WEED CONTROL AND COTTON VARIETAL SENSITIVITY WITH STAPLE HERBICIDE

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Abstract

Staple is the first true over-the-top herbicide that controls broadleaf weeds without causing excessive cotton injury. Earlier research suggested that Buctril-tolerant cotton cultivars (BXN 57 and 58) may be more sensitive to Staple than other cultivars. Experiments were conducted to compare weed control and cultivar sensitivity with Staple herbicide. The weed control experiment was conducted in 1994 and 1995 on a silt loam soil. The standard herbicide programs included soil- applied herbicides followed by three post-directed applications (3 inch, 10 inch, and layby). The comparison treatments included soil-applied herbicides followed by Staple 1.0 oz ai/A early over-the-top (EOT). The EOT application was followed by either one post-directed (layby) or two post-directed (10 inch and layby) applications. Programs that replaced either the early post-directed (EDIR) or both the EDIR and late post-directed (LDIR) applications with an EOT application of Staple provided equal control of pigweed, entireleaf morningglory, velvetleaf, and prickly sida when compared to the standard herbicide programs. But, when both the EDIR and LDIR applications were replaced with Staple EOT, control of pitted morningglory decreased. When Cotoran preemergence was replaced with 0.5 oz ai/A Staple in the soil component, broadleaf signalgrass control decreased regardless of the postemergence program. Three cotton cultivar sensitivity experiments were conducted in 1995 (two in Louisiana and one in Arkansas) and compared injury from four Staple treatments on the cultivars Coker 315, BXN 57, BXN 58, Stoneville 132, Stoneville 474, DPL 51, DPL 5409, DPL 20, and Suregrow 501. The Staple treatments included 1oz ai/A PRE followed by 1 oz EOT, 1 oz EOT, 2 oz EOT, and an untreated check. Minimal injury was observed in both Louisiana experiments, but a high level of injury was observed in the Arkansas experiment. In the Arkansas experiment, BXN 57 and BXN 58 were more sensitive to the sequential treatment than other cultivars, and there was a trend for BXN 58 and Stoneville 132 to be more sensitive to EOT applications than the other cultivars. This research indicates that Staple has the potential to replace one, or possibly two, post-directed applications, depending on weed populations. And, the BXN cultivars can express more Staple injury than other cultivars under some conditions.

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Introduction

Staple® (pyrithiobac), a broadleaf-weed cotton herbicide developed by Dupont, will be marketed in 1996 as an over-the-top herbicide. Staple is the first true over-the-top herbicide that controls broadleaf weeds without causing excessive cotton injury (1,7,11,14,15). This is an important advance in cotton weed control because, until now, producers had to establish a height differential between the cotton and weeds so that Cotoran®, Caparol®, Bladex®, Goal®, Cobra®, MSMA, and DSMA could be POST-directed under the foliage of the cotton plant to maintain an acceptable level of weed control (13).

Preemergence herbicides often are not adequately activated by rain after planting, resulting in cotton and weeds of equal height. Prior to the introduction of Staple, producers were forced to apply Cotoran, DSMA, or MSMA over-the-top at low rates to slow weed growth and establish a height differential. The salvage application of these more-phytotoxic herbicides often delays cotton maturity and decreases yields (2,5,6,8,9,12). An early, over-the-top application of Staple has the potential to provide an acceptable level of weed control under these conditions without delaying maturity or decreasing yields (1,7,11,14,15).

Staple also provides excellent preemergence (PRE) control of pigweed species, prickly sida, spurge species, and entireleaf morningglory. Staple applied postemergence (POST) often results in excellent control of pigweed species, entireleaf morningglory, and hemp sesbania. However, the POST control of velvetleaf, common cocklebur, pitted morningglory, and prickly sida is less consistent and more dependent on weed size and density (3,4,10). The introduction of Staple into the cotton-weed control market can result in superior weed control in cotton production because it can allow producers to control broadleaf weeds with an over-the-top application that is not dependent on establishing a height differential between the cotton plants and weeds.

Genetic transformation has also expanded the weed control options in cotton production. Buctril®-tolerant cotton was developed with the cultivar names BXN 57 and BXN 58 and sold on a small scale in 1995. Buctril (bromoxynil) herbicide can be safely applied over-the-top of BXN® cotton. Buctril also provides excellent postemergence control of pitted morningglory, entireleaf morningglory, and common cocklebur. However, control of prickly sida and velvetleaf is less consistent and is dependent on higher rates and earlier application. Pigweed control is poor with Buctril regardless of herbicide rate or weed size.

Separately, Staple herbicide and Buctril-tolerant cotton expand the tools that are available for producers to use for cotton weed control, but each has its own strenghts and weaknesses. Because Staple and Buctril have very different spectrums of weed control, the two technologies may be used in combination to maximize the spectrum of weeds controlled.

Initial research across the mid-South suggested that the BXN lines of cotton may express more Staple injury than currently used commercial varieties. However, there is no direct comparison of Staple sensitivity of BXN lines to the parent cultivar, Coker 315, and other commonly used cultivars.

Weed Control with Staple Herbicide

Materials and Methods

A weed control experiment was conducted in 1994 and 1995 on a silt loam soil at Marianna, Arkansas, at the Cotton Branch Experiment Station to compare herbicide systems that replace either the early POST-directed (EDIR) application or the EDIR and the late POST-directed (LDIR) applications with an early over-the-top (EOT) application of Staple at 1 oz. ai/A (all herbicide rates in active ingredient per acre). The experiment consisted of two standard herbicide programs with the same postemergence treatments but different soil-applied herbicides. All herbicide treatments were applied on a 20-inch band, and cultivation was used to control weeds in the row middles.

The first standard was Treflan applied preplant incorporated (PPI) at 0.75 lb followed by (fb) a preemergence (PRE) application of Cotoran and Zorial at 1.2 plus 0.75 lb/A, respectively. The second standard consisted of Cotoran 1.2 + Command 1.0 lb/A applied PRE. Both standard soil-applied programs were followed by Cotoran 0.8 + MSMA 1.5 lb/A, EDIR; Bladex 0. 9 + MSMA 1.5 lb/A, LDIR; and Bladex 0.9 lb/A + 1% crop oil, layby. EDIR, LDIR and layby applications were made to 2- and 8-leaf cotton and at the last cultivation, respectively.

The herbicide systems that included Staple consisted of four soil-applied programs. The two standard soil herbicide treatments (Treflan, PPI fb Cotoran + Zorial, PRE; and Cotoran + Command, PRE) were included, as well as two others, Treflan, PPI fb Cotoran, PRE; and Treflan, PPI fb Staple 0.5 oz/A, PRE. Treflan, Zorial, Cotoran, and Command soil-applied rates were the same as in the standard herbicide treatments. All four soil-applied herbicide programs were followed with two postemergence programs. Instead of using three POST-directed (DIR) applications, as in the standard herbicide systems, either the EDIR or the EDIR and LDIR applications were replaced with an EOT application of Staple, 1.0 oz / A + 0.25% (v/v) non-ionic surfactant. When both the EDIR and LDIR applications were replaced, the layby application included Bladex + MSMA instead of Bladex + crop oil. All directed-herbicide rates were the same as in the standard herbicide systems.

Visual ratings of weed control and crop injury were made 2 weeks after every herbicide application and at the time of crop defoliation, but data from the last two ratings will be discussed.

Results and Discussion

Crop injury and yield were not affected by herbicide treatment. When averaged over both years and all herbicide treatments, the seedcotton yield was 2325 lb/A (data not shown). All herbicide treatments regardless of soil-applied or POST components provided at least 97% control of Palmer amaranth, smooth pigweed, entireleaf momingglory, velvetleaf, and prickly sida (data not shown). However, herbicide treatments differed in the control of pitted morningglory and broadleaf signalgrass.

Both standard herbicide systems provided 98% control of pitted momingglory at the time of defoliation (Table 1), and when 1 oz of Staple was substituted for the EDIR application of Cotoran 0. 8 + MSMA 1. 5 lb, pitted momingglory control was equal to the standard programs. But, when the EOT application of Staple was used to replace both the EDIR and LDIR applications, pitted morningglory control decreased with all soil-applied programs except Cotoran 1.2 + Command 1.0 lb. Because pitted morningglory control was reduced when Staple replaced two-out-of-three DIR applications, we can assume that with more difficult-to-control weeds, it may not be possible to replace more than the EDIR application with an EOT application of Staple without reducing weed control.

At 2 weeks after the layby application, broadleaf signalgrass control was at least 92% for all herbicide treatments, but there were statistical differences between treatments. All soil-applied components, except Treflan fb Staple 0.5 oz, PRE, provided similar broadleaf signalgrass control. But, when Cotoran was completely replaced by Staple, as in the Treflan fb Staple treatments, broadleaf signalgrass control was reduced. Cotoran is primarily a broadleaf-weed herbicide, but it also has grass activity. Staple also has PRE and POST grass activity, but it has far less than Cotoran. As a result, when Cotoran was completely replaced by Staple, a reduction in broadleaf signalgrass control was often observed.

Conclusion

Staple at 1 oz/A applied EOT at the 2-leaf stage of cotton followed by a layby application of Bladex 0. 9 + MSMA 1. 5 lb/A at the last cultivation provided pigweed, entireleaf morningglory, prickly sida, and velvetleaf control equivalent to standard herbicide programs that use three DIR applications. But, in order to achieve pitted morningglory control equal to the standard treatments, the EOT application of Staple had to be followed with a LDIR application of Bladex 0.9 + MSMA 1.5 lb/A and Bladex 0.9

lb/A + 1% COC at the last cultivation. Although broadleaf weed control was acceptable when Staple PRE replaced Cotoran PRE in the soil component, broadleaf signalgrass control was statistically reduced.

Cultivar Sensitivity to Staple Herbicide

Materials and Methods

Two experiments at Baton Rouge, Louisiana, and one at Clarkedale, Arkansas, were conducted to determine if BXN cotton cultivars were more sensitive to Staple herbicide than their non-transgenic parent or other commercially available cultivars. The soil types were Mhoon silty clay loam (2.1% OM) and Dubbs silt loam (1.2%OM) at the Louisiana and Arkansas locations, respectively.

Nine cotton cultivars with four levels of Staple treatments were arranged in two RCB design experiments at Louisiana and a split-plot design (main-plot factor cultivar and subplot factor Staple treatment) experiment at Arkansas. The cotton cultivars at Louisiana included Coker 315, BXN 57, BXN 58, Stoneville 132, Stoneville 474, LA 887, DPL 5409, DPL 20, and Suregrow 501. In Arkansas the same cultivars were used, except DPL 51 replaced LA 887. Coker 3l5 is the parent cultivar of transgenic cultivars BXN 57 and BXN 58. The other cultivars were selected to represent a range of commonly grown commercial cotton.

At Baton Rouge, one experiment was conducted under normal soil moisture conditions, but the soil in the second experiment was brought to saturation with furrow irrigation prior to the EOT applications of Staple to examine the influence of soil moisture on EOT Staple injury. Visual observations from earlier experiments indicated a correlation between high soil moisture and POST Staple injury. In both Louisiana experiments, plot size was two, 40-inch rows by 11 feet. At Arkansas, the main plots were four, 40-inch rows by 30 ft, and the subplots were one row.

Staple treatments included 1 oz/A PRE followed by 1 oz EOT (at 2-leaf cotton), 1 oz EOT, 2 oz EOT, and an untreated check. The 1 oz/A rate is considered a labeled postemergence rate but is probably higher than the rate that will be labeled for PRE application. All EOT applications included 0.25% (v/v) non-ionic surfactant.

At Baton Rouge, both experiments were planted May 29, 1995. Preemergence Staple treatments were applied with a backpack CO_2 sprayer after planting. EOT Staple treatments were applied over-the-top to two-leaf cotton, 3 weeks after planting (WAP) with a backpack $C0_2$ sprayer. Visual ratings for cotton injury were taken at 1, 2, 4, and 6 weeks after EOT treatment (WAT). Cotton height was measured at 2, 3, 4, and 6 WAT. The data were homogeneous across both soil moisture experiments, so both experiments were combined and analyzed as a split-plot with soil moisture as the main-plot factor. Equality of means was determined using ANOVA at alpha = 0.05; treatments were separated with LSD.

At Clarkedale, cotton was planted with a cone planter May 24, 1995. A blanket treatment of Treflan 0. 84 kg/ha PPI followed by Cotoran 1. 3 kg/ha PRE was used for standard weed control. Preemergence Staple treatments were applied with a backpack $C0_2$ sprayer after planting. A total of 4.5 inches of rain was recorded during the first week after planting. EOT Staple treatments were applied over-the-top to two-leaf cotton, 3 WAP with a backpack CO_2 sprayer. Visual ratings for cotton injury were taken 2 and 3 WAP and 1, 2, and 4 WAT. Cotton height was also measured at 2 and 3 WAP and 2 and 4 WAT. Equality of means was determined using ANOVA at alpha = 0.05; treatments were separated with LSD.

Results and Discussion

Louisiana. In the two Louisiana experiments, Staple injury was minimal regardless of soil moisture, cultivar, rate, or time of application. When averaged over both experiments and all cotton cultivars, all three Staple treatments reduced cotton heights by 0. 5 to 1 inch (data not shown). Soil moisture and cultivar interacted to affect cotton height and yield, but these data are not presented.

Arkansas cotton injury. At Clarkedale, Arkansas, the PRE application of Staple resulted in stunting and chlorosis regardless of cotton cultivar; however, cotton injury was most severe in the two BXN cotton cultivars (Table 2). At 2 WAP, cotton injury with BXN 57 and BXN 58 was 24% and 25%, respectively. Both transgenic cultivars tended to have more injury than the commercial standards, but the BXN cotton injury was not significantly greater than the parent, Coker 315. At 3 WAP, all cotton treated with Staple PRE, regardless of cultivar, had more injury than the untreated cotton. BXN 57, BXN 58, and Stoneville 132 were injured 20%, 24%, and 19%, respectively (Table 2). Both transgenic lines of cotton were injured more than the parent Coker 315. DPL 51 and Suregrow 501 expressed the least injury at 3 WAP with 9% and 7% injury, respectively.

At 1 week after the EOT treatment (WAT), an interaction between cultivar and Staple treatment existed for cotton injury. All cultivars treated with Staple showed signs of Staple injury when compared to the untreated plants of the same cultivar. The primary injury symptoms were chlorosis, crinkled leaves, and stunting. Stoneville 132 was the most injured cultivar from the 1 and 2 oz/A rates of Staple applied EOT, 16% and 20%, respectively (Table 2). Injury was not severe from either rate applied EOT, but there was a trend for the BXN 58 and Stoneville 132 to show more visual symptoms than the other cultivars.

The sequential treatments of Staple (PRE followed by EOT) caused greater cotton injury than the EOT Staple treatments. The EOT component of the sequential treatment increased the crop injury that was already present from the PRE application. At 1 WAT, BXN 57 and BXN 58 had 43% and 39% injury, respectively, compared to 28% for Coker 315 (Table 2). Injury in the commercial standards ranged from a low of 23% with DPL 51 to a high of 31% with Stoneville 132.

An interaction between cultivar and Staple treatment was still present at 4 WAT (Table 2). Injury from the sequential applications was apparent in all cultivars. The BXN 57 and 58 cultivars had 37% and 35% injury, respectively, compared to 17% injury in Coker 315. Stoneville 132, Stoneville 474, DPL 5409, and DPL 20 were injured from 13% to 16%. The least sensitive cultivars, DPL 51 and Suregrow 501, had only 10% and 11% injury, respectively.

Arkansas height reduction. Percentage height reduction, relative to the untreated check of the same cultivar, followed the same general pattern as cotton injury. At 2 WAP, the heights of all cultivars were reduced at least 30% from 1 oz of Staple applied PRE (Table 3). Coker 315 had the smallest reduction in height, 31%, and BXN 57 and 58 had a 41% and 40% reduction in height, respectively. At 3 WAP, there was a greater separation among cultivars from the PRE component. The heights of BXN 57 and BXN 58 were reduced by 30% and 43%, respectively, compared to a 22% reduction in Coker 315. DPL 51 and Suregrow 501 showed the least sensitivity and had only a 9% and 10% reduction, respectively.

At 2 WAT, the heights of BXN 58, DPL 20, Stoneville 474, and Suregrow 501 were reduced slightly by 1 oz EOT when compared to the untreated checks (Table 3). All cultivars, except Coker 315 and BXN 57, had a significant height reduction from the 2-oz EOT treatment. The sequential Staple treatment resulted in at least a 20% reduction in the height of all cultivars. The largest reduction occurred with the BXN 57 and BXN 58 cultivars, 40% and 44%, respectively. Coker 315 and DPL 51 were the least affected. At 4 WAT, cultivars did not differ in height reduction, but when averaged over cultivars, the sequential and 2-oz EOT Staple treatments reduced heights by 27% and 11%, respectively (data not shown).

Arkansas yield reduction. The sequential application of Staple reduced yields of BXN 57 and 58 by 45% and 40%, respectively, when compared to yield of the untreated cultivar (Table 3). Coker 315, Stoneville 132, Stoneville 474, and Suregrow 501 yields were reduced 18 to 24%. The yields of DPL 51, DPL 5409, and DPL 20 were not reduced by the sequential application of Staple. There were no yield reductions from the 1 or 2 oz EOT applications of Staple regardless of cultivar, but the 1 oz EOT application did enhance the yield of Coker 315 (Table 3).

Conclusion

In summary, the PRE component of the sequential Staple treatment resulted in a significant amount of visual injury and height reduction in all cultivars at 2 and 3 WAP. Crop injury and height reduction from the PRE application were additive when the EOT application was applied at 3 WAP. At 3 WAT, all cultivars were injured from the sequential Staple treatment, but both BXN 57 and BXN 58 showed considerably more injury and height and yield reductions than any other cultivar including the parent cultivar, Coker 315. This suggests that the gene insertion, expression of the nitrilase gene, or plant breeding after the transformation resulted in the BXN cultivars having a higher sensitivity to sequential applications of Staple herbicide. Cultivars did not appear to differ greatly in their sensitivity to EOT applications, but a trend existed for BXN 58 and Stoneville 132 to express more injury than the other cultivars.

These results raise questions as to how genetic manipulation and the subsequent plant breeding has changed the original characteristics of the parent cultivar, Coker 315. Research into insect and disease tolerance, growth and development characteristics, and sensitivity to labeled and "off-target" herbicides is warranted with all transgenic cultivars. The initial findings of this research indicate that varietal characteristics of the parent cultivar, other than the inserted trait, have changed. These possible alterations need to be identified.

Cotton injury from Staple herbicide seems to be related to environmental conditions. Cotton herbicides applied on the Dubbs silt loam soil consistently show a high level of activity compared to many of the other soils in Arkansas. This, combined with the 4.5 inches of rain during the first 7 days after planting, resulted in significant cotton injury. Early-over-the-top Staple injury (chlorosis and stunting) was observed in all cultivars but was not excessive. Assuming that postemergence injury is also related to environmental conditions, further research concerning varietal differences in Staple metabolism and crop injury is needed.

Future research into these areas will allow us to better understand the potential for crop injury and impact on yield and profitability that could result from changes in disease and insect susceptibility, fertility response, and herbicide sensitivity in newly released transgenic cultivars. We can only begin to address these questions with the fall cooperation between chemical/seed companies and the university research systems. Hopefully cooperative research will prevent some of the potential difficulties when these new technologies are implemented in commercial cotton production.

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Table 1. Weed control at Marianna, averaged over 1994 and 1995.

	Pitted morningglory[a]		Broadleaf signalgrass[b]	
Herbicide treatment	Staple[c] fb LDIR[e] fb Layby1[f]	Staple[c] fb Layby2[g]	Staple[c] fb LDIR[e] fb Layby1[f]	Staple[c] fb Layby2[g]
	------ (%) ------			
Treflan 0.75, PPI fb Cotoran 1.2 + Zorial 0.75 lb/A, PRE	97	88	98	96
Cotoran 1.2 + Command 1.0 lb/A, PRE	94	92	98	97
Treflan 0.75, PPI fb Cotoran 1.2 lb/A, PRE	96	84	93	92
Treflan 0.75 lb/A, PPI fb Staple 0.5 oz/A, PRE	99	96	98	100
Treflan 0.75, PPI bf Cotoran 1.2 + Zorial 0.75 lb/A, PRE fb EDIR[d], LDIR[e], Layby1[f]	98		100	
Cotoran 1.2 + Command 1.0 lb/A, PRE fb EDIR[d], LDIR[e], Layby1[f]	98		100	
LSD (0.05)	6		4	

[a]pitted morningglory control at time of defoliation
[b]broadleaf signalgrass control 2 weeks after Layby
[c]Staple 1.0 oz/A + 0.25% surfactant v/v, 2-leaf cotton
[d]EDIR = Cotoran 0.8 + MSMA 1.5 lb/A + 0.25% surfactant v/v, 2-leaf cotton
[e]LDIR = Bladex 0.9 + MSMA 1.5 lb/A + 0.25% surfactant v/v, 8-leaf cotton
[f]Layby1 = Bladex 0.9 + crop oil 1% v/v, last cultivation
[g]Layby2 = Bladex 0.9 + MSMA 1.5 lb/A + 0.25% surfactant v/v, last cultivation

Table 2. Visual injury ratings from Staple 1 oz ai/A PRE fb 1 oz EOT, 1 oz EOT, and 2 oz EOT, Clarkedale, 1995.

	1 oz PRE[a]		1 WAT[c]			4 WAT[c]		
Cultivars	2 WAP[b]	3 WAP[b]	PRE fb EOT[d]	1 oz EOT	2 oz EOT	PRE fb EOT[d]	1 oz EOT	2 oz EOT
	------ (%) ------							
Coker 315	18	13	28	12	15	17	1	7
BXN 57	24	20	43	13	17	37	2	6
BXN 58	25	24	39	15	19	35	7	9
Stoneville132	15	19	31	16	20	15	3	7
Stoneville 474	15	16	30	13	13	16	4	6
DPL 51	17	9	23	13	15	10	2	4
DPL 5409	14	16	26	13	16	13	2	6
DPL 20	13	12	27	13	16	15	4	8
Suregrow 501	14	7	24	10	15	11	2	5
LSD (0.05)	8[e]	5[e]	----------5[f]--------			------------6[f]--------		

[a]Injury from PRE component of sequential application.
[b]WAP: weeks after planting.
[c]WAT: weeks after EOT treatment.
[d]PRE fb EOT: 1 oz PRE fb 1 oz EOT.
[e]LSD for comparing means within a column.
[f]LSD for comparing means of cultivars at same or different Staple treatment or means of Staple treatment in the same or different cultivar.

Table 3. Percentage height and yield reduction of nine cultivars treated with Staple 1 oz ai/A PRE fb 1 oz EOT, 1 oz EOT, and 2 oz EOT, Clarkedale, 1995.

	Height reduction					Yield reduction		
	1 oz PRE[a]		2 WAT[c]					
Cultivars	2 WAP[b]	3 WAP[b]	PRE fb EOT[d]	1 oz EOT	2 oz EOT	PRE fb EOT[d]	1 oz EOT	2 oz EOT
	(%)							
Coker 315	31	22	20	0	7	18	-19	0
BXN 57	41	30	40	1	4	45	3	-1
BXN 58	40	43	44	15	17	40	7	-2
Stoneville 132	34	29	30	7	13	24	16	12
Stoneville 474	33	25	28	9	10	24	15	5
DPL 51	36	9	19	1	13	16	5	15
DPL 5409	34	27	26	2	9	8	-17	-11
DPL 20	37	17	26	13	13	7	14	7
Suregrow 501	34	11	26	10	18	18	-7	7
LSD (0.05)	9[e]	10[e]	8[f]			18[f]		

[a]Height reduction from PRE component of sequential application.
[b]WAP: weeks after planting.
[c]WAT: weeks after EOT treatment.
[d]PRE fb EOT: 1 oz PRE fb 1 oz EOT.
[e]LSD for comparing means within a column.
[f]LSD for comparing means of cultivars at same or different Staple treatment or means of Staple treatment in the same or different cultivar.