual herbicides with special layby and hooded equipment have been used to provide extended control of emerging weeds without harming the crop (Koger et al. 2007). Mid-season fertilizer application is also a common practice, and these applications are often made with broadcast fertilization equipment at squaring and early bloom (Wells and Green 1991). Furthermore, using herbicide-coated fertilizers in cotton production has prompted interest from producers because of the practical notion that both residual herbicides and granular fertilizers can be applied simultaneously late into the season without causing substantial injury.

The application of required nutrients in cotton is paramount for ensuring season-long crop health and optimizing yields. Applications of either macro- or micronutrients depend on the recommendations for specific production regions and states. Potassium (K), Nitrogen (N), Phosphorus, (P), and Sulfur (S) are all commonly applied granularly. K, an important macro-nutrient, is often applied as muriate of potash as a granular fertilizer. Because producers can experience decreased crop health and yield due to late-season deficiencies, potassium application is based on soil test recommendations (kg K ha^{-1}) (Mullins et al. 1997). In addition, in some areas of cotton production, K deficiency and acidic soils can decrease productivity (Sun 2018). Cotton will luxury consume K if the supply is overabundant. Therefore, it is recommended to apply K in cotton at the requirement peak, which is when bolls begin to develop, also known as the squaring stage (Kerby and Adams 1985).

Nitrogen (N) can be applied as urea, ammonium sulfate, and ammonium nitrate to crops (Gatiboni and Hardy 2024). Urea is a commonly used fertilizer in cotton production and is recommended in split applications (Robertson et al. 2007). The first urea application is usually made at squaring, and the second before flowering (Robertson et al. 2007). Applying split applications of N minimizes loss and provides the plants with this essential nutrient at critical

https://doi.org/10.1017/wet.2024.106 Published online by Cambridge University Press

growth stages (Hallikeri et al. 2010). Nutrient uptake increases rapidly at square and flowering, making these two timings essential for N application (Feng et al. 2023). Two common N fertilizer spreading methods are surface banding and broadcasting (Adotey et al. 2021). Phosphorus (P) applications only occur when a soil test indicates mineral deficiencies. Additional P will be applied when deficiencies are detected based on the current parts per million in the soil (Mitchell and Baker 2000). Sulfur (S) is only applied when a deficiency has previously occurred, or soil test results have indicated sulfur deficiency. Whenever the nutritional needs of cotton are adequately met, cotton plants should add a new node, with every degree day above 15.6 C (Robertson et al. 2007).

Bulk blending fertilizers combine two or more granular products into one, which producers will then apply (Wells and Green 1991). Depending on the granule size and crop requirements, many nutrients can be bulk blended. A similar granule size of each fertilizer is critical to the success of the bulk blended fertilizer application (Maguire et al. 2019). If the granule size of each fertilizer is not similar, segregation will likely occur, which results in an uneven fertilizer rate distributed throughout the field. Granule size is the determining factor in segregation; shape and density do not strongly impact the segregation of a fertilizer bulk blend (Maguire et al. 2019; Hoffmeister et al. 1964). A bulk blend of urea and muriate of potash is one example of a successful blend, as both are relatively similar in size (Maguire et al. 2019).

Herbicide applications can be split into three main groups that dictate the application timing and type of herbicide: preplant (PP), preemergence (PRE), and postemergence (POST) (Culpepper and York 1998; Wilcut et al. 1997). The PP herbicides are often applied to control emerged weeds before planting. Residual herbicides may be included in PP applications and are often broadcast applied on the soil surface or incorporated into the soil. Preemergence herbicides are applied before the emergence of either the crops, weeds, or both (Zimdahl 2019). Preemergence applications often provide soil residual control and kill germinating weeds quickly. In contrast to PRE herbicides, POST herbicides are applied following crop or weed emergence. Postemergence herbicides provide foliar control, with occasional residual soil activity (Zimdahl 2019). Postemergence-directed applications are made directly to weeds underneath the crop while minimizing exposure of crop leaves, and subsequent injury. Layby, a

https://doi.org/10.1017/wet.2024.106 Published online by Cambridge University Press

term used mostly for cotton, is the last POST-directed application in the season and has historically been applied using a hooded boom (Koger et al. 2007).

Residual herbicides are essential to most complete herbicide programs to control the targeted weeds until crop canopy formation; typically, canopy closure occurs 75 days after planting (Oosterhuis 1990). Residual herbicides are typically accompanied by a POST herbicide to kill emerged weeds (Price et al. 2008; Wilcut et al. 1997). For example, glyphosate and glufosinate are two POST, non-residual herbicides that can be combined with residual herbicides (Price et al. 2008). The activity of residual herbicides depends on multiple factors, including soil moisture or rainfall, chemical characteristics of the herbicide, and placement, among others (Zimdahl 2019). Soil moisture or rainfall plays a crucial role in activating soil-applied herbicides, as it helps incorporate them into the soil, making them available for plant uptake. Physical adsorption to soil colloids and cation exchange affects herbicide removal from the soil solution while leaching moves herbicides offsite (Sebastian et al. 2016; Zimdahl 2019). Volatilization of a herbicide can lead to crop damage and environmental harm. Finally, it is important that the correct application method be used for the specific herbicide and crop, such as banded, broadcast, and directed (among others) for effective uptake (Zimdahl 2019).

The herbicides fluridone, fluometuron, diuron, fomesafen, saflufenacil, flumioxazin, pyroxasulfone, *S*-metolachlor, and dimethenamid-P all provide residual weed control (Main et al. 2012; Price et al. 2008; Everman et al. 2009; Askew et al. 2022; Grichar et al. 2020; Koger et al. 2007). Fomesafen and saflufenacil are typically applied PP in cotton and fluridone is applied PRE (Main et al. 2012; Li et al. 2018; Grichar et al. 2020; Price et al. 2008; Anonymous 2024d). Flumioxazin, pyroxasulfone, fluometuron, and diuron are labeled POST-directed in cotton (Everman et al. 2009; Askew et al. 2002; Main et al. 2012). Only *S*-metolachlor, fluometuron, and dimethenamid-P are labeled for over-the-top applications of the aforementioned herbicides. All these herbicides share the need for irrigation or rainfall for activation, with most residual herbicides requiring 1.3 to 2.5 cm of precipitation or irrigation within 7 to 10 d after application (Hager 2011).

Cotton producers need a practical way to apply residual herbicides without causing crop injury. Residual herbicides are often applied throughout the season to control problematic weeds such as Palmer amaranth. Layby application equipment or hooded sprayers have been used to reduce the risk of injury that can occur when herbicide contacts the leaves of the cotton crop (Koger et al. 2007). Some herbicide combinations labeled for over-the-top use can cause severe crop injury. For example, applying *S*-metolachlor, glyphosate, and glufosinate can cause up to 33% injury to cotton (Steckel et al. 2012). Concurrently with some herbicide applications, producers must apply fertilizer, often at squaring (6- to 8-leaf) and early bloom (10- to 12-node) growth stages. Thus, coating herbicides onto fertilizers could provide late-season weed control. Additionally, herbicide-coated fertilizers may allow for the safe use of residual herbicides in cotton that are not currently applied over the crop. As a result, two essential processes, fertilization and residual herbicide application, can co-occur without using layby or hooded equipment.

Some herbicide-coated fertilizers are already labeled to be used in other cropping systems, such as rice (*Oryza sativa* L.), where florpyrauxifen-benzyl can be applied on urea from the 2-leaf growth stage up to 60 d before harvest (Anonymous 2024a). In cotton, pyroxasulfone is the only herbicide registered for over-the-top use as a coated treatment onto dry bulk fertilizer (Anonymous 2024c). Due to its practicality, cotton producers and extension specialists are highly interested in this technique. If a producer already applies fertilizer with a spreader within the crop, applying a residual herbicide simultaneously without changing equipment would be ideal. Hence, research was conducted to evaluate which herbicides can be safely applied over the top of cotton when coated on fertilizer.

Materials and Methods

Experiments were conducted at the Milo J. Schult Agricultural Research and Extension Center in Fayetteville, AR, (36.09287, -94.17223) on a Leaf silt loam (fine, mixed, active, thermic Typic Albaquults) composed of 27.1% sand, 54.4 silt, 18.5% clay, and 2% organic matter with a 6.9 pH in the summer of 2022 and 2023. Cotton variety 'PHY360W3FE' (Corteva Agriscience Indianapolis, IN) was seeded at 106,000 seeds ha^{-1} to a depth of 1.9 using a four-row vacuum planter on May 11th in 2022 and on May 4th in 2023. The planter was a John Deere Max Emerge (John Deere Moline, IL). Plots were four 7.6 m rows spaced 0.91 m apart. Alleys of 1.5 m in width separated replications.

Standard cotton crop management was practiced throughout the trial and consisted of weed control, plant growth regulation, and irrigation. Irrigation amounts were based off the needs of the cotton at certain growth stages (Robertson et al. 2007). At planting, the trials received a broadcast PRE application of fluometuron (Cotoran®, 479 g ai L^{-1}, ADAMA, 8601 Six Forks Road, Suite 300, Raleigh, NC 27615) at 1120 g ai ha^{-1} and fluridone (Brake®, 168 g ai L^{-1}, SePRO Corporation, 11550 N. Meridian St., Suite 600, Carmel, IN 46032). Additional applications of glufosinate-ammonium (Interline®, UPL NA Inc., King of Prussia, PA) at 656 g ai ha^{-1} and glyphosate (N-phosphonomethyl glycine; Roundup PowerMax3®, Bayer Crop Science LP, St. Louis, MO) at 1,260 g ae ha^{-1} were applied to keep the trials free of weeds until complete cotton canopy. One of the glyphosate and glufosinate applications occurred immediately following the herbicide-coated fertilizer treatments.

Maintenance applications were delivered using a hand-held CO_2-pressurized backpack sprayer with AIXR 110015 nozzles (TeeJet Technologies, Springfield, IL) at 140 L ha^{-1}. The entire trial was treated with mepiquat chloride (Pix® Ultra Plant Regulator, 49 g ha^{-1} BASF Corp, Research Triangle Park, NC) at 49 g ha^{-1} twice throughout the season. Insecticide was applied as necessary to control any pests. In 2022, the trial was overhead irrigated for three weeks, beginning at the 2- to 3-leaf stage and then furrow-irrigated throughout the summer. In 2023, the trial was overhead irrigated whenever less than 2.5 cm of rainfall was present within a week following application (Figure 1).

The experimental design was a randomized complete block with 13 treatments comprised of one nontreated and twelve herbicide treatments (Table 1) replicated 4 times. Each herbicide treatment was coated onto a fertilizer blend and broadcasted over the cotton at the 6- to 8-leaf growth stage. Herbicide rates were selected based off the label suggestion for the crop and target weeds. Urea and muriate of potash fertilizer rates applied for each treatment were 196 kg ha^{-1} and 112 kg ha^{-1}, respectively, based on University of Arkansas recommendations (McConnel and Krist 2000; Robertson et al. 2022). The nontreated received an application of nontreated fertilizer. For each treatment, 542 g of urea and 309 grams of muriate of potash were weighed and uniformly blended using a 0.91 m^3 concrete mixer (Central Machinery, Camarilo, CA). Each herbicide rate was converted to the amount needed per treatment, mixed with BullsEye Blue Spray Pattern Indicator (SPI) (Milliken Chemical, Spartanburg, SC) at 0.112 L ha^{-1} to ensure fertilizer granules were evenly coated, and applied to blended fertilizer while in the concrete mixer. Prior to application, each treatment was evenly distributed among the four replications.

https://doi.org/10.1017/wet.2024.106 Published online by Cambridge University Press

Treatments were applied using a GroundWork hand spreader (Tractor Supply Co, Brentwood, TN). The applicator of the herbicide-coated fertilizer walked at 4.8 km $hour^{-1}$ through the three furrows of each plot, making two passes through each furrow. The two middle rows were evaluated to eliminate the possibility of influence from other herbicide treatments that may have flown into the rows between the two treatments. The fertilizer treatments were activated two days following the application using overhead irrigation.

Cotton tolerance to the herbicide coated onto fertilizer treatments was evaluated using visible crop injury ratings on a scale of 0 to 100, with 0 representing no injury and 100 representing complete plant death (Frans et al. 1986). Visible crop injury ratings were taken from the two center rows of four-row plots at 7 and 28 d after treatment (DAT). Aerial images were taken using a DJI Mavic Mini Drone (SZ DJI Technology Co., Ltd, Nanshan, Shenzhen, China) at 14 DAT, and the percent groundcover was analyzed using the TurfAnalyzer companion FieldAnalyzer (Green Research Services LLC, Fayetteville, AR). The two middle rows of each four-row plot were harvested by hand, and seed cotton yield was calculated (kg ha^{-1}).

Statistical analysis. Evaluation of the data prior to analysis indicated variation among years due to environmental factors. In 2022, the herbicide-coated fertilizer treatments were applied in the morning, when dew was present on the leaves. In 2023, the treatments were applied in the afternoon to dry leaves. Data were analyzed by year using an analysis of variance in SAS 9.4 (SAS Institute, Cary, NC) using PROC GLIMMIX featuring a beta distribution for injury analysis, as data was concentrated between the bounds of 1 and 0. Herbicide treatment was set as a fixed effect, and percent injury was considered the response variable. Denominator degrees of freedom were adjusted using the Kenward and Roger (1997) approximation. Distributions were checked using the distribution platform, where seed cotton yield and percent groundcover were found to be normally distributed as the data did not violate normality assumptions. Means were separated using Tukey's HSD post-hoc analysis ($\alpha = 0.05$).

Results and Discussion

Cotton tolerance. Differences in cotton injury occurred among the 12 herbicide-coated fertilizers 7 DAT in both years, however, by 28 DAT, injury was no more than 6% and equivalent among herbicides (Table 2). Cotton injury 7 DAT was manifested as two main symptoms. First, general necrosis and chlorosis to cotton were characteristic of some herbicide

https://doi.org/10.1017/wet.2024.106 Published online by Cambridge University Press

treatments, mainly those with a protoporphyrinogen oxidase (PPO) inhibitor (Figure 2). The second symptom consisted of multiple prill-sized raised projections on leaves, displayed by cotton treated with florpyrauxifen-benzyl (Figure 3). Both symptoms only lasted 7 to 14 d, and by 28 DAT, there was no more than 6% injury to cotton in 2022 and no more than 3% in 2023 by any herbicide treatment (Table 2).

In 2022, cotton was injured 18% to 30% following treatments containing flumioxazin, fomesafen, or saflufenacil (Table 2). In 2023, the same treatments caused only 4 to 11% injury 7 DAT, with differences between years attributed to varying application times during the day. In 2022, the herbicide-coated fertilizer treatments were applied in the morning when dew was still present on the leaves; however, the application was made in the afternoon when the leaves were dry in 2023, resulting in less fertilizer retention on the foliage. Regardless of plant injury and year, the PPO-inhibiting herbicides did not affect cottonseed yield (Table 3).

Humidity can affect herbicide uptake; typically, when humidity levels are higher, the droplets dry slower, and the cuticle is more hydrated (Price 1983). As a result, herbicide absorption increases (Devine et al. 1984). Although the relative humidity at the time of application was similar for both years (49% in 2022 and 45% in 2023), the dew on the leaves in 2022 may have hydrated the cuticle and allowed herbicide wicked from prills on foliage to remain in solution, aiding uptake, which would have led to increased injury from the PPO herbicides in 2022 (Price 1983). Fertilizer prills on the leaf surface, especially those that encounter moisture, may cause increased plant injury; however, information on this phenomenon in cotton is minimal and requires further investigation.

Florpyrauxifen-benzyl caused consistent injury across both years, ranging from 17% to 21% at 7 DAT (Table 2). The injury manifested as projections on the lower and upper leaf surfaces of the plants (Figure 3). These projections were visible at 7 DAT but only persisted for one week; newly emerged leaves did not exhibit projections, and overall injury was low. Notably, these raised projections, which are believed to be associated with the herbicide-coated prills remaining on the leaves, have not been previously documented in cotton at the 6- to 8-leaf growth stage when utilizing florpyrauxifen-benzyl, prompting further investigation into this symptomology. In other research, when applied as a POST-directed spray to 6- to 8-leaf cotton, florpyrauxifen-benzyl caused 6 to 11% injury to cotton in the form of epinasty (Doherty et al.

2020). Regardless of the injury to cotton at 7 DAT, florpyrauxifen-benzyl applied on fertilizer did not reduce seed cotton yield because of the recovery of the crop (Tables 2, 3), unlike yield loss in other research following POST-directed application of the herbicide (Doherty et al. 2022).

The herbicides diuron, fluometuron, and fluridone caused no more than 8% injury in both 2022 and 2023 (Table 2). When applied postemergence-directed, diuron or fluometuron at 1120 g ai ha^{-1} tank-mixed with either glyphosate at 860 g ae ha^{-1} or glufosinate at 470 g ai ha^{-1} at layby did not injure cotton or reduce seed cotton yield (Koger et al. 2007). Furthermore, fluometuron applied postemergence over-the-top at 1100 g ai ha^{-1} either 23 or 25 d after planting can cause an increase in the number of bolls produced, resulting in no loss in lint yield. (Guthrie and York 1989). Similarly, while stunting and chlorosis did occur following application, fluometuron applied 28 d after emergence at a rate of 1100 g ai ha^{-1} did not cause any reduction in cotton yield (Arle and Hamilton 1976).The present study applied a broadcast application of glyphosate and glufosinate (1260 g ae ha^{-1} and 656 g ai ha^{-1}, respectively) immediately following the herbicide-coated fertilizer treatments. These results highlight the tolerance of cotton to these herbicides when coated onto fertilizer, even when subjected to various tank-mix combinations applied immediately after treatments.

When pyroxasulfone was coated onto fertilizer, only 3 to 5% injury to cotton occurred (Table 2). The injury appeared transient and did not translate into yield reduction compared to the nontreated check (Table 3). In contrast, when pyroxasulfone was applied POST in other research and mixed with glyphosate at 1680 g ae ha^{-1}, as much as 23% cotton injury to occurred; however, there was no yield reduction in this case (Webb et al. 2019). Injury to cotton caused by *S*-metolachlor coated onto dry bulk fertilizer followed by a broadcast application of glyphosate and glufosinate did not exceed 3% either year (Table 2). In other research, when *S*-metolachlor at 1060 g ha^{-1} was applied as a spray to 2-leaf WideStrike® Flex cotton and mixed with glyphosate at 860 g ae ha^{-1} and glufosinate at 590 g ha^{-1}, the crop was injured 33%, resulting in reduced lint yield. However, it is important to emphasize that WideStrike® Flex cotton is more sensitive to glufosinate compared to other commercially available varieties (Steckel et al. 2012). Similarly, *S*-metolachlor at 1100 g ha^{-1} applied at 3- to 6-leaf cotton with glyphosate at 1100 g ha^{-1} and glufosinate at 600 g ha^{-1} caused up to 24% injury to cotton (Samples et al. 2021). Contrastingly, when *S*-metolachlor was sprayed alone to 4-leaf cotton at 1,070 g ai ha^{-1} crop injury ranged from

https://doi.org/10.1017/wet.2024.106 Published online by Cambridge University Press

2-6% (Stephenson et al. 2013). While direct comparisons were not made between *S*-metolachlor applied on fertilizer versus spray application, both with glyphosate and glufosinate spray applied, it is likely that reduction in solvent load in the spray mix, with the exclusion of *S*-metolachlor as a spray, may safen cotton over a mixture of the three herbicides applied as a spray. However, additional research would be needed to test this hypothesis. The increased tolerance of cotton to this application, among others, may have been due to decreased contact of the herbicide on the cotton leaves when utilizing the herbicide-coated fertilizers.

The size of herbicide-coated granular urea and muriate of potash prills are usually 2.2 and 2.3 mm in diameter, respectively (Fulton and Port 2016)**.** The crop might have displayed little injury in response to the tested herbicides due to the increased size of the herbicide carrier, the fertilizer. The phytotoxicity of a herbicide, especially one that causes rapid necrosis, can be greatly influenced by droplet size, density, and coverage (Prasad and Cadogan 1992; McKinlay et al. 1972). It is generally accepted that smaller droplets provide better herbicide coverage on the plant surface as there is an 8-fold increase in the number of droplets as the radius of a spray droplet is reduced by 50% (Prasad and Cadogan 1992; McKinlay et al. 1972). Herbicides applied in small droplets are generally more phytotoxic than large droplets due to greater coverage, uptake, and translocation (Prasad and Cadogan 1992). The large prills with the herbicide would most likely provide less coverage compared to recommended nozzles for spray applications, which usually range from approximately very fine (50 microns) to ultra-coarse (622 microns) (Anonymous 2024b). This decrease in coverage leads to decreased contact of the herbicide with the crop leaves compared to a spray application, for much of the fertilizer prills will land on or drop to the ground. Furthermore, while some fertilizer prills might sit on the top of leaves for some time due to dew or where they landed during application and may cause some injury to the plants. Although this study did not directly compare broadcast versus coated fertilizer applications, the total damage to cotton is smaller when herbicides are coated according to previous literature with spray applications (Doherty et al. 2020, Samples et al. 2021, Webb et al. 2019. Further studies evaluating spray versus coated applications are needed to properly evaluate the crop response.

These findings indicate that a diverse range of herbicides, encompassing those registered for PP, PRE, and POST-directed/layby use in cotton, alongside herbicides not labeled for cotton,

https://doi.org/10.1017/wet.2024.106 Published online by Cambridge University Press

can be safely employed in cotton production if coated onto fertilizer without causing yield reductions. Specifically, when these herbicides are coated onto a bulk blend of urea and muriate of potash and applied over 6- to 8-leaf cotton with dry leaves. Crop injury, assessed throughout 2022 and 2023, remained within an acceptable level of crop safety. Furthermore, most injury was transient and did not result in a decrease in seed cotton yield.

Groundcover. Aerial imagery data collected 14 d after treatment shows that the cotton groundcover or canopy development was not affected by any herbicide-coated fertilizer treatments in either 2022 or 2023 (Table 3). Thus, injury at the 7 and 28 DAT evaluation dates did not translate into a reduction in the canopy cover of the cotton plants. Even the herbicide treatments that resulted in higher levels of injury (11 to 30%) did not impact the groundcover and canopy size of the cotton. Since this study focused on injury to cotton and a full-season weed control program was employed, the effect of weed presence on groundcover did not influence the results. In such cases, the level of weed control provided by the herbicide-coated fertilizer treatments could affect the groundcover results. These findings provide evidence that herbicide-coated fertilizers do not affect the cotton canopy to the extent of a visible reduction.

Practical Implications

While herbicide-coated fertilizers have been approved in cropping systems such as rice, few herbicides have been registered in cotton for use to coat fertilizers. The experiments demonstrate that, when coated on fertilizer, several herbicides will injure cotton no more than 10%. Due to low crop injury, certain herbicides from this study should be considered for future research and possible registration for over-the-top postemergence use when coated onto dry-bulk fertilizers. Furthermore, the herbicide-coated fertilizer technique may lower the risk of injury to cotton with herbicides already labeled in cotton, such as *S*-metolachlor when applied prior to a tank mix of glyphosate and glufosinate. It is important that the level of weed control provided by treatments reduces interference with the crop, for weed control and risk of injury are together important limitations. Efforts to quantify the extent of safening of over-the-top application of herbicides coated on fertilizer versus spray applied may further point to the degree of safening associated with this application technique. Additionally, further research into the effect of prill size may assist in quantifying the safety of these applications.

Funding

This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Competing Interests

Competing interests: The author(s) declare none.

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Tables and Figures

Table 1. Herbicide information and rates used in this experiment.

Common name	Product name	Rate	Group number	Manufacturer	Address
		g ai ha^{-1}			
Diuron	Direx®	840	5	Adama	Raleigh, NC
Florpyrauxifen-benzyl	Loyant®	29	4	Corteva Agriscience LLC	Indianapolis, IN
Flumioxazin	Valor®	105	14	Valent USA Corp.	Walnut Creek, CA
Flumioxazin + pyroxasulfone	Fierce EZ®	35 + 45	14 & 15	Valent USA Corp.	Walnut Creek, CA
Fluometuron	Cotoran®	840	5	Syngenta Crop Protection LLC	Greensboro, NC
Fluridone	Brake®	168	12	SePRO Corp.	Carmel, IN
Fomesafen	Reflex®	280	14	Syngenta Crop Protection LLC	Greensboro, NC
Pyroxasulfone	Zidua SC®	128	15	BASF Corp.	Research Triangle Park, NC
Saflufenacil	Sharpen®	66	14	BASF Corp.	Research Triangle Park, NC
Saflufenacil + dimethenamid-P	Verdict®	25 + 219	14 & 15	BASF Corp.	Research Triangle Park, NC
S-metolachlor	Dual Magnum®	1388	15	Syngenta Crop Protection LLC	Greensboro, NC

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Table 2. Cotton injury in response to herbicide-coated fertilizers applied at the 6- to 8-leaf stage of cotton in Fayetteville, AR, in 2022 and 2023.

		Injury					
		7 DAT[a]				28 DAT	
Herbicide	Rate	2022		2023		2022	2023
	g ai ha^{-1}	----------------------- % -------------------------					
Diuron	840	5	cd[b]	4	bcd	3	0
Florpyrauxifen-benzyl	29	17	b	21	a	3	3
Flumioxazin	105	18	b	11	ab	1	2
Flumioxazin + pyroxasulfone	35 + 45	30	a	6	bcd	3	3
Fluometuron	840	1	d	2	d	0	0
Fluridone	168	8	c	4	bcd	3	0
Fomesafen	280	21	ab	11	abc	3	2
Pyroxasulfone	128	3	cd	5	bcd	0	2
Saflufenacil	65	25	ab	5	bcd	6	1
Saflufenacil + dimethenamid-P	25 + 219	20	ab	4	bcd	0	1
Saflufenacil + pyroxasulfone	44 + 90	25	ab	9	bcd	4	1
S-metolachlor	1388	1	d	3	cd	1	1
P-value[c]		<0.0001		<0.0001		0.3313	0.2314

[a] Abbreviations: DAT, d after treatment

[b] Means within a column for each year not containing the same letter are significantly different according to Tukey's HSD (α=0.05)

[c] *P*-values were generated using the GLIMMIX procedure in SAS 9.4 with a beta distribution

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Table 3. Seed cotton yield in response to herbicide-coated fertilizer treatment in Fayetteville, AR, in 2022 and 2023.

Herbicide	Rate	Seed cotton yield		Groundcover 14 DAT	
		2022	2023	2022	2023
				--------------- % -------------	
	g ai ha^{-1}	---------- kg ha^{-1} -----------		--	
Nontreated	---	3240	2580	100	100
Diuron	840	3020	2900	97	97
Florpyrauxifen-benzyl	29	3060	2560	102	93
Flumioxazin	105	4250	2580	101	93
Flumioxazin + pyroxasulfone	35 + 45	3810	2570	100	102
Fluometuron	840	3270	2870	102	109
Fluridone	168	2410	2360	105	94
Fomesafen	280	3480	2130	100	101
Pyroxasulfone	128	3440	2590	95	105
Saflufenacil	65	2710	2880	99	103
Saflufenacil + dimethenamid-P	25 + 219	3060	2610	101	96
Saflufenacil + pyroxasulfone	44 + 90	3540	2220	101	97
S-metolachlor	1388	3780	2860	98	111
P-value[a]		0.1922	0.5197	0.6920	0.3321

[a] *P*-values were generated using the GLIMMIX procedure in SAS 9.4 with a normal distribution

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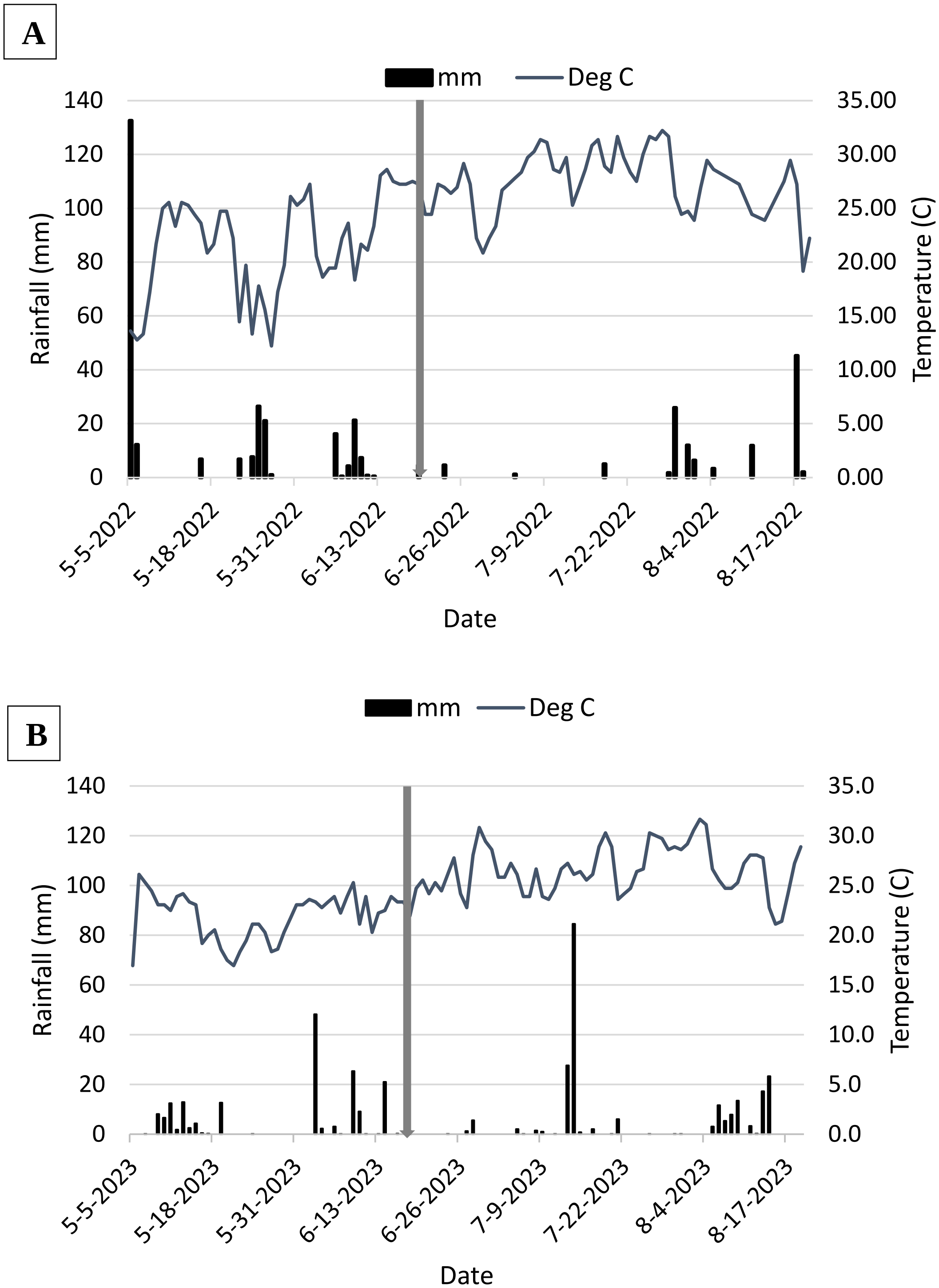

Figure 1. Rainfall and temperature data over the growing season at the Milo J. Shult Agricultural Research and Extension Center in Fayetteville, AR, in (A) 2022 and (B) 2023. The gray vertical arrows represent herbicide-coated fertilizer application. For weeks when rainfall was insufficient, supplemental irrigation was provided via overhead or furrow irrigation.

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Figure 2. Necrosis and spotting on cotton leaves (7 d after treatment) caused by flumioxazin plus pyroxasulfone coated muriate of potash and urea. Close-up picture is on left (A) and plot picture is on the right (B).

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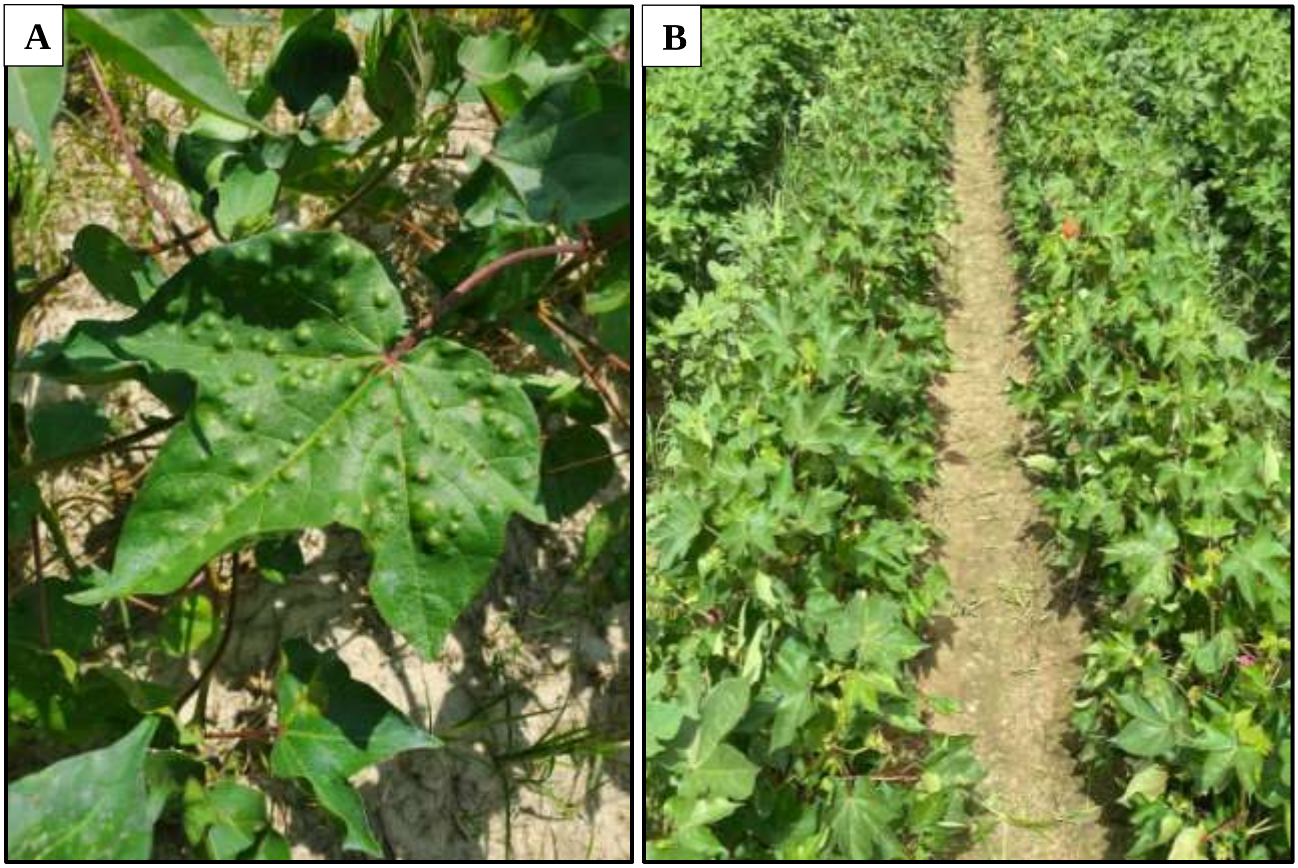

Figure 3. Projections on cotton leaves (7 d after treatment) caused by florpyrauxifen-benzyl coated urea and muriate of potash. An individual leaf is on left (A) and plot picture is on the right (B).

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