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Axant™ Flex cotton response to topramezone applied early- or mid-postemergence

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Abstract

The continued development of herbicide-resistant weeds, such as Palmer amaranth, represents a growing concern across the United States Cotton Belt. To mitigate this issue, BASF Corp. developed Axant™ Flex cotton, the first quadruple-stacked herbicide resistance germplasm to improve the control of troublesome weed species in cotton. Field studies were conducted in 2022 and 2023 at the Texas Tech University Research Farm near New Deal, TX, to evaluate the response of Axant Flex cotton to topramezone applied alone or in combinations when applied to three-leaf cotton (early-postemergence or EPOST) or to seven-leaf cotton (mid-postemergence or MPOST). No difference in cotton stand was observed between isoxaflutole or prometryn preemergence treatments compared to the nontreated control. In 2022, no EPOST treatment caused greater than 6% crop response at 7 and 14 d after application (DAA). When treatments were made to seven-leaf cotton, crop response did not exceed 18% at 7 and 14 DAA. In 2023, crop response was ≤2% at 28 DAA regardless of application timing. No differences in lint yield were observed following any herbicide treatment when compared to the nontreated control in either year. Additionally, fiber length and strength were not adversely affected by treatments containing topramezone EPOST or MPOST in 2022 and 2023. These results support the potential use of topramezone in Axant Flex cotton to help manage troublesome weeds without detrimental effects on yield and fiber quality.

Introduction

Cotton is the most commonly grown textile crop in the United States (USDA-ERS 2022). Among the 17 states where cotton is grown, Texas produces the largest quantity and accounts for 56% of the country's total cotton hectarage (USDA-NASS 2024). In Texas, 1,172,000 (37%) of the state's cotton hectares in 2022 were planted in the Southern High Plains, which is considered the largest contiguous production region in the world (USDA-NASS 2022; Vyavhare et al. 2018).

Weed pressure can have a significant impact on cotton growth and development (Oerke 2006). Weed species such as Palmer amaranth are found across most cotton-producing regions in the United States and can reduce yield by 65% if poorly managed (MacRae et al. 2013). A recent survey conducted by the Weed Science Society of America listed Palmer amaranth as the most common and troublesome weed to control in cotton. Other species identified from this survey include morningglory species (*Ipomoea* spp.), goosegrass [*Eleusine indica* (L.) Gaern.], barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.], prickly sida (*Sida spinosa* L.), and large crabgrass (*Digitaria sanguinalis* L.) (Van Wychen 2022).

Palmer amaranth has developed resistance to 33 herbicide active ingredients within 10 herbicide mode-of-action groups in the United States (Heap 2024). In Texas, atrazine- (1993) and glyphosate- (2011) resistant Palmer amaranth have been confirmed (Heap 2024). Research is needed on new active ingredients and modes of action that can effectively control glyphosate-resistant Palmer amaranth and other difficult-to-control weed species in cotton.

Axant™ Flex herbicide tolerance technology, developed by BASF Corp., is the first quadruple-stacked herbicide trait technology in cotton. Cotton varieties containing the Axant Flex technology have traits that confer resistance to the herbicides glyphosate, glufosinate, dicamba, and isoxaflutole (Anonymous 2023), with isoxaflutole being the most recent herbicide-resistant trait in cotton. Isoxaflutole is a Herbicide Resistance Action Committee

(HRAC) Group 27 herbicide that provides soil-residual control of selective broadleaf and grassy weeds, including glyphosate-resistant Palmer amaranth (Anonymous 2020).

Group 27 herbicides are inhibitors of 4-hydroxyphenylpyruvate dioxygenase (HPPD), one of several enzymes required for the biosynthesis of carotenoids (Ndikuryayo et al. 2017). Susceptible plants treated with HPPD inhibitors undergo a reduction in plastoquinone enzymes, which interrupts the production of new carotenoids and disrupts the photosynthetic system. The lack of new carotenoid turnover in the chloroplast leads to insufficient chlorophyll production, causing newly emerged foliage to appear whitened or bleached (Dayan et al. 2007).

Four Axant Flex cotton cultivars (FM765AX, FM823AXTP, FM868AXTP, and ST6000AXTP) were commercially released prior to the 2024 growing season. BASF's isoxaflutole herbicide product, Alite™ 27 (EPA Reg. No.7969-433), is currently pending the United States Environmental Protection Agency's (EPA) approval for use on HPPD-resistant cotton (Anonymous 2023). Once approved, producers will have an additional mode of action and active ingredient to manage troublesome weed species preemergence in cotton.

The Axant Flex trait technology creates an opportunity to explore the potential tolerance to other HPPD-inhibiting herbicide active ingredients such as topramezone. Topramezone, the active ingredient in Armezon® (EPA Reg. No. 7969-262), is labeled for postemergence control of broadleaf and grassy weeds in field and specialty corn (*Zea mays* L.) and sugarcane (*Saccharum officinarum* L.) (Anonymous 2022). Topramezone has the ability to control emerged weeds and would add an additional mode of action to control escaped weed species after cotton emergence.

There are no published studies examining Axant Flex cotton tolerance to HPPD-inhibiting herbicides beyond isoxaflutole. The objectives of these studies were to assess the response of Axant Flex cotton to solo and mixtures that include topramezone applied postemergence at two growth stages and determine whether the addition of isoxaflutole applied preemergence increases cotton response to topramezone when applied postemergence alone or combinations with glyphosate, glufosinate, or dicamba.

Materials and Methods

Field studies were conducted in 2022 and 2023 at the Texas Tech University Research Farm near New Deal, TX (33.73045°N, 101.73498°W). The soil type was a Pullman clay loam (19% sand, 42% silt, and 39% clay) with an organic matter content of 0.96% and a pH of 8.1 (USDA-NRCS 2024). An experimental cotton breeding line with the Axant Flex herbicide trait technology, BX2350 (BASF, Research Triangle, NC), was planted on May 19, 2022 and May 23, 2023 using a John Deere MaxEmerge planter at a rate of 145,300 seeds ha^{-1}. The field site was equipped with a subsurface drip irrigation system. Plots were four 101.6-cm rows by 9 m in length. Treatments were arranged in a randomized complete block design with three replications.

Trifluralin (Trifluralin 4EC, Drexel) at 0.84 kg ai ha^{-1} was applied preplant and incorporated twice with a rolling cultivator at a 5-cm soil depth on April 21, 2022 and April 25, 2023. A broadcast burndown application of glyphosate (Roundup PowerMax®3, Bayer) at 1.35 kg ae ha^{-1} plus ammonium sulfate at 2.52 kg ha^{-1} was used on May 23, 2023 to control emerged weeds at-plant. Treatments in Study 1 included a nontreated weed-free control, isoxaflutole (Alite™ 27, BASF) at 0.105 kg ai ha^{-1} or prometryn (Caparol® 4L, Syngenta) at 1.33 kg ai ha^{-1} applied preemergence followed by (fb) topramezone (Armezon®, BASF) at 0.025 kg ai ha^{-1} applied alone or in combinations with isoxaflutole at 0.105 kg ai ha^{-1}, glufosinate (Liberty® 280 SL, BASF) at 0.88 kg ai ha^{-1}, glyphosate at 1.35 kg ae ha^{-1}, and/or dicamba (Engenia®, BASF) at 0.56 kg ae ha^{-1} applied to cotton at the three-leaf (early-postemergence, EPOST) growth stage (Table 1). Treatments in Study 2 included the same herbicide combinations and rates but were applied to cotton at the seven-leaf (mid-postemergence, MPOST) growth stage. Ammonium sulfate at 2.52 kg ha^{-1} was added to all postemergence applications except those with dicamba, crop oil concentrate at 1% v/v was added to applications of isoxaflutole applied alone or in a mixture postemergence and topramezone applied alone postemergence, and potassium carbonate at 0.407 kg ha^{-1} was added to treatments containing dicamba postemergence.

Herbicide treatments were applied using a CO_2-pressurized backpack sprayer with a four-nozzle boom calibrated to deliver 140 L ha^{-1} at 179 to 214 kPa at 4.8 kph. Turbo TeeJet (TT) 11002 nozzles (TeeJet® Technologies, Spring field, IL) were used for all preemergence and postemergence applications, and Turbo TeeJet Induction (TTI) 11002 and 110015 nozzles were used for postemergence treatments containing dicamba. Preemergence treatments were applied at planting on May 19, 2022 and May 23, 2023. Within 5 d of the application, 65 mm and 83 mm of rainfall was recorded in 2022 and 2023, respectively, to activate preemergence treatments.

Cotton density was determined by recording the number of emerged seedlings from 2 m of the center two rows in each plot at 12 d after planting and prior to postemergence applications. Cotton canopy height was recorded from four representative plants from the center two rows 14 d after postemergence applications and prior to harvest. Visible cotton response (a composite of stunting, chlorosis, and necrosis) was evaluated 14 d after the preemergence application, and 7, 14, and 28 d after each postemergence application using a scale from 0 to 100%, with 0 being no response and 100% being complete cotton death (Frans et al. 1986).

Plots were kept weed-free for the duration of the season by cultivation and hand-hoeing. A harvest aid mix of ethephon + cyclanilide at 1.68 + 0.105 kg ai ha^{-1}, thidiazuron + diuron at 0.11 + 0.05 kg ai ha^{-1}, and 0.25% non-ionic surfactant was applied at 60% boll opening on October 13, 2022 and October 11, 2023. Paraquat at 0.56 kg ai ha^{-1} plus 0.25% non-ionic surfactant was applied as a desiccant on October 27, 2022 and October 20, 2023 to prepare the cotton for harvest.

Plants from the center two rows in each plot were harvested and weighed with a John Deere cotton stripper modified with a mounted scale to calculate harvested seed cotton yield. Seed cotton samples were collected from each plot and ginned at the BASF Agricultural Solutions Breeding and Trait Development Station in Lubbock, TX and at the Texas A&M AgriLife Research and Extension Center in Lubbock, TX in 2022 and 2023, respectively. Lint yield was determined by multiplying the harvested seed cotton weight of a sample by its respective lint turnout. Fiber samples were analyzed for micronaire, length, strength, uniformity, and elongation using high- volume instrument (HVI) testing at BASF's internal lab in Leland, MS in 2022 and at the Texas Tech Fiber and Biopolymer Institute in Lubbock, TX in 2023.

Within each study, statistical analysis was conducted using the Generalized Linear Mixed Model (GLIMMIX) procedure in SAS® 9.4 (SAS Institute, Cary, NC, USA). The combination of herbicide treatment, rate, and application timing were treated as a fixed

Table 1. Preemergence and postemergence herbicides used for early-postemergence (EPOST) and mid-postemergence (MPOST) studies.

Common name	Product name	Formulation concentration	Manufacturer	Address
		g ai or ae L^{-1}		
Dicamba	Engenia®	600	BASF Corp.	BASF Corp., 26 Davis Drive, Research Triangle Park, NC 27709
Glufosinate	Liberty® 280 SL	280	BASF Corp.	BASF Corp., 26 Davis Drive Research Triangle Park, NC 27709
Glyphosate	Roundup PowerMax® 3	575	Bayer CropScience	Bayer CropScience LP 800 N. Lindbergh Blvd. St. Louis, MO 63167
Isoxaflutole	Alite™ 27	479	BASF Corp.	BASF Corp., 26 Davis Drive Research Triangle Park, NC 27709
Prometryn	Caparol® 4L	479	Syngenta Crop Protection	Syngenta Crop Protection, LLC, P.O. Box 18300 Greensboro, NC 27419-8300
Topramezone	Armezon®	336	BASF Corp.	BASF Corp., 26 Davis Drive Research Triangle Park, NC 27709

effect, and replication was treated as a random effect based on the recommendation of Littell et al. (2006). Year was treated as a random effect due to the limited number of sampling years, and year-by-treatment interactions were tested to determine whether to pool information by year. For all parameters, treatment means were separated using Fisher's Protected LSD at $\alpha = 0.05$.

Results and Discussion

Cotton Density

There was no significant interaction between year and treatment for the cotton density parameter. As a result, cotton density data from Study 1 (EPOST) and Study 2 (MPOST) were pooled across years. Cotton density was averaged across 2022 and 2023 for each respective study. Cotton density in either Study 1 (88,583 to 100,886 plants ha$^{-1)}$ or in Study 2 (101,312 to 107,119 plants ha^{-1}) did not differ from the nontreated control (data not shown).

Visible Cotton Response

There was no significant interaction between year and treatment for the visible cotton response to preemergence treatments, so the data were pooled across years. There was a significant interaction between year and treatment for the visible cotton response to postemergence treatments, so the data were analyzed separately by year.

In 2022 and 2023, cotton response to prometryn or isoxaflutole preemergence treatments did not differ from the nontreated control 14 d after planting (data not shown). In 2022, cotton response 7 d after EPOST applications was ≤1% with the exception of prometryn preemergence fb isoxaflutole EPOST (3%) (Table 2). At 7 d after the EPOST application in 2023, cotton response was greatest following isoxaflutole preemergence fb topramezone + glyphosate EPOST (13%). The greatest cotton response to an EPOST application in 2022 was observed with prometryn preemergence fb topramezone + glyphosate EPOST (6%). Similar results were observed by Schultz et al. (2015) who reported 6% to 16% visible injury 7 d after topramezone at 0.02 kg ai ha^{-1} was applied EPOST to HPPD-resistant soybean.

The addition of dicamba to topramezone + glyphosate EPOST decreased cotton response by 5% when compared to topramezone + glyphosate alone in 2022. Similarly in 2023, cotton response 14 d after isoxaflutole preemergence fb topramezone + glyphosate + dicamba (1%) EPOST was reduced when compared to isoxaflutole preemergence fb topramezone + glyphosate (9%).

Cotton response was not adversely influenced by treatments containing isoxaflutole preemergence fb topramezone alone or in mixture applied EPOST in 2022. Conversely in 2023, treatments containing isoxaflutole preemergence fb isoxaflutole + topramezone or topramezone + glyphosate EPOST caused greater cotton response at each postemergence evaluation compared to prometryn applied preemergence. By 28 d after the EPOST application in 2022 and 2023, cotton response was ≤1% across all treatments (Table 2). A study conducted by Soltani et al. (2007) also reported transient bleaching of topramezone when applied to early growth stages of sweet corn.

In Study 2, cotton response to prometryn or isoxaflutole preemergence were similar to the nontreated control 14 d after planting (data not shown). In 2022, 7 d after the MPOST application, prometryn or isoxaflutole preemergence fb topramezone + glufosinate MPOST and isoxaflutole preemergence fb topramezone + glyphosate MPOST caused the greatest crop response (18%) (Table 3).

Cotton response in 2023 ranged from 2% to 13% and 1% to 7% at 7 and 14 d after the MPOST application, respectively (Table 3). Treatments containing isoxaflutole preemergence did not increase cotton response to MPOST applications above that observed for topramezone alone or in a mixture in both study years, with the exception of isoxaflutole preemergence fb isoxaflutole + topramezone MPOST in 2023. The addition of dicamba to MPOST applications of topramezone + glyphosate reduced cotton response 7 DAA from 18% to 3% in 2022 and from 10% to 0% in 2023 compared to topramezone + glyphosate applied alone. By 28 d after the MPOST application, cotton response across treatments was ≤5% in 2022 and ≤2% in 2023.

Cotton Height

Similar to visible cotton response to postemergence treatments, there was a significant interaction between year and treatment for cotton height, so the data were analyzed separately by year. Early-season cotton heights recorded 14 d after EPOST treatments ranged from 19 to 23 cm in 2022 and 2023 (Table 4). Early-season cotton heights were not adversely affected by EPOST treatments in either year compared to the nontreated.

When recorded prior to harvest, of the EPOST treatments containing topramezone in 2022, a 4- to 8-cm reduction in cotton height was observed from isoxaflutole preemergence followed by EPOST applications of topramezone, topramezone + isoxaflutole, topramezone + glyphosate, topramezone + glyphosate + dicamba, and prometryn preemergence fb topramezone + glufosinate, and topramezone + glyphosate + dicamba EPOST when compared to the nontreated control (Table 4). Although cotton height near harvest in 2023 differed between herbicide treatments, no treatments caused a reduction in height relative to the nontreated control.

In 2022, isoxaflutole preemergence fb topramezone + glyphosate + dicamba MPOST reduced early-season cotton

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Table 2. Visible cotton response 7, 14, and 28 d after early-postemergence application (EPOST) treatments (DAA), in 2022 and 2023.[a]

Treatment	Herbicide[b]	Rate	Application timing[a]	Cotton response[a,c,d] 2022 7 DAA	2022 14 DAA	2022 28 DAA	2023 7 DAA	2023 14 DAA	2023 28 DAA
		kg ai or ae ha^{-1}		——%					
1	Nontreated control	—	—	0.0 b	0.0 d	0.0	0.0 h	0.0 e	0.0 b
2	Prometryn	1.33	PRE	0.0 b	0.0 d	0.0	0.7 gh	0.0 e	0.0 b
3	Isoxaflutole	0.105	PRE	0.0 b	0.0 d	0.0	1.7 fgh	0.0 e	0.0 b
4	Prometryn	1.33	PRE	3.3 a	1.7 cd	0.0	0.0 h	1.3 de	0.0 b
	Isoxaflutole + COC + AMS	0.105	EPOST						
5	Isoxaflutole	0.105	PRE	0.0 b	0.7 d	0.0	1.7 fgh	1.3 de	0.0 b
	Isoxaflutole + COC + AMS	0.105	EPOST						
6	Prometryn	1.33	PRE	0.0 b	0.0 d	0.0	2.3 e–h	1.3 de	0.0 b
	Topramezone + COC + AMS	0.0246	EPOST						
7	Isoxaflutole	0.105	PRE	0.0 b	0.0 d	0.0	2.7 e–h	2.7 cde	0.0 b
	Topramezone + COC + AMS	0.0246	EPOST						
8	Prometryn	1.33	PRE	0.0 b	2.3 bcd	0.0	4.3 c–h	3.7 cd	0.0 b
	Isoxaflutole + topramezone + COC + AMS	0.105	EPOST						
9	Isoxaflutole	0.105	PRE	0.0 b	4.7 abc	0.7	9.3 ab	7.7 ab	1.3 a
	Isoxaflutole + topramezone + COC + AMS	0.105 + 0.0246	EPOST						
10	Prometryn	1.33	PRE	0.7 b	1.7 cd	0.0	2.0 fgh	0.0 e	0.0 b
	Glufosinate + AMS	0.88	EPOST						
11	Isoxaflutole	0.105	PRE	0.0 b	0.7 d	0.0	3.3 d–h	0.3 e	0.0 b
	Glufosinate + AMS	0.88	EPOST						
12	Prometryn	1.33	PRE	0.0 b	0.0 d	0.0	6.0 b–f	1.7 de	0.0 b
	Topramezone + glufosinate + AMS	0.0246 + 0.88	EPOST						
13	Isoxaflutole	0.105	PRE	0.0 b	2.3 bcd	0.0	8.3 abc	2.7 cde	0.0 b
	Topramezone + glufosinate + AMS	0.0246 + 0.88	EPOST						
14	Prometryn	1.33	PRE	0.7 b	0.0 d	0.0	0.0 h	0.0 e	0.0 b
	Glyphosate + AMS	1.35	EPOST						
15	Isoxaflutole	0.105	PRE	0.7 b	0.7 d	0.0	0.0 h	0.3 e	0.0 b
	Glyphosate + AMS	1.35	EPOST						
16	Prometryn	1.33	PRE	0.7 b	5.7 a	0.0	9.0 ab	5.3 bc	0.0 b
	Topramezone + glyphosate + AMS	0.0246 + 1.35	EPOST						
17	Isoxaflutole	0.105	PRE	1.3 b	5.0 ab	0.0	12.7 a	8.7 a	1.3 a
	Topramezone + glyphosate + AMS	0.0246 + 1.35	EPOST						
18	Prometryn	1.33	PRE	0.0 b	1.3 d	0.0	7.7 bcd	1.0 de	0.0 b
	Glyphosate + dicamba + VRA	1.35 + 0.56	EPOST						
19	Isoxaflutole	0.105	PRE	0.0 b	0.7 d	0.0	6.0 b–f	0.0 e	0.0 b
	Glyphosate + dicamba + VRA	1.35 + 0.56	EPOST						
20	Prometryn	1.33	PRE	0.7 b	1.7 cd	0.7	5.0 b–g	1.0 e	0.0 b
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	EPOST						
21	Isoxaflutole	0.105	PRE	0.0 b	0.0 d	0.0	7.0 b–e	1.0 de	0.0 b
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	EPOST						

[a]Abbreviations: AMS, ammonium sulfate; COC, crop coil concentrate; PRE, preemergence; VRA, volatility-reduction adjuvant (potassium carbonate).
[b]Crop oil concentrate (1% v/v), ammonium sulfate (2.52 kg ha^{-1}), and a volatility-reduction adjuvant (0.407 kg ha^{-1}) were added based on product label recommendations.
[c]Means followed by a common letter or no letter within the same column are not significantly different at the 0.05 level of significance.
[d]Rating scale: 0 being no response and 100% being complete cotton death. Cotton response is a composite of stunt, chlorosis, and necrosis.

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Table 3. Visible cotton response 7, 14, and 28 d after mid-postemergence (MPOST) treatments (DAA) in 2022 and 2023.[a]

Treatment	Herbicide[b]	Rate	Application timing[a]	Cotton response[a,c,d] 2022 7 DAA	2022 14 DAA	2022 28 DAA	2023 7 DAA	2023 14 DAA	2023 28 DAA
		kg ai or ae ha^{-1}		----------------%	----------------				
1	Nontreated control	—	—	0.0 g	0.0 f	0.0 f	0.0 g	0.0 f	0.0 e
2	Prometryn	1.33	PRE	0.7 fg	0.0 f	0.0 f	0.0 g	0.0 f	0.0 e
3	Isoxaflutole	0.105	PRE	0.0 g	0.0 f	0.0 f	0.0 g	0.0 f	0.0 e
4	Prometryn	1.33	PRE	1.7 efg	4.0 d	1.0 ef	2.3 efg	1.3 def	0.3 de
	Isoxaflutole + COC + AMS	0.105	MPOST						
5	Isoxaflutole	0.105	PRE	0.7 fg	2.3 def	1.0 ef	1.7 fg	0.7 ef	0.7 cd
	Isoxaflutole + COC + AMS	0.105	MPOST						
6	Prometryn	1.33	PRE	2.3 efg	4.0 d	0.7 ef	3.7 ef	1.3 def	0.7 cd
	Topramezone + COC + AMS	0.0246	MPOST						
7	Isoxaflutole	0.105	PRE	4.0 def	3.0 de	1.3 de	5.0 de	2.3 cd	1.0 bc
	Topramezone + COC + AMS	0.0246	MPOST						
8	Prometryn	1.33	PRE	16.7 ab	13.0 c	3.3 bc	9.3 bc	7.0 a	2.0 a
	Isoxaflutole + topramezone + COC + AMS	0.105	MPOST						
9	Isoxaflutole	0.105	PRE	13.3 b	13.0 c	4.3 ab	12.7 a	7.0 a	2.3 a
	Isoxaflutole + topramezone + COC + AMS	0.105 + 0.0246	MPOST						
10	Prometryn	1.33	PRE	8.3 c	1.3 ef	0.0 f	0.0 g	0.0 f	0.0 e
	Glufosinate + AMS	0.88	MPOST						
11	Isoxaflutole	0.105	PRE	6.7 cd	0.7 ef	0.0 f	0.0 g	0.0 f	0.0 e
	Glufosinate + AMS	0.88	MPOST						
12	Prometryn	1.33	PRE	18.3 a	14.0 bc	2.3 cd	11.0 ab	4.0 b	1.0 bc
	Topramezone + glufosinate + AMS	0.0246 + 0.88	MPOST						
13	Isoxaflutole	0.105	PRE	18.3 a	12.3 c	2.3 cd	12.0 ab	3.7 bc	1.3 b
	Topramezone + glufosinate + AMS	0.0246 + 0.88	MPOST						
14	Prometryn	1.33	PRE	0.0 g	0.0 f	0.0 f	0.0 g	0.0 f	0.0 e
	Glyphosate + AMS	1.35	MPOST						
15	Isoxaflutole	0.105	PRE	1.3 efg	0.0 f	0.0 f	0.0 g	0.0 f	0.3 de
	Glyphosate + AMS	1.35	MPOST						
16	Prometryn	1.33	PRE	16.7 ab	16.0 ab	5.0 a	7.3 cd	2.7 bcd	1.0 bc
	Topramezone + glyphosate + AMS	0.0246 + 1.35	MPOST						
17	Isoxaflutole	0.105	PRE	18.3 a	17.0 a	4.3 ab	10.0 abc	2.0 ed	1.0 bc
	Topramezone + glyphosate + AMS	0.0246 + 1.35	MPOST						
18	Prometryn	1.33	PRE	4.0 efg	0.0 f	0.0 f	0.0 g	0.0 f	0.0 e
	Glyphosate + dicamba + VRA	1.35 + 0.56	MPOST						
19	Isoxaflutole	0.105	PRE	5.0 cde	0.7 ef	0.0 f	0.0 g	0.0 f	0.0 e
	Glyphosate + dicamba + VRA	1.35 + 0.56	MPOST						
20	Prometryn	1.33	PRE	6.7 cd	2.0 def	0.3 ef	0.3 g	0.0 f	0.3 de
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	MPOST						
21	Isoxaflutole	0.105	PRE	3.0 d–g	0.7 ef	0.0 f	0.3 g	0.0 f	0.0 e
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	MPOST						

[a]Abbreviations: AMS, ammonium sulfate; COC, crop coil concentrate; PRE, preemergence; VRA, volatility-reduction adjuvant (potassium carbonate).
[b]Crop oil concentrate (1% v/v), ammonium sulfate (2.52 kg ha^{-1}), and a volatility-reduction adjuvant (0.407 kg ha^{-1}) were added based on product label recommendations.
[c]Means followed by a common letter or no letter within the same column are not significantly different at the 0.05 level of significance.
[d]Rating scale: 0 being no response and 100% being complete cotton death. Cotton response is a composite of stunt, chlorosis, and necrosis.

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Table 4. Cotton height 14 d after early-postemergence (EPOST) applications and near harvest in 2022 and 2023.[a]

Treatment	Herbicide[b]	Rate	Application timing[a]	Height[c] 14 DAA[a] 2022	Height[c] 14 DAA[a] 2023	Height[c] At-harvest 2022	Height[c] At-harvest 2023
		kg ai or ae ha^{-1}		cm			
1	Nontreated control	—	—	20.3 c-g	20.3 def	68.0 ab	57.2 a-d
2	Prometryn	1.33	PRE	22.9 a	22.4 ab	65.4 b–e	59.5 a
3	Isoxaflutole	0.105	PRE	19.3 g	23.2 a	66.5 a–d	58.8 a
4	Prometryn	1.33	PRE	21.0 a–g	22.7 a	67.3 abc	59.2 a
	Isoxaflutole + COC + AMS	0.105	EPOST				
5	Isoxaflutole	0.105	PRE	21.8 a–e	20.5 c–f	61.2 fgh	55.4 bcd
	Isoxaflutole + COC + AMS	0.105	EPOST				
6	Prometryn	1.33	PRE	21.5 a–f	20.1 ef	65.3 b–e	57.0 a–d
	Topramezone + COC + AMS	0.0246 EPOST					
7	Isoxaflutole	0.105	PRE	22.3 ab	20.4 c–f	61.6 e–h	55.2 bcd
	Topramezone + COC + AMS	0.0246 EPOST					
8	Prometryn	1.33	PRE	20.0 d–g	20.6 c–f	69.3 a	57.5 abc
	Isoxaflutole + topramezone + COC + AMS	0.105	EPOST				
9	Isoxaflutole	0.105	PRE	21.1 a–g	20.9 b–f	63.1 d–h	55.7 bcd
	Isoxaflutole + topramezone + COC + AMS	0.105 + 0.0246	EPOST				
10	Prometryn	1.33	PRE	21.6 a–f	20.5 c–f	64.1 c–g	57.6 ab
	Glufosinate + AMS	0.88	EPOST				
	Glufosinate + AMS	0.88	EPOST				
12	Prometryn	1.33	PRE	21.2 a–g	20.0 ef	63.2 d–h	57.3 a–d
	Topramezone + glufosinate + AMS	0.0246 + 0.88	EPOST				
13	Isoxaflutole	0.105	PRE	19.7 fg	19.3 f	66.4 a–d	57.8 ab
	Topramezone + glufosinate + AMS	0.0246 + 0.88	EPOST				
14	Prometryn	1.33	PRE	22.0 a–d	22.0 abc	65.3 b–e	58.7 a
	Glyphosate + AMS	1.35	EPOST				
15	Isoxaflutole	0.105	PRE	20.0 efg	21.8 a–d	69.5 a	54.6 cd
	Glyphosate + AMS	1.35	EPOST				
16	Prometryn	1.33	PRE	20.9 b–g	22.9 a	64.7 b–f	57.5 abc
	Topramezone + glyphosate + AMS	0.0246 + 1.35	EPOST				
17	Isoxaflutole	0.105	PRE	22.5 ab	21.6 a–e	60.9 gh	54.4 d
	Topramezone + glyphosate + AMS	0.0246 + 1.35	EPOST				
18	Prometryn	1.33	PRE	22.8 ab	20.1 ef	64.3 b–g	57.2 a–d
	Glyphosate + dicamba + VRA	1.35 + 0.56	EPOST				
19	Isoxaflutole	0.105	PRE	22.0 abc	19.7 f	66.7 a–d	58.0 ab
	Glyphosate + dicamba + VRA	1.35 + 0.56	EPOST				
20	Prometryn	1.33	PRE	22.5 ab	22.4 ab	59.6 h	58.9 a
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	EPOST				
21	Isoxaflutole	0.105	PRE	21.5 a–f	19.8 f	60.3 h	57.0 a–d
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	EPOST				

[a]Abbreviations: AMS, ammonium sulfate; COC, crop coil concentrate; DAA, days after early-postemergence application; PRE, preemergence; VRA, volatility-reduction adjuvant (potassium carbonate).
[b]Crop oil concentrate (1% v/v), ammonium sulfate (2.52 kg ha^{-1}), and a volatility-reduction adjuvant (0.407 kg ha^{-1}) were added based on product label recommendations.
[c]Means followed by a common letter or no letter within the same column are not significantly different at the 0.05 level of significance.

Table 5. Cotton height 14 d after mid-postemergence (MPOST) applications and near harvest in 2022 and 2023.[a]

				Height[c]			
				14 DAA[a]		At-harvest	
Treatment	Herbicide[b]	Rate	Application timing[a]	2022	2023	2022	2023
		kg ai or ae ha^{-1}		---cm---			
1	Nontreated control	—	—	34.0 a–f	38.9 abc	68.4 bcd	60.3 bcd
2	Prometryn	1.33	PRE	36.0 a	36.8 b–h	65.9 c–f	59.8 b–e
3	Isoxaflutole	0.105	PRE	34.9 abc	39.5 ab	68.1 b–e	62.1 ab
4	Prometryn	1.33	PRE	35.8 ab	36.3 c–h	65.4 d–g	59.5 b–e
	Isoxaflutole + COC + AMS	0.105	MPOST				
5	Isoxaflutole	0.105	PRE	33.5 c–f	37.0 b–g	65.8 c–f	59.8 b–e
	Isoxaflutole + COC + AMS	0.105	MPOST				
6	Prometryn	1.33	PRE	32.5 fg	37.5 a–g	63.4 fg	58.6 cde
	Topramezone + COC + AMS	0.0246	MPOST				
7	Isoxaflutole	0.105	PRE	34.5 a–e	35.7 e–h	63.2 fg	57.5 def
	Topramezone + COC + AMS	0.0246	MPOST				
8	Prometryn	1.33	PRE	32.3 fg	35.5 e–h	61.8 g	56.9 ef
	Isoxaflutole + topramezone + COC + AMS	0.105	MPOST				
9	Isoxaflutole	0.105	PRE	33.9 b–f	34.0 h	65.9 c–f	54.5 f
	Isoxaflutole + topramezone + COC + AMS	0.105 + 0.0246	MPOST				
10	Prometryn	1.33	PRE	34.5 a–e	38.3 a–e	67.8 b–e	61.1 abc
	Glufosinate + AMS	0.88	MPOST				
11	Isoxaflutole	0.105	PRE	34.1 a–f	34.9 gh	64.7 d–g	60.3 bcd
	Glufosinate + AMS	0.88	MPOST				
12	Prometryn	1.33	PRE	32.8 efg	35.3 fgh	67.5 b–e	59.8 b–e
	Topramezone + glufosinate + AMS	0.0246 + 0.88	MPOST				
13	Isoxaflutole	0.105	PRE	34.0 a–f	36.9 b–g	75.1 a	59.5 b–e
	Topramezone + glufosinate + AMS	0.0246 + 0.88	MPOST				
14	Prometryn	1.33	PRE	35.9 ab	39.9 a	68.5 bcd	64.0 a
	Glyphosate + AMS	1.35	MPOST				
15	Isoxaflutole	0.105	PRE	34.0 b–f	37.7 a–f	64.2 efg	61.1 abc
	Glyphosate + AMS	1.35	MPOST				
16	Prometryn	1.33	PRE	35.3 abc	36.0 d–h	65.0 d–g	60.2 bcd
	Topramezone + glyphosate + AMS	0.0246 + 1.35	MPOST				
17	Isoxaflutole	0.105	PRE	32.8 d–g	37.1 b–g	69.4 bc	59.7 b–e
	Topramezone + glyphosate + AMS	0.0246 + 1.35	MPOST				
18	Prometryn	1.33	PRE	34.8 a–d	38.8 a–d	70.5 b	57.7 de
	Glyphosate + dicamba + VRA	1.35 + 0.56	MPOST				
19	Isoxaflutole	0.105	PRE	35.1 abc	36.2 c–h	65.4 d–g	59.4 b–e
	Glyphosate + dicamba + VRA	1.35 + 0.56	MPOST				
20	Prometryn	1.33	PRE	33.7 c–f	37.1 a–g	67.6 b–e	59.1 b–e
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	MPOST				
21	Isoxaflutole	0.105	PRE	31.1 g	36.3 c–h	67.7 b–e	56.8 ef
	Topramezone + glyphosate + dicamba + VRA	0.0246 + 1.35 + 0.56	MPOST				

[a]Abbreviations: AMS, ammonium sulfate; COC, crop coil concentrate; DAA, d after mid-postemergence application; PRE, preemergence; VRA, volatility-reduction adjuvant (potassium carbonate).
[b]Crop oil concentrate (1% v/v), ammonium sulfate (2.52 kg ha^{-1}), and a volatility-reduction adjuvant (0.407 kg ha^{-1}) were added based on product label recommendations.
[c]Means followed by a common letter or no letter within the same column are not significantly different at the 0.05 level of significance.

height by 3 cm when compared to the nontreated control (Table 5). A reduction in cotton height of 4 to 6 cm near harvest was observed following prometryn preemergence fb topramezone or topramezone + isoxaflutole MPOST, and isoxaflutole preemergence fb topramezone or glyphosate MPOST.

In 2023, cotton height 14 d after the MPOST treatments was reduced by 3 to 5 cm with prometryn preemergence fb topramezone + isoxaflutole, glufosinate, or glyphosate MPOST, and isoxaflutole preemergence fb topramezone applied alone or mixed with isoxaflutole, or glufosinate MPOST when compared to the nontreated control. Cotton height near harvest was reduced by 3 to 5 cm following topramezone + isoxaflutole MPOST regardless of the preemergence, and isoxaflutole preemergence fb topramezone + glyphosate + dicamba MPOST (Table 5).

Lint Yield

Cotton lint yield in 2022 and 2023 was averaged due to a lack of significant treatment-by-year interaction. Lint yield from the EPOST study ranged from 1,463 to 1,613 kg ha^{-1} and were not adversely affected by herbicide treatments relative to the nontreated control (1,463 kg ha^{-1}) (data not shown). Farr et al. (2022), Foster et al. (2022), and Joyner et al. (2022) also reported no decrease in lint yield from EPOST applications of isoxaflutole when used alone or in a mixture with other commonly used cotton herbicides. Despite differences in cotton height near harvest, no MPOST treatment reduced lint yield in relation to the nontreated control (1,675 kg ha^{-1}). Yield from MPOST treatments ranged from 1,523 to 1,788 kg ha^{-1} (data not shown).

High-Volume Instrument Data

High-volume instrument (HVI) measurements consisted of micronaire, length, uniformity, strength, and elongation. Year-by-treatment interactions were not significant for all the HVI measurements. As a result, data from both years were averaged for each HVI measurement within each study. The nontreated control in the EPOST study had a micronaire rating of 4.48, measured 28.10 mm in length, uniformity of 81.78%, strength of 29.217 g tex^{-1}, and 7.65% elongation (data not shown). Fiber HVI measurements were not affected by herbicide applications applied to cotton at a three-leaf growth stage. Similarly, MPOST herbicide applications did not reduce lint quality based on the HVI measurements evaluated (data not shown).

Practical Implications

Visible cotton response to EPOST and MPOST applications of topramezone applied solo or in mixture with isoxaflutole, glufosinate, glyphosate, and glyphosate + dicamba did not exceed 5% 28 d after EPOST and MPOST applications. Although cotton response from MPOST treatments containing topramezone were transient by 4 wk after application, EPOST applications no larger than four-leaf cotton may lessen the risk regarding visible bleaching symptoms. Isoxaflutole and topramezone at the rates evaluated may be used within the same weed management program with minimal cotton response. No treatment containing topramezone EPOST or MPOST negatively impacted fiber quality or lint yield in relation to the nontreated control. During the conductance of the field studies, herbicide rates and application timings with isoxaflutole and topramezone herbicides alone or in combination with other herbicides were investigated for educational purposes. The herbicide rates, application timings, and mixture options investigated in these field studies may or may not be included in the registration of either isoxaflutole or topramezone. Only the EPA-approved product label for isoxaflutole and topramezone herbicides for use on Axant Flex cotton should be addressed for claims regarding product safety and efficacy. These results support the potential use of topramezone postemergence in Axant Flex cotton to manage troublesome weeds, such as glyphosate-resistant Palmer amaranth, with no adverse effects on cotton lint yield and fiber quality.

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