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WEED SCIENCE

Flue-cured Tobacco and Peanut Response to Diuron, Fluometuron, and Prometryn Applied to a Preceding Cotton Crop

Loren R. Fisher, Alan. C. York*, and David L. Jordan

ABSTRACT

Flue-cured tobacco (*Nicotiana tabacum* L.) and peanut (*Arachis hypogaea* L.) are commonly rotated with cotton (*Gossypium hirsutum* L.) in North Carolina. Residual herbicides are a recommended component of a weed resistance management strategy in glyphosate-resistant cotton; however, growers are concerned about potential adverse effects of such herbicides on rotational crops. Research was conducted at three locations in the coastal plain of North Carolina to determine the potential for the residual herbicides fluometuron, diuron, and prometryn applied to cotton to carryover to tobacco and peanut planted the following year. Treatments included fluometuron applied preemergence (PRE) at 0 or 1340 g a.i. ha^{-1} with late or early and late postemergence-directed (PDIR) applications of diuron or prometryn arranged factorially. Diuron was applied at 480 and 840 g a.i. ha^{-1} early PDIR and late PDIR, respectively. Prometryn was applied at 740 and 1340 g a.i. ha^{-1} early PDIR and late PDIR, respectively. No visible injury was noted with any treatment in either tobacco or peanut, and no treatment adversely affected tobacco or peanut yield or quality. These results indicate that fluometuron applied PRE and diuron or prometryn applied PDIR can be included in cotton weed management programs without adversely impacting subsequent crops of tobacco or peanut.

Weed control in cotton historically was achieved by multiple herbicides applied preplant incorporated, preemergence (PRE), and postemergence-directed (PDIR) in conjunction with mechanical cultivation (Buchanan, 1992; Wilcut et al., 1995). Glyphosate-resistant (GR) cotton, which was commercially introduced in 1997, allowed growers to control a broad spectrum of weeds with topical postemergence applications of glyphosate, while reducing or eliminating most of the herbicides previously used. With GR cotton, producers were also able to eliminate cultivation and adopt conservation tillage. For these and other reasons (Culpepper and York, 1999; Mueller et al., 2005), the technology has been widely accepted by growers across the Southeast and Mid-south of the United States. In 2006, growers in 13 of the 17 cotton-producing states in the United States planted at least 97% of the crop to a GR cultivar (USDA-AMS, 2006).

Excellent weed control has been obtained in GR cotton using glyphosate-based weed management programs. Except for a few species not controlled by glyphosate (Culpepper, 2006; Culpepper et al., 2004; Shaner, 2000; York and Culpepper, 2007), excellent results have been obtained with glyphosate-only systems (Faircloth et al., 2002; Stephenson et al., 2005; York and Culpepper, 2006). With timely glyphosate application to avoid early season weed competition, soil-applied residual herbicides often are of little value in glyphosate-based systems (Culpepper and York, 1998, 1999; Reddy, 2004; York and Culpepper, 2006), and use of such herbicides has declined significantly since commercialization of GR cotton (USDA-NASS, 1997, 2006). Residual herbicides applied PRE, however, can be beneficial when initial glyphosate applications are delayed (Askew et al., 2002; Culpepper and York, 1998; Scott et al., 2003; Walden et al., 2004; York and Culpepper, 2006). The number of glyphosate applications required for good weed control and crop yield may also be reduced when PRE herbicides are included in the system (Askew and Wilcut, 1999; Burke et al., 2005; York and Culpepper, 2006). Additionally, residual herbicides applied PDIR are generally thought to be beneficial in controlling later-emerging weeds, although published research is limited (York and Culpepper, 2006; 2007).

The wide-spread planting of GR cotton and other GR crops and the associated reduction or elimination of tillage and use of other herbicides has increased

L. R. Fisher, A.C. York, and D. L. Jordan, Department of Crop Science, North Carolina State University, Raleigh, NC 27695-7620
*Corresponding author: alan_york@ncsu.edu

the threat of GR weeds. Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* L.) has recently been discovered in the Southeast and Mid-south of the United States (Culpepper et al., 2006; Scott et al., 2007; York et al., 2007), and glyphosate-resistant common ragweed (*Ambrosia artemisiifolia* L.), giant ragweed (*Ambrosia trifida* L.), and common waterhemp (*Amaranthus rudis* L.) have been reported in the midwestern United States (Heap, 2007). In addition to these weeds, there is GR horseweed [*Conyza canadensis* (L.) Cronq.] in 14 states and other GR biotypes elsewhere in the world (Heap, 2007).

The threat of glyphosate resistance in weeds has caused extension personnel to re-emphasize the need for resistance management strategies. A key component of an herbicide resistance management strategy is use of multiple herbicides within a specific crop that represent multiple modes of action (Burgos et al., 2006). In GR cotton, this can be accomplished by use of PRE herbicides and/or various herbicides either mixed with glyphosate applied as a late PDIR spray or used as alternatives to glyphosate (Burgos et al., 2006; Main, 2007; York, 2006; York and Culpepper, 2007).

Diuron, fluometuron, and prometryn are residual herbicides that have historically been widely used in cotton (Buchanan, 1992). Each of these herbicides can be applied PRE or PDIR (Anonymous, 2007a; 2007b; 2007c). In the southeastern United States, fluometuron has commonly been used PRE, while diuron and prometryn have been PDIR. Each of these herbicides has the potential to persist in the soil and injure crops planted in rotation with cotton. Half-lives in field soils are estimated to be about 60, 85, and 90 d for prometryn, fluometuron, and diuron, respectively (Ahrens, 1994). Environmental conditions, application rates, and soil pH, however, can strongly influence soil persistence (Best and Weber, 1974; Johnson et al., 1995; Walker, 1976; Willian et al., 1997).

Cotton, peanut, and tobacco were grown on 352,200 ha, 34,400 ha, and 62,800 ha, respectively, in North Carolina in 2006 (NCDACS, 2007). Two-thirds of the tobacco, all the peanut, and at least 90% of the cotton grown in North Carolina are produced in the coastal plain region, and tobacco and peanut are commonly rotated with cotton. Research to evaluate carryover potential of cotton herbicides to tobacco or peanut has been limited. Studies have shown that fluometuron applied to cotton can persist in the soil and injure soybean (*Glycine max* L.) and cucumber (*Cucumis sativis* L.) planted the following year (Rogers et al., 1985, 1986). Bradley et al. (2001) observed injury to tobacco planted the year following PRE application of fluometuron to cotton. Greater injury was noted when fluometuron applied PDIR followed fluometuron applied PRE, although tobacco yield reductions were not observed. York (1993) reported that fluometuron applied PRE followed by two PDIR applications of fluometuron in cotton did not injure peanut planted the following year; however, both prometryn and fluometuron can be used to control volunteer peanut in cotton (York et al., 1994). Owen et al. (1983) found that peanut was tolerant to prometryn applied PRE when planted at least 11.4 cm deep but not when planted shallow at a depth of 3.8 to 7.6 cm. These results indicate that peanut is sensitive to both prometryn and fluometuron even though they may not carryover to peanut when used alone.

As extension personnel promote the use of residual herbicides, such as fluometuron, diuron, and prometryn, to aid in resistance management, it is important that the potential impact of such herbicides on subsequent crops be understood. The objective of this research was to determine the impact of fluometuron applied PRE alone or followed by diuron or prometryn applied PDIR on peanut and tobacco planted the following year.

MATERIALS AND METHODS

Two-year experiments with cotton/peanut rotations were initiated in separate areas of the same field in 2000, 2001, and 2002 at the Upper Coastal Plain Research Station near Rocky Mount, NC, and in different fields in 2000 and 2001 at the Peanut Belt Research Station near Lewiston, NC. Cotton/tobacco rotations were initiated in 2000, 2001, and 2002 at the Rocky Mount site adjacent to the cotton/peanut experiment and in 2002 on the Lower Coastal Plain Research Station near Kinston, NC. The soil at Rocky Mount was a Norfolk sandy loam (fine-loamy, kaolinitic, thermic Typic Kandiudults) with 1.6% organic matter and pH 6.2. The soil at Lewiston was a Norfolk sandy loam with 1.8% organic matter and pH 6.0 in 2000/2001 and a Goldsboro sandy loam (fine-loamy, siliceous, subactive, thermic Aquic Paleudults) with 2.8% organic matter and pH 5.9 in 2001/2002. The Kinston site had a Norfolk sandy loam with 1.4% organic matter and pH 6.0 in 2002/2003.

Cotton was planted during the first year of the experiment in plots eight rows wide (91-cm spacing) by 18 m. Conventional seedbeds were prepared by disking and then bedding with in-row subsoiling at all locations except Lewiston and Rocky Mount in 2000. Those two locations were strip-tilled into a wheat (*Triticum aestivum* L.) cover crop desiccated 4 wk prior to planting. Cotton planting dates are listed in Table 1. Cotton cultivars included the following: PayMaster 1220 BG/RR (Delta Pine and Land Co.; Scott, MS) at Lewiston in 2000; Deltapine 655 B/RR (Delta and Pine Land Co.) at Kinston and at Rocky Mount in 2000; Sure-Grow 125 BR (Delta Pine and Land Co.) at Rocky Mount in 2001; and Stoneville 4892BR (Stoneville Pedigreed Seed Co.; Memphis, TN) at Lewiston in 2001 and at Rocky Mount in 2002.

The experimental design was a randomized complete block with treatments replicated four times. Treatments applied to cotton consisted of a factorial arrangement of PRE and PDIR herbicides plus a non-treated check. The PRE herbicide was fluometuron (Cotoran 4L; Griffin LLC; Valdosta, GA) at 0 or 1340 g ha^{-1}. Postemergence-directed herbicides included diuron (Direx 4L; Griffin LLC) or prometryn (Caparol 4L; Syngenta Crop Protection, Inc.; Greensboro, NC) applied late PDIR (53 to 63 d after planting; cotton 50 to 65 cm tall) and diuron or prometryn applied early PDIR (41 to 49 d after planting; cotton 25 to 35 cm tall) and late PDIR. Diuron was applied at 480 and 840 g ha^{-1} early PDIR and late PDIR, respectively. Prometryn was applied at 740 and 1340 g ha^{-1} at early PDIR and late PDIR, respectively. Application dates of these herbicides are listed in Table 1. Rates of each herbicide are within the application rate ranges recommended by the manufacturers (Anonymous, 2007a; 2007b; 2007c). Fluometuron was broadcast using a CO_2-pressurized backpack sprayer equipped with flat-fan nozzles (TeeJet XR 11002 nozzles; Spraying Systems Co.; Wheaton, IL) delivering 140 L ha^{-1} at 165 kPa. Diuron and prometryn were broadcast using a CO_2-pressurized backpack sprayer equipped with three flat-fan nozzles (TeeJet XR 110015 nozzles; Spraying Systems Co.) per row middle delivering 140 L ha^{-1} at 138 kPa. All plots received glyphosate isopropylamine salt (Roundup Ultramax; Monsanto Co.; St. Louis, MO) at 620 g a.e. ha^{-1} at the two- and four-leaf cotton growth stages. The experiment sites had low weed infestations, so glyphosate applied twice kept the crop weed-free. Cotton was not cultivated. Fertilization, insect management, growth regulation, and defoliation practices were based on Cooperative Extension Service recommendations for the region. Seed cotton yield at all locations, except Kinston, was determined by mechanical harvest with a spindle picker. Following cotton harvest, stalks were mowed and plots were disked once.

The experimental area was disked again in the spring following cotton and beds for either flue-cured tobacco or peanut were formed based on reference points established the previous year. Tillage and bedding operations were performed parallel to previous cotton rows to minimize lateral movement of treated soil to adjacent plots. Plots, established in the longitudinal center of the previous year's cotton plots,

Table 1. Cotton herbicide application dates and rotational crop planting dates

	Cotton herbicide application dates[z]			Rotational crop	
Location	**PRE**	**Early PDIR**	**Late PDIR**	**Crop**	**Planting date**
Kinston	**8 May 2002**	**21 June 2002**	**9 July 2002**	**Tobacco**	**28 April 2003**
Lewiston	**9 May 2000**	**20 June 2000**	**5 July 2000**	**Peanut**	**12 May 2001**
Lewiston	**1 May 2001**	**18 June 2001**	**29 June 2001**	**Peanut**	**8 May 2002**
Rocky Mount	**4 May 2000**	**20 June 2000**	**5 July 2000**	**Peanut**	**5 May 2001**
Rocky Mount	**1 May 2001**	**18 June 2001**	**29 June 2001**	**Peanut**	**15 May 2002**
Rocky Mount	**10 May 2002**	**20 June 2002**	**2 July 2002**	**Peanut**	**8 May 2003**
Rocky Mount	**4 May 2000**	**20 June 2000**	**5 July 2000**	**Tobacco**	**1 May 2001**
Rocky Mount	**1 May 2001**	**18 June 2001**	**2 July 2001**	**Tobacco**	**3 May 2002**
Rocky Mount	**10 May 2002**	**20 June 2002**	**2 July 2002**	**Tobacco**	**30 April 2003**

[z] PRE = preemergence, applied on day of cotton planting; PDIR = postemergence-directed. Early and late PDIR applied to cotton 25 to 35 cm and 50 to 65 cm tall, respectively.

were eight rows (91-cm spacing) by 12 m for peanut and six rows (1.2-m spacing) by 12 m for tobacco. Tobacco cultivars K 346 and NC 71 (both from Gold Leaf Seed Co.; Hartsville, SC) were planted at Kinston and Rocky Mount, respectively. Peanut cultivar NC 12C (North Carolina Agricultural Research Service; Raleigh, NC) was planted at Lewiston and Rocky Mount. Peanut and tobacco planting dates are listed in Table 1. Weeds were controlled in tobacco with clomazone (Command 3 ME; FMC Corp.; Philadelphia, PA) at 840 g a.i. ha^{-1} applied preplant incorporated and cultivation. Peanut weed control was achieved with pendimethalin (Prowl 3.3 EC; BASF Ag Products; Research Triangle Park, NC) at 840 g a.i. ha^{-1} applied preplant incorporated, metolachlor (Dual 8E; Syngenta Crop Protection) at 2240 g a.i. ha^{-1} applied PRE, and bentazon sodium salt (Basagran; BASF Ag Products) at 560 g a.e. ha^{-1} plus acifluorfen sodium salt (Ultra Blazer; United Phosphorus; Trenton, NJ) at 280 g a.e. ha^{-1} plus 2,4-DB dimethylamine salt (Butyrac 200; Albaugh; Ankeny, IA) at 140 g a.e. ha^{-1} applied postemergence. Peanut was not cultivated. These herbicide programs, along with cultivation of tobacco, kept peanut and tobacco weed-free. Other production practices for tobacco and peanut were based on North Carolina Cooperative Extension Service recommendations to optimize crop yield.

Data were collected from the center two rows of each plot for tobacco and peanut. Visual estimates of percentage peanut and tobacco injury were recorded at 2, 4, and 6 wk after transplanting of tobacco or emergence of peanut. Injury, including chlorosis, necrosis, and plant stunting, was rated on a scale of 0 to 100, where 0 = no injury and 100 = plant death (Frans et al., 1986). Tobacco was harvested four times by stalk position based on maturity and ripeness, and it was cured according to standard procedures for flue-cured tobacco. Cured leaves from individual harvests were weighed and graded separately. Grades were assigned according to USDA standards (USDA-AMS, 1995). A leaf grade index was calculated according to Bowman et al. (1988). Peanut was mechanically dug and inverted in late September or early October based on pod mesocarp color to optimize pod yield (Jordan, 2007). Pods were allowed to air-dry for 4 to 7 d prior to threshing. A 500-g sample of pods was removed from two of the four replicates at Lewiston and Rocky Mount in 2001 to determine percentages of extra large kernels (ELK), total sound mature kernels (TSMK), and fancy pods (FP) (Davidson et al., 1982).

Data were subjected to analysis of variance using the PROC GLM procedure of the Statistical Analysis System (version 9.1; SAS Institute Inc.; Cary, NC) with treatment sums of squares partitioned to reflect the factorial treatment arrangement. Locations were considered as random effects (McIntosh, 1983). Tobacco and peanut yields, tobacco leaf grade index, and percentages of ELK, FP, and TSMK were converted to percentages of the non-treated prior to this analysis. Means were separated using Fisher's Protected LSD test at $P \leq 0.05$. A separate analysis of variance was conducted to compare tobacco and peanut yields, tobacco leaf grade index, and percentages of ELK, FP, and TSMK of treated plots to the non-treated. Means were separated using Dunnett's Procedure at $P \leq 0.05$.

RESULTS AND DISCUSSION

No cotton injury was noted from fluometuron applied PRE. Injury from PDIR herbicides was less than 5% and was limited to minor necrosis on lower leaves contacted by the herbicides (data not shown). Cotton yields did not differ among treatments (data not shown). Averaged over treatments, seed cotton yields were 3430, 3470, and 1490 kg ha^{-1} in 2000, 2001, and 2002, respectively, in the cotton/peanut rotations at Rocky Mount and 3090, 3390, and 1410 kg ha^{-1} in 2000, 2001, and 2002, respectively, in the cotton/tobacco rotations. Lower yields in 2002 were likely associated with dry conditions early in the growing season followed by wet conditions in the later part of the season. The yield trends over this 3-yr period were similar to those for cotton production across the state. Average cotton yields in North Carolina in 2002 were 56 and 50% of the average yields in 2000 and 2001, respectively (USDA-NASS, 2003). Average seed cotton yields at Lewiston were 3870 and 3440 kg ha^{-1} in 2000 and 2001, respectively. Cotton yields were not determined at Kinston.

No visible injury was observed on either tobacco or peanut in the year following application of fluometuron, diuron, or prometryn to cotton (data not shown). Moreover, there was no effect of the previous year's treatment on yield or quality of either tobacco or peanut. When data were subjected to analysis of variance for a randomized complete block treatment arrangement with the no-residual herbicide check included, the treatment by experiment (location and year) interaction was not significant. Averaged over experiments, tobacco yield and leaf grade index in plots receiving cotton herbicides the previous year were not different from the no-residual herbicide check (Table 2). This is similar to the observations by Bradley et al. (2001) that fluometuron applied to cotton had no impact on yield or quality of a succeeding tobacco crop. Similarly, cotton herbicides had no effect on peanut yield or quality measurements (Table 3). York (1993) also observed no adverse effect of fluometuron applied multiple times to cotton on yield or quality of peanut planted the following year.

When peanut and tobacco yield data were converted to a percentage of the no-residual herbicide check and analyzed as a two (rates of fluometuron) by two (either diuron or prometryn PDIR) by two (one or two applications of diuron or prometryn) factorial arrangement, neither main effects nor interactions were significant (Table 4). There also were no significant main effects or interactions for tobacco leaf grade index and peanut quality parameters subjected to the same analysis (analysis not shown).

Table 2. Effect of herbicides applied to a preceding cotton crop on tobacco yield and leaf grade index

Herbicides applied to cotton[y]				
Preemergence	Early PDIR	Late PDIR	Yield (kg ha^{-1})[z]	Leaf grade index[z]
None	None	None	3,360	64
None	None	Diuron	3,330	56
None	Diuron	Diuron	3,570	63
None	None	Prometryn	3,400	62
None	Prometryn	Prometryn	3,340	60
Fluometuron	None	Diuron	3,350	60
Fluometuron	Diuron	Diuron	3,490	63
Fluometuron	None	Prometryn	3,330	60
Fluometuron	Prometryn	Prometryn	3,340	57

[y] Fluometuron preemergence applied at 1340 g ha^{-1}. Diuron and prometryn applied early postemergence-directed (PDIR) at 480 and 740 g ha^{-1}, respectively. Diuron and prometryn applied late PDIR at 840 and 1340 g ha^{-1}, respectively.

[z] Data are averaged over four locations. No treatment differed from the no-residual herbicide check according to Dunnett's procedure at $P \leq 0.05$.

Table 3. Effect of herbicides applied to a preceding cotton crop on peanut yield and quality parameters

Herbicides applied to cotton[y]				Quality parameters[z]		
Preemergence	Early PDIR	Late PDIR	Yield (kg ha^{-1})[z]	ELK (%)	TSMK (%)	FP (%)
None	None	None	3,080	47	70	78
None	None	Diuron	3,030	41	69	77
None	Diuron	Diuron	2,980	46	70	77
None	None	Prometryn	3,180	46	71	76
None	Prometryn	Prometryn	3,030	46	70	79
Fluometuron	None	Diuron	3,070	38	69	72
Fluometuron	Diuron	Diuron	3,080	47	72	77
Fluometuron	None	Prometryn	2,950	48	73	76
Fluometuron	Prometryn	Prometryn	3,030	43	70	78

[y] Fluometuron applied preemergence at 1340 g ha^{-1}. Diuron and prometryn applied early postemergence-directed (PDIR) at 480 and 740 g ha^{-1}, respectively. Diuron and prometryn applied late PDIR at 840 and 1340 g ha^{-1}, respectively.

[z] Yield and quality data are averaged over five and two locations, respectively. No treatment differed from the no-residual herbicide check according to Dunnett's procedure at $P \leq 0.05$. ELK = extra large kernels; TSMK = total sound mature kernels; FP = fancy pods.

Table 4. Analyses of variance (*p*-values) for herbicides applied to the preceding cotton crop for peanut and tobacco yield

Source	Peanut		Tobacco	
	Degrees of freedom	Yield (*p*-value)	Degrees of freedom	Yield (*p*-value)
Experiment (EXP)	4	<0.0001	3	0.1193
Error A	15	-	12	-
Rate fluometuron PRE (FLUO)	1	0.8907	1	0.5384
Number PDIR applications (No. PDIR)	1	0.8103	1	0.0852
PDIR herbicide (PDHERB)	1	0.8464	1	0.0797
FLUO * No. PDIR	1	0.2706	1	0.8621
FLUO * PDHERB	1	0.3212	1	0.9752
No. PD IR* PDHERB	1	0.6116	1	0.0612
FLUO * No. PDIR * PDHERB	1	0.4235	1	0.3679
EXP * FLUO	4	0.9166	3	0.8614
EXP * No. PDIR	4	0.9332	3	0.7831
EXP * PDHERB	4	0.1498	3	0.8185
EXP * FLUO * No. PDIR	4	0.9604	3	0.9518
EXP * FLUO * PDHERB	4	0.9329	3	0.4912
EXP * No. PDIR * PDHERB	4	0.1450	3	0.7542
EXP * FLUO * No. PDIR * PDHERB	4	0.3283	3	0.4722
Error B	105	-	84	-
Coefficient of variation		19.7		8.7

Microbial degradation is the primary means of dissipation of diuron, fluometuron, and prometryn (Andrieux et al., 1997; Mueller et al., 1992; Suzuki and Otani, 2004). Soil moisture during the warmer months of the year, therefore, would have a major impact on herbicide persistence (Bradley et al., 2001; Rogers et al., 1985; Walker, 1976). One might anticipate a greater potential for carryover of these herbicides following a dry growing season. The 2000 growing season (May through October) at Lewiston and Rocky Mount was generally drier than normal (Tables 5 and 6). Total rainfall during this 6-mo period was 16 and 5 cm below the 30-yr average at Lewiston and Rocky Mount, respectively. The first half of the 2001 growing season was generally wetter than normal at Lewiston and Rocky Mount, while the second half of the season had less than normal rainfall. Total rainfall during the 6-mo period of May through October was 1 and 6 cm below normal at Lewiston and Rocky Mount, respectively. The remaining 6 mo (November, 2001 through April, 2002) were drier than normal at both locations. May and June of 2002 were drier than normal at Rocky Mount, but total rainfall for the period of May through October was 10 cm above normal. In contrast, total rainfall during the 2002 growing season at Kinston was 31 cm below normal (Table 7).

Table 5. Precipitation at Lewiston

Month	Precipitation (cm)			
	30-year average[z]	Deviation from 30-year average		
		2000	2001	2002
January	10.9		-8.8	1.3
February	9.0		-3.0	-5.7
March	11.2		0.6	-1.7
April	8.1		-3.3	-3.6
May	9.8	-0.5	-4.7	-5.4
June	11.4	0	14.8	-4.9
July	13.4	-4.5	9.1	-3.2
August	13.6	-2.7	-5.7	-0.8
September	14.3	-0.1	-7.6	-3.1
October	8.4	-8.4	-7.0	
November	7.4	-0.7	-5.7	
December	8.4	-5.4	-5.8	

[z] Data provided by State Climate Office of North Carolina, Raleigh, NC.

Table 6. Precipitation at Rocky Mount

Month	Precipitation (cm)				
	30-year average[z]	Deviation from 30-year average			
		2000	2001	2002	2003
January	10.9		-8.6	1.4	-6.3
February	9.0		-2.5	-5.2	4.5
March	11.2		-2.1	-10.0	-0.9
April	10.5		-6.4	-9.4	3.2
May	8.6	-1.3	-0.1	-5.6	-5.4
June	11.0	-1.4	2.6	-3.4	-3.4
July	8.1	3.6	8.0	10.6	9.0
August	13.6	3.6	-0.7	8.2	7.8
September	14.3	-0.9	-8.8	-5.0	-5.0
October	8.4	-8.4	-7.4	5.3	
November	7.4	-2.4	-5.1	2.8	
December	9.7	-6.6	-7.3	2.0	

[z] Data provided by State Climate Office of North Carolina, Raleigh, NC.

Table 7. Precipitation at Kinston

Month	Precipitation (cm)		
	30-year average[z]	Deviation from 30-year average	
		2002	2003
January	10.9		-8.6
February	9.0		2.0
March	11.2		-2.1
April	8.1		2.6
May	9.8	-3.8	17.2
June	11.4	-5.2	-7.5
July	13.4	-2.3	9.6
August	13.6	-7.1	-1.2
September	14.3	-11.1	-9.8
October	8.4	-1.1	
November	7.4	4.4	
December	8.4	-1.5	

[z] Data provided by State Climate Office of North Carolina, Raleigh, NC.

Results from this research indicate that cotton growers can integrate PRE and PDIR applications of the residual herbicides fluometuron, diuron, and prometryn into a glyphosate-based weed management program to aid in weed resistance management without concern for injury to succeeding crops of peanut or tobacco. Lack of detectable carryover to peanut or tobacco following application of these herbicides during the drier seasons lends confidence to this conclusion.

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