The *Journal of Cotton Science 8:213–222 (2004)*
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WEED SCIENCE

Response of Strip-tilled Cotton to Preplant Applications of Dicamba and 2,4-D

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ABSTRACT

Conservation tillage is being adopted by cotton (*Gossypium hirsutum* L.) growers across the southeastern United States. Glyphosate is commonly applied prior to planting to control winter vegetation, but preplant control of certain weeds, especially cutleaf eveningprimrose (*Oenothera laciniata* Hill), requires 2,4-D or dicamba mixed with glyphosate. A field experiment was conducted at seven locations to determine response of strip-tilled cotton to dicamba diglycolamine salt at 280 and 560 g acid equivalent (a.e.) ha^{-1} or 2,4-D dimethylamine salt at 530 and 1060 g a.e. ha^{-1} applied 1 to 6 wk before planting (WBP). These rates are 1 and 2 times the labeled rates. No adverse effects on cotton were noted when 2,4-D was applied 3 or more WBP. Visible leaf distortion on more than 10% of the seedlings and stand reduction was noted at 1 of 7 locations when 2,4-D was applied 2 WBP and at 2 of 7 locations when applied 1 WBP. Cotton yield was not reduced by 2,4-D at 530 g ha^{-1} at any application time, and it was reduced by 2,4-D at 1060 g ha^{-1} applied 1 WBP at 1 of 7 locations. Dicamba at 280 g ha^{-1} applied 3 or more WBP did not cause leaf distortion or affect stands. Leaf distortion on more than 10% of seedlings was noted at 1 of 7 locations with 280 g ha^{-1} dicamba applied 2 WBP, but yield was unaffected regardless of time of application. Dicamba at 560 g ha^{-1} applied 3 WBP caused leaf distortion on more than 10% of the seedlings and reduced yield at 1 of 7 locations. Cotton response to dicamba, but not 2,4-D, was generally correlated with rainfall between application and planting.

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Conservation tillage is being adopted by cotton growers across the southeastern U.S. In North Carolina, less than 5% of the crop was planted in conservation tillage in 1992 compared with 9, 19, 30, and 40% in 1996, 1998, 2000, and 2002, respectively (CTIC, 2004). Much of the impetus initially was to meet conservation compliance provisions, beginning with the 1985 farm bill and continuing with the 1990, 1996, and 2002 farm bills (Crozier et al., 2004). Commercialization of herbicide-tolerant cotton has facilitated continued expansion of conservation tillage (Fawcett and Towery, 2002). In addition to being the most practical means to meet conservation compliance requirements and to reduce soil erosion, conservation tillage offers other benefits, such as moisture conservation on drought-prone soils, protection of young cotton seedlings from sand-blasting, improved soil tilth, reduced soil crusting and more rapid water infiltration, protection of water quality, and reduced equipment, labor, and time requirements because seedbed preparation is reduced or eliminated (Naderman, 1993; Wilcut et al., 1993).

Preplant burndown herbicides, primarily glyphosate and paraquat, replace primary tillage in conservation tillage systems. Most winter annual weeds typically encountered in conservation tillage systems in North Carolina are controlled by one or both of these herbicides. The most notable exception is cutleaf eveningprimrose, which is not adequately controlled by either glyphosate or paraquat (Culpepper et al., 2002; York and Culpepper, 2004). Research in several southern states has shown that this troublesome weed is most effectively, consistently, and economically controlled by 2,4-D at 0.43 to 0.75 kg ha^{-1} applied alone or mixed with glyphosate or paraquat (Culpepper et al., 2002; Kelly et al., 2002; Reynolds et al., 2000; Smith et al., 1996). In recent studies in North Carolina and Georgia, 99% of the cutleaf eveningprimrose was controlled by 2,4-D at rates as low as 0.13 kg ha^{-1} (Wilson et al., 2004).

When mixed with glyphosate or paraquat, dicamba improved control of cutleaf eveningprimrose (Guy and Ashcraft, 1996; Smith et al., 1996). Ferguson (1996) reported similar control of cutleaf eveningprimrose by combinations of dicamba plus glyphosate or paraquat and 2,4-D plus glyphosate or paraquat. In North Carolina and Georgia, dicamba plus glyphosate was less effective on cutleaf eveningprimrose than 2,4-D plus glyphosate but more effective than carfentrazone, diuron, flumiclorac pentyl ester, oxyfluorfen, or thifensulfuron plus tribenuron mixed with glyphosate (Culpepper et al., 2002). In Louisiana, 2,4-D plus glyphosate also was more effective than dicamba plus glyphosate (Kelly et al., 2002).

The diglycolamine salt of dicamba is labeled for preplant application in conservation-tillage cotton (Anonymous, 2004b). The label specifies that cotton planting be delayed for at least 21 d after herbicide application and after the accumulation of 2.5 cm or more of rainfall or overhead irrigation. Labels for most 2,4-D products are ambiguous concerning preplant application to cotton. These labels generally state that cotton should not be planted for 3 mo after 2,4-D application or until the herbicide has dissipated from the soil (Anonymous, 2004e; 2004f), but labels for certain 2,4-D products have been amended to allow application 30 d prior to planting of cotton (Anonymous, 2004a; 2004c; 2004d). These labels do not specify a rainfall requirement, but do warn the user of potential injury to the crop.

Ferguson (1996) observed cotton injury from the sodium salt of dicamba at 0.28 kg a.e. ha^{-1} applied 1 or 2 WBP and reported that injury appeared to be inversely correlated with rainfall accumulation. Montgomery et al. (2002) noted cotton injury when an ester formulation of 2,4-D at 0.9 kg a.e. ha^{-1} was applied 1 WBP but not with longer intervals between application and cotton planting. Guy and Ashcraft (1996) noted cotton injury by both 2,4-D (rate and formulation not specified) and dicamba sodium salt at 0.28 kg ha^{-1} applied 2 WBP. Injury was greater with dicamba, but no injury was noted with either herbicide if 2.5 cm or more rainfall accumulated between application and cotton planting. In Alabama, an unspecified formulation of 2,4-D at 0.56 and 1.12 kg ha^{-1} applied in early February or early March did not injure cotton planted in mid- to late-April (Patterson et al., 1995). In 1 of 2 yr, 5 and 23% of the cotton was injured by 2,4-D at 0.56 and 1.12 kg ha^{-1}, respectively, applied in early April. In a more recent study conducted at 24 locations across the U.S. Cotton Belt, 2,4-D dimethylamine salt at 0.4 or 0.8 kg ha^{-1} or 2-ethylhexyl ester of 2,4-D at 0.53 or 1.07 kg a.e. ha^{-1} applied 2 or 3 WBP did not adversely affect cotton yield, although severe injury was noted at one location (Vidrine et al., 2003). There was no correlation between cotton injury and rainfall accumulation between application and planting.

The increasing popularity of conservation tillage cotton and the need for effective burndown options to control problem weeds, such as cutleaf eveningprimrose, along with limited and sometimes conflicting information on cotton response to burndown herbicides, points to the need for additional research. Studies were conducted in North Carolina and Georgia to determine the response of strip-tilled cotton to 2,4-D and dicamba applied at various intervals prior to cotton planting.

MATERIALS AND METHODS

The experiment was conducted on the Peanut Belt Research Station at Lewiston, NC in 1999 and 2000, the Upper Coastal Plain Research Station at Rocky Mount, NC in 1999 and 2000, the Central Crops Research Station at Clayton, NC in 2000, a private farm at Woodland, NC in 1999, and the Lang Research Farm at Tifton, GA in 2000. Soil characteristics of each site are listed in Table 1. Soils were

Table 1. Description of soils at experimental sites

Location	Soil series [z]	Texture	pH	Organic matter content (%)	Cation exchange capacity (cmolc kg-1)
Lewiston, 1999	Bonneau	Loamy sand	6.0	1.5	2.4
Rocky Mount, 1999	Norfolk	Sandy loam	6.1	1.0	3.3
Woodland, 1999	Goldsboro	Loam	6.1	1.8	5.1
Clayton, 2000	Gilead	Loamy sand	5.9	0.8	2.4
Lewiston, 2000	Norfolk	Sandy loam	5.5	3.0	3.4
Rocky Mount, 2000	Norfolk	Sandy loam	6.2	3.4	6.8
Tifton, 2000	Tifton	Loamy sand	5.7	1.2	2.8

[z] Bonneau soils are loamy, siliceous, subactive, thermic Arenic Paleudults; Norfolk soils are fine-loamy, kaolinitic, thermic Typic Kandiudults; Goldsboro soils are fine-loamy, siliceous, subactive, thermic Aquic Paleudults; Gilead soils are fine, kaolinitic, thermic Aquic Hapludults; Tifton soils are fine-loamy, kaolinitic, thermic Plinthic Kandiudults.

characterized by a commercial laboratory (A&L Eastern Agricultural Laboratories, Inc.; Richmond, VA), and organic matter was determined using the chromic acid colorimetric method (Nelson and Sommers, 1982). A wheat (*Triticum aestivum* L.) cover crop was established during the preceding fall at the Lewiston 1999 and 2000 sites, the Clayton and Woodland sites, and the Rocky Mount 2000 site. The Rocky Mount 1999 site had corn (*Zea mays* L.) stubble from the preceding crop, and the Tifton site had cotton stubble from the preceding crop. Glyphosate isopropylamine salt (Roundup Ultra; Monsanto Co.; St. Louis, MO) at 840 g a.e. ha^{-1} was applied 3 to 4 WBP to kill the cover crop or winter annual weeds at all sites except Rocky Mount in 1999, where paraquat (Gramoxone Extra; Syngenta Crop Protection, Inc.; Greensboro, NC) at 1.0 kg a.i. ha^{-1} was applied on the day of planting.

A split-plot treatment design with herbicides and application rates as main plots and time of herbicide application as subplots was used. Subplots, which were randomized within main plots and replicated four times in North Carolina or three times in Georgia, consisted of four 91-cm cotton rows by 15 m. Herbicides included the diglycolamine salt of dicamba (Clarity; BASF Corp.; Research Triangle Park, NC) at 280 and 560 g ha^{-1} and the dimethylamine salt of 2,4-D (Weedar 64; Nufarm Inc.; Burr Ridge, IL) at 530 and 1060 g ha^{-1}. Subplots included no herbicide or herbicides applied 1, 2, 3, 4, or 6 WBP. Herbicide application dates are listed in Table 2. Herbicides were applied with a CO_2-pressurized backpack sprayer equipped with flat-fan nozzles delivering 140 L ha^{-1} at 166 kPa.

A 30-cm band over the rows of each plot was strip-tilled using a strip-tillage unit (Naderman, 1993) immediately ahead of the cotton planter. Cotton cultivars Sure-Grow 125B/R (Delta and Pine Land Co.; Scott, MS) and ST 4892BR (Stoneville Pedigreed Seed Co.; Memphis, TN) were planted in North Carolina and Georgia, respectively, on the dates listed in Table 2. Aldicarb (Temik 15G; Bayer CropScience; Research Triangle Park, NC) at 0.67 to 0.84 kg a.i. ha^{-1} was applied in the seed furrow during planting. Weeds were controlled by glyphosate at 0.56 kg ha^{-1} applied postemergence to 1- and 4-leaf cotton followed by cyanazine (Bladex 4L; E. I. du Pont de Nemours and Co.; Wilmington, DE) at 1.1 kg a.i. ha^{-1} plus MSMA (MSMA 6.6; Drexel Chemical Co.; Memphis, TN) at 1.8 kg a.i. ha^{-1} applied postemergence-directed to 30- to 40-cm cotton. Fertilization, insect control, growth management, and defoliation were standard for the respective states.

The number of live cotton plants in each of the two center rows of each plot was determined 20 to 26 d after planting. The percentage of plants exhibiting visible leaf distortion typical of dicamba or 2,4-D injury was determined 27 to 35 d after planting by examining all plants in the two center rows of each plot. In 1999 only, cotton height and number of main-stem nodes were determined on 20 randomly selected plants per plot during the second to third week of July, or during the peak bloom period. Seed cotton yield was determined by mechanically harvesting the two center rows of each plot. At each North Carolina location, a sample of the mechanically harvested seed cotton was collected from each plot to determine lint percentage and fiber properties. Seed cotton was ginned in a laboratory gin without lint cleaning. Cotton grades are not presented because they would not be representative of cotton ginned commercially. Fiber upper half mean length, fiber length uniformity index, fiber strength, and micronaire were determined by high volume instrumentation (HVI) testing (Sasser, 1981). Fiber

Table 2. Herbicide application dates and cotton planting dates

Locations	Herbicide application dates (weeks before planting)					Cotton planting dates
	6	4	3	2	1	
Lewiston, 1999	23 March	6 April	13 April	20 April	28 April	4 May
Rocky Mount, 1999	23 March	6 April	13 April	20 April	28 April	4 May
Woodland, 1999	24 March	7 April	13 April	20 April	28 April	4 May
Clayton, 2000	29 March	12 April	19 April	26 April	3 May	10 May
Lewiston, 2000	29 March	12 April	19 April	26 April	3 May	10 May
Rocky Mount, 2000	29 March	12 April	19 April	26 April	3 May	10 May
Tifton, 2000	15 March	31 March	4 April	11 April	18 April	26 April

properties and lint percentage were not determined at the Georgia location.

Data were subjected to analysis of variance using the general linear models procedure of the Statistical Analysis System (version 8.02; SAS Institute Inc.; Cary, NC), with treatment sums of squares partitioned to reflect the split-plot treatment design and location effects (McIntosh, 1983). Data for percentage of plants with distorted leaves were square-root transformed (Little and Hills, 1972) before analysis. Non-transformed data are presented with statistical interpretation based on transformed data. Data for cotton stand, percentage of plants with distorted leaves, and seed cotton yield are presented by location due to treatment by location interactions (Table 3). Data for fiber properties and lint percentage are averaged over the six North Carolina locations. Means for main effects of herbicides and rates and for time of application and for their interactions were separated as appropriate using Fisher's Protected LSD at $P = 0.05$.

RESULTS AND DISCUSSION

So that treatments could be delineated more effectively, the percentage of plants expressing visible leaf distortion typical of phenoxyacetic acid or benzoic acid herbicides was determined in lieu of traditional visual estimates of injury (Frans et al., 1986). Leaf distortion was generally minor, which would lead to low visual estimates of injury even in situations where a relatively high percentage of the plants had distorted leaves.

None of the treatments caused visible leaf distortion at Tifton (data not shown). The herbicide and application rate by time of herbicide application interaction was noted for percentage of plants with distorted leaves at each North Carolina location. Regardless of rate or time of application, distorted leaves were not observed in plots treated with 2,4-D at Lewiston, Rocky Mount, or Woodland in 1999 (Table 4). At Clayton and Rocky Mount in 2000, 2,4-D caused distorted leaves only when applied 1 WBP. The greatest response to 2,4-D was noted at Lewiston in 2000, where 2,4-D at 530 g ha^{-1} distorted leaves on 15 and 27% of the plants when applied 2 and 1 WBP, respectively, and 2,4-D at 1060 g ha^{-1} distorted leaves on 6, 27, and 29% of the plants when applied 3, 2, and 1 WBP, respectively.

At the North Carolina locations, a greater percentage of plants exhibiting distorted leaves was often noted in dicamba-treated plots compared with those treated with 2,4-D. None of the plants at Woodland exhibited distorted leaves in plots treated with dicamba at 280 g ha^{-1}, and only 1 to 2% of the plants in plots treated with dicamba at 560 g ha^{-1} 1 to 3 WBP exhibited distorted leaves (Table 4). Dicamba at 280 g ha^{-1} applied 2 or 1 WBP at Lewiston and Rocky Mount in 1999 caused distorted leaves on 10% or less of the plants. Five percent of the plants at Rocky Mount in 1999 had distorted leaves when dicamba at 560 g ha^{-1} was applied 4 WBP.

Except for dicamba at 560 g ha^{-1} applied 2 WBP at Clayton, which caused distorted leaves on 8% of the plants, leaf distortion at Clayton and Rocky Mount in 2000 was primarily confined to plots receiving dicamba applied 1 WBP (Table 4). Similar to results with 2,4-D, the greatest leaf distortion from dicamba was noted at Lewiston in 2000. Thirty and 40% of plants in plots treated with dicamba at 280 g ha^{-1} 2 and 1 WBP, respectively, exhibited leaf distortion. Dicamba at 560 g ha^{-1} applied 3, 2, and 1 WBP caused leaf distortion on 17, 43, and 74% of the plants, respectively.

Table 3. Partial split-plot analysis of variance for main effects and interactions on cotton stands, percentage of plants with distorted leaves, and seed cotton yield

Source	df	*F* statistic [z]		
		Cotton stand	Percentage of plants with distorted leaves	Seed cotton yield
Location	6	72.95***	71.23***	771.08***
Herbicides and rates	3	1.30	11.27***	0.86
Herbicides and rates x location	18	5.08***	5.69***	3.97***
Application timing	5	4.14**	5.13***	1.54
Application timing x location	30	2.51***	26.04***	1.98**
Herbicides and rates x application timing	15	2.63***	22.87***	1.37
Herbicides and rates x application timing x location	90	1.57**	2.19***	1.24

[z] Values followed by ** and *** are significantly different at the $P = 0.01$ and $= 0.001$, respectively.

In most cases, cotton stands followed trends similar to the percentage of plants with distorted leaves. There was no interaction of herbicides and application rates by time of application for cotton stands at Woodland in 1999 or at any of the four locations in 2000. Additionally, the main effect of herbicides and application rates was not significant at any of these locations (data not shown). At Woodland and Tifton, where 2% or less of the plants exhibited distorted leaves, cotton stand was not reduced by any herbicide treatment compared with the non-treated (Table 5). Regardless of herbicides and rates, cotton stands at Clayton, Lewiston, and Rocky Mount in 2000 were reduced by 9 to 16% when the herbicides were applied 1 WBP compared with the non-treated.

The herbicide and application rate by time of application interaction was significant for cotton stands at Lewiston and Rocky Mount in 1999 (Table 6). At Lewiston, dicamba at 280 g ha^{-1} applied 1 WBP reduced stand by 17% compared with the non-treated control. Dicamba at 560 g ha^{-1} applied 2 and 1 WBP reduced stands 20 and 35%, respectively. Cotton stand at Lewiston was not reduced by 2,4-D regardless of rate or time of application. At Rocky Mount, dicamba at 280 kg ha^{-1} did not reduce cotton stand, but dicamba at 560 g ha^{-1} reduced stands

Table 4. Interaction of herbicides and application rates by time of application on percentage of plants with distorted leaves

Locations	Herbicides	Application rates (g ha^{-1})	Plants with distorted leaves (%) [z]					
			Time of application (weeks before planting)					
			Non-treated	6	4	3	2	1
Lewiston	**Dicamba**	**280**	**0 e**	**0 e**	**0 e**	**1 de**	**2 cd**	**6 c**
1999	**Dicamba**	**560**	**0 e**	**0 e**	**1 de**	**9 b**	**14 b**	**31 a**
	2,4-D	**530**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**
	2,4-D	**1060**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**
Rocky Mount	**Dicamba**	**280**	**0 e**	**0 e**	**1 de**	**1 de**	**6 cd**	**10 c**
1999	**Dicamba**	**560**	**0 e**	**1 de**	**5 cd**	**19 b**	**25 b**	**40 a**
	2,4-D	**530**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**
	2,4-D	**1060**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**	**0 e**
Woodland	**Dicamba**	**280**	**0 b**	**0 b**	**0 b**	**0 b**	**0 b**	**0 b**
1999	**Dicamba**	**560**	**0 b**	**0 b**	**0 b**	**1 a**	**2 a**	**2 a**
	2,4-D	**530**	**0 b**	**0 b**	**0 b**	**0 b**	**0 b**	**0 b**
	2,4-D	**1060**	**0 b**	**0 b**	**0 b**	**0 b**	**0 b**	**0 b**
Clayton	**Dicamba**	**280**	**0 d**	**0 d**	**0 d**	**0 d**	**0 d**	**20 b**
2000	**Dicamba**	**560**	**0 d**	**0 d**	**0 d**	**1 d**	**8 c**	**49 a**
	2,4-D	**530**	**0 d**	**0 d**	**0 d**	**0 d**	**0 d**	**0 d**
	2,4-D	**1060**	**0 d**	**0 d**	**0 d**	**1 d**	**0 d**	**9 c**
Lewiston	**Dicamba**	**280**	**0 h**	**0 h**	**0 h**	**0 h**	**30 bcd**	**40 bc**
2000	**Dicamba**	**560**	**0 h**	**0 h**	**2 gh**	**17 ef**	**43 b**	**74 a**
	2,4-D	**530**	**0 h**	**0 h**	**0 h**	**2 gh**	**15 f**	**27 de**
	2,4-D	**1060**	**0 h**	**0 h**	**1 h**	**6 g**	**27 de**	**29 cd**
Rocky Mount	**Dicamba**	**280**	**0 c**	**0 c**	**0 c**	**0 c**	**0 c**	**12 b**
2000	**Dicamba**	**560**	**0 c**	**0 c**	**0 c**	**0 c**	**2 c**	**41 a**
	2,4-D	**530**	**0 c**	**0 c**	**0 c**	**0 c**	**0 c**	**13 b**
	2,4-D	**1060**	**0 c**	**0 c**	**0 c**	**0 c**	**0 c**	**17 b**

[z] Means within a location followed by the same letter are not significantly different according to Fisher's Protected LSD (*P* = 0.05).

38, 54, and 79% when applied 3, 2, and 1 WBP, respectively. Except for 2,4-D at 1060 g ha^{-1} applied 1 WBP, which reduced stand by 55%, 2,4-D did not affect cotton stands at Rocky Mount compared with the non-treated control.

An interaction of herbicides and rates by time of application was not observed for seed cotton yield at Lewiston or Woodland in 1999 or at Lewiston, Rocky Mount, or Tifton in 2000. Additionally, there was no significant main effect of herbicides and application rates or time of application at these locations. Compared with non-treated plots, the herbicides applied 1 to 6 WBP did not reduce cotton yield. Averaged over treatments, seed cotton yields were 2390, 2670, 3520, 2910, and 1650 kg ha^{-1} at Lewiston and Woodland in 1999 and Lewiston, Rocky Mount, and Tifton in 2000, respectively (data not shown).

A herbicide and application rate by time of application interaction was observed for seed cotton yields at Rocky Mount in 1999 and Clayton in 2000 (Table 7). Dicamba at 560 g ha^{-1} applied 1 WBP, which reduced yield 15%, was the only treatment that reduced yield at Clayton. Treatment effects on seed cotton yield at Rocky Mount in 1999 were very similar to the effects on stand (Table 6). Dicamba at 280 g ha^{-1} did not affect cotton yield regardless of time of application, but dicamba at 560 g ha^{-1} applied 3, 2, and 1 WBP reduced yield 21, 24, and 52%, respectively (Table 7). At Rocky Mount, yield was reduced by 27% only when 2,4-D was applied at 1060 g ha^{-1} 1 WBP.

No herbicide treatment affected lint percentage or fiber properties in North Carolina. Averaged over treatments, lint percentage, micronaire read-

Table 5. Main effects of time of dicamba and 2, 4-D application on cotton stands

Time of application [z]	Plants/30m row [y]				
	Woodland	Clayton	Lewiston	Rocky Mount	Tifton
	1999	2000	2000	2000	2000
Non-treated	275 b	275 ab	241 a	327 ab	339 a
6 WBP	292 a	269 b	227 a	317 bc	332 a
4 WPB	281 ab	288 a	226 a	317 bc	338 a
3 WBP	268 b	270 b	243 a	343 a	317 a
2 WBP	278 ab	280 ab	224 a	340 ab	352 a
1 WBP	271 b	250 c	202 b	296 c	316 a

[y] Data averaged over herbicides and application rates. Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD (*P* = 0.05).

[z] WBP = weeks before planting.

Table 6. Interaction of herbicides and application rates by time of application on cotton stands

Location	Herbicides	Application rate (kg ha^{-1})	Plants/30m row [z]					
			Time of application (weeks before planting)					
			Non-treated	6	4	3	2	1
Lewiston	Dicamba	280	319 a	303 ab	302 ab	321 a	299 ab	264 b
1999	Dicamba	560	326 a	328 a	298 ab	285 ab	261 bc	213 c
	2,4-D	530	316 a	288 ab	316 a	290 ab	286 ab	297 ab
	2,4-D	1060	284 ab	321 a	285 ab	319 a	304 ab	315 a
Rocky Mount	Dicamba	280	299 a-d	335 ab	317 abc	317 abc	283 bcd	257 d
1999	Dicamba	560	289 a-d	310 a-d	259 cd	180 e	132 e	61 f
	2,4-D	530	319 ab	325 ab	293 a-d	343 a	301 a-d	298 a-d
	2,4-D	1060	293 a-d	309 a-d	337 ab	304 a-d	296 a-d	131 e

[z] Means within a location followed by the same letter are not significantly different according to Fisher's Protected LSD (*P* = 0.05).

ing, fiber length, fiber length uniformity, and fiber strength ranged from 40.5 to 45.5%, 3.7 to 5.2, 26.2 to 28.4 mm, 82.8 to 85.2%, and 247 to 286 kN m kg^{-1}, respectively, depending on location (data not shown). Lint percentage and fiber properties were not examined at the Georgia location. Cotton height and number of main-stem nodes in mid July, determined only in North Carolina in 1999, also were not affected by herbicide treatments (data not shown).

Ferguson (1996) and Guy and Ashcraft (1996) observed a trend for an inverse relationship between cotton injury by dicamba applied preplant and rainfall received between herbicide application and cotton planting. In these experiments, there also appeared to be a general relationship between dicamba injury and rainfall. Dicamba had the greatest impact on cotton at Lewiston and Rocky Mount in 1999 and at Lewiston in 2000. Dicamba applied 3 or fewer WBP caused distorted leaves at each of these locations (Table 4) and reduced stands at Lewiston and Rocky Mount in 1999 (Table 6). These locations had the least accumulated rainfall during the 3 wk preceding planting (Table 8). Dicamba caused distorted leaves and reduced stands when applied 1 WBP at Clayton and Rocky Mount in 2000 and reduced yield at Clayton but had little effect on cotton when applied 2 or more WBP (Tables 4, 5, and 7). These locations received only 0 to 0.2 cm accumulated rainfall between the 1 WBP application and planting but 1.3 to 2.0 cm between the 2 WBP application and planting (Table 8). Dicamba had little to no effect on cotton leaf distortion, stand, or yield at Woodland and Tifton. These locations had the greatest rainfall during the 2-wk period preceding planting. There appeared to be no correlation between cotton response and rainfall after planting. Rainfall totals during the first week after planting were 0, 0.2, 0.2, 0.4, 0.6, 0.8, and 1.0 cm at Rocky Mount in 2000, Clayton, Lewiston in 2000, Lewiston in 1999, Woodville, Rocky Mount in 1999, and Tifton, respectively (data not shown).

Table 7. Interaction of herbicides and application times on seed cotton yield

Locations	Herbicides	Application rate (g ha^{-1})	Seed cotton yield (kg ha^{-1}) [z]					
			Time of application (weeks before planting)					
			Non-treated	6	4	3	2	1
Rocky Mount	Dicamba	280	2120 cd	2470 abc	2250 a-d	2300 a-d	2130 bcd	2080 de
1999	Dicamba	560	2240 a-d	2360 a-d	2250 a-d	1760 ef	1700 f	1080 g
	2,4-D	530	2220 a-d	2490 a	2480 ab	2410 a-d	2410 a-d	2210 a-d
	2,4-D	1060	2160 a-d	2410 a-d	2260 a-d	2340 a-d	2310 a-d	1580 f
Clayton	Dicamba	280	2920 a-e	3050 ab	2550 e	2590 a-e	3190 a	2630 cde
2000	Dicamba	560	2960 a-d	2600 de	2700 b-e	2740 b-e	2730 b-e	2520 e
	2,4-D	530	2870 a-e	2910 a-e	2890 a-e	3080 ab	2880 a-e	3090 ab
	2,4-D	1060	3050 ab	3220 a	2910 a-e	2860 a-e	2690 b-e	3020 abc

[z] Means within a location followed by the same letter are not significantly different according to Fisher's Protected LSD ($P = 0.05$).

Table 8. Accumulated rainfall between herbicide application and planting of cotton

Herbicide application [z]	Rainfall (cm)						
	Lewiston	Rocky Mount	Woodville	Clayton	Lewiston	Rocky Mount	Tifton
	1999	1999	1999	2000	2000	2000	2000
1 WBP	0.7	1.0	2.5	0.2	0	0	1.8
2 WBP	0.9	1.1	2.6	2.0	1.0	1.3	2.1
3 WBP	1.0	1.1	4.5	2.5	1.0	2.5	2.3
4 WBP	2.3	4.4	7.7	5.8	1.0	5.2	2.3
6 WBP	5.3	6.2	9.9	8.1	1.1	6.6	12.9

[z] WBP = weeks before planting.

Results of these experiments indicate that dicamba can be applied as a preplant burndown treatment for weed control in conservation tillage cotton under the conditions specified on the label without adversely affecting the crop. The label for dicamba diglycolamine salt instructs the user to delay cotton planting for at least 21 d after herbicide application and accumulation of 2.5 cm of rainfall or overhead irrigation (Anonymous, 2004b). These conditions were met with applications 6 WBP at Lewiston in 1999 and Tifton in 2000 and with applications 4 WBP at Rocky Mount and Woodland in 1999 and at Clayton and Rocky Mount in 2000 (Table 9). These applications had no adverse effects on cotton, even with dicamba at 560 g ha^{-1}. At 280 g ha^{-1}, the recommended rate, no adverse effects were noted when the herbicide was applied 3 WBP regardless of rainfall.

Labels of 2,4-D products registered for preplant burndown application to conservation tillage cotton instruct the user to delay cotton planting for at least 30 d after application, but these labels do not specify a rainfall requirement (Anonymous, 2004a; 2004c; 2004d). The labels, however, do mention that the risk for crop injury is reduced under good soil moisture conditions. Similar to results of other researchers (Guy, 1995; Guy and Ashcraft, 1996), 2,4-D was less injurious to cotton than dicamba in our experiment. No adverse effects on cotton stand or yield were noted at any location with 2,4-D at 1060 g ha^{-1} applied 2 WBP, and cotton leaf distortion was noted at only 1 of 7 locations. That rate of 2,4-D is twice the labeled rate and up to eight times greater than the rate needed to control cutleaf eveningprimrose (Wilson et al., 2004). Similar to results by Vidrine et al. (2003), there was not a good correlation between rainfall and cotton response to 2,4-D. When applied 1 WBP, 2,4-D caused distorted leaves and reduced stands at Clayton, Lewiston, and Rocky Mount in 2000 (Tables 4 and 5), the locations receiving the least rainfall between the 1 WBP application and planting (Table 8). Stand and yield also were reduced by 2,4-D at 1060 g ha^{-1} at Rocky Mount in 1999 (Tables 6 and 7). Rainfall at this location was less than that at Woodland or Tifton but similar to that at Lewiston in 1999 (Table 8). There was little to no impact of 2,4-D on cotton at Woodland, Tifton, or Lewiston in 1999.

ACKNOWLEDGMENTS

Partial funding was provided by the cotton growers of North Carolina through the Cotton Incorporated State Support Program.

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Table 9. Days between accumulation of 2.5 cm of rainfall and cotton planting

Herbicide application [z]	Days						
	Lewiston 1999	Rocky Mount 1999	Woodland 1999	Clayton 2000	Lewiston 2000	Rocky Mount 2000	Tifton 2000
1 WBP	0	0	4	0	0	0	0
2 WBP	0	0	4	0	0	0	2
3 WBP	0	0	6	10	0	12	2
4 WBP	0	22	22	23	0	24	2
6 WBP	33	25	29	27	0	25	41

[z] WBP = weeks before planting.

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