The *Journal of Cotton Science 2* :174-185 (1998)
http://journal.cotton.org, © The Cotton Foundation 1998

WEED MANAGEMENT

Weed Management in Glyphosate-Tolerant Cotton

Alfred S. Culpepper and Alan C. York*

INTERPRETIVE SUMMARY

Cotton is less competitive with weeds than other row crops such as corn or soybean. Additionally, weeds generally interfere more with harvesting of cotton and have a greater adverse impact on quality of the harvested product in cotton as compared with corn or soybean. Hence, effective weed control is one of the most important components of a cotton production system.

Cotton growers rely heavily upon herbicides for weed control. A typical herbicide program for cotton in the Southeast begins with application of two or more herbicides at planting. Most fields also require postemergence herbicides for adequate weed control. Several herbicides can be applied postemergence over the top of cotton for annual and perennial grass control without injury to the crop. Postemergence control of broadleaf weeds has typically been achieved with directed herbicide applications. For effective weed control and adequate crop safety with postemergence-directed herbicides, a height differential between the crop and weeds is required. This height differential is often difficult to achieve as cotton usually grows more slowly early in the season than broadleaf weeds. Additionally, directed application of herbicides to small cotton is a slow and tedious operation requiring special equipment and precise operation. Growers prefer to apply herbicides over the top of cotton. Fluometuron (Cotoran, Meturon, and others) and the organic arsenicals MSMA and DSMA can be applied overtop but weed scientists caution that these herbicides applied in this manner can delay cotton maturity and reduce yield.

Pyrithiobac (Staple) was registered for postemergence over-the-top application to cotton in 1996. Cotton tolerance to pyrithiobac applied in this manner is normally good, and pyrithiobac controls many common annual broadleaf weeds. However, there are several commonly occurring broadleaf weeds not adequately controlled by pyrithiobac. Additionally, pyrithiobac does not control grasses and it only suppresses nutsedge species. Soil-applied herbicides and postemergence-directed herbicides applied after pyrithiobac are normally required for adequate broad spectrum weed control.

Glyphosate (Roundup) is recognized as an environmentally benign herbicide that is very effective on a broad spectrum of annual and perennial grasses, broadleaf weeds, and sedges. This typically nonselective herbicide may be a viable alternative to other commonly used herbicides in cotton production now that transgenic, glyphosate-tolerant cotton is commercially available. Research was conducted in North Carolina to compare weed control and cotton yield, fiber quality, and net returns from glyphosate-tolerant cotton treated with various glyphosate and traditional herbicide systems.

The standard herbicide program of trifluralin (Treflan and others) preplant incorporated and fluometuron preemergence followed by fluometuron plus MSMA postemergence directed 3 to 4 weeks after planting and cyanazine (Bladex, Cy-Pro) plus MSMA directed 6 to 7 weeks after planting controlled large crabgrass, common cocklebur, common lambsquarters, common ragweed, Palmer amaranth, pitted morningglory, prickly sida, sicklepod, smooth pigweed, and tall morningglory at least 98% at late season. Weed control, cotton yield, and net returns were similar when pyrithiobac applied postemergence overtop was substituted for fluometuron plus MSMA postemergence directed.

Glyphosate applied once did not adequately control most species, and cotton yield and net returns were less than with the standard herbicide program. However, weed control, cotton yield, and net returns in systems with glyphosate applied overtop 3 to 4 weeks after planting followed by

Dep. of Crop Science, North Carolina State University, Box 7620, Raleigh, NC 27695-7620. Received 4 May 1998. *Corresp. author (ayork@cropserv1.cropsci.ncsu.edu).

glyphosate or cyanazine plus MSMA directed 6 to 7 weeks after planting were similar to those with the standard herbicide system. Three applications of glyphosate were no more effective than two. Trifluralin and fluometuron were of no benefit in systems with glyphosate applied twice or glyphosate followed by cyanazine plus MSMA. No treatment affected fiber quality.

This research demonstrates that glyphosate applied to glyphosate-tolerant cotton is a convenient and effective alternative to traditional herbicides. Yields and net returns with the glyphosate systems were similar to, but no greater, than with the more effective traditional systems. However, fewer herbicide applications and less total herbicide were required to produce equivalent yields and net returns with the glyphosate systems.

ABSTRACT

An experiment conducted at three locations in North Carolina during 1996 and 1997 compared weed control and cotton (*Gossypium hirsutum* L.) yield, fiber quality, and net returns from glyphosate [*N*-(phosphonomethyl)glycine]-tolerant cotton treated with various glyphosate and traditional herbicide systems. The standard system of trifluralin [2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl) benzenamine] preplant incorporated and fluometuron {*N*,*N*-dimethyl-*N'*-[3-(trifluoromethyl)phenyl]urea} preemergence followed by fluometuron plus MSMA (monosodium methanearsonate) postemergence directed 3 to 4 weeks after planting and cyanazine {2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile} plus MSMA postemergence directed 6 to 7 weeks after planting controlled large crabgrass [*Digitaria sanguinalis* (L.) Scop.], common cocklebur (*Xanthium strumarium* L.), common lambsquarters (*Chenopodium album* L.), common ragweed (*Ambrosia artemisiifolia* L.), *Amaranthus* species, *Ipomoea* species, prickly sida (*Sida spinosa* L.), and sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby] at least 98% at late season. Weed control, cotton yield, and net returns were similar when pyrithiobac {2-chloro-6-[(4,6-dimethoxy-2-pyrimidinyl)thio]benzoic acid, sodium salt} applied postemergence over-the-top was substituted for fluometuron plus MSMA postemergence directed. Glyphosate applied once did not adequately control most species, and cotton yield and net returns were less than with the standard system. However, weed control, cotton yield, and net returns in systems with glyphosate applied postemergence over-the-top 3 to 4 weeks after planting followed by glyphosate or cyanazine plus MSMA postemergence directed 6 to 7 weeks after planting were similar to those with the standard system. Three applications of glyphosate were no more effective than two. Trifluralin and fluometuron were of no benefit in systems with glyphosate applied twice or glyphosate followed by cyanazine plus MSMA. No treatment affected fiber quality.

Soil-applied herbicides such as trifluralin and fluometuron are routinely used to control annual grass and broadleaf weeds in cotton (Wilcut et al., 1995). However, these and other soil-applied herbicides seldom adequately control weeds season-long (Batts and York, 1997; Buchanan, 1992; Culpepper and York, 1997). Consequently, postemergence herbicides are routinely used in conjunction with soil-applied herbicides (Buchanan, 1992). Various herbicides applied postemergence directed can be used to control weeds that escape earlier treatment if a height differential exists between cotton and weeds (Buchanan, 1992; Wilcut et al., 1997). However, growers prefer to apply herbicides postemergence over-the-top rather than postemergence directed, especially on small cotton (Wilcut et al., 1996).

Several graminicides can be applied postemergence over-the-top to control grass weeds without adversely affecting cotton (Wilcut et al., 1995). Fluometuron and MSMA can be applied postemergence over-the-top to control broadleaf weeds. However, postemergence-directed application is generally recommended (York and Culpepper, 1998) because postemergence over-the-top application of these herbicides can injure cotton, delay maturity, and reduce yield (Byrd and York, 1987; Guthrie and York, 1989; Snipes and Byrd, 1994).

Pyrithiobac was registered in 1996 for postemergence over-the-top application to cotton to control broadleaf weeds (Jordan et al., 1993d; Smith et al., 1997). Cotton is normally tolerant of pyrithiobac applied postemergence over-the-top (Jordan et al., 1993a; Culpepper and York, 1997). Pyrithiobac applied postemergence over-the-top controls many of the commonly occurring broadleaf weeds (Wilcut et al., 1995; York and Culpepper, 1998). However, there are some important broadleaf weeds not controlled by pyrithiobac such as common lambsquarters, common ragweed, prickly sida, and sicklepod (Culpepper and York, 1997; Jordan et al., 1993b). Hence, traditional soil-applied herbicides and late postemergence-directed herbicides are generally recommended in conjunction with pyrithiobac (Culpepper and York, 1997; Turner and Allison, 1997; York and Culpepper, 1998). Additionally, grass control by pyrithiobac is inadequate (Ferreira et al. 1995). Graminicides can be mixed with pyrithiobac but reduced grass control may be observed with these mixtures (Jordan et al., 1993c; Tredaway et al., 1998).

Glyphosate is recognized as an effective and environmentally benign herbicide (Franz et al., 1997). In susceptible plants, glyphosate inhibits 5-enolpyruvylshikimate-3-phosphate synthase (E.C. 2.5.1.19), thus limiting synthesis and regulation of the aromatic amino acids (Devine et al., 1993; Franz, 1985). Glyphosate-tolerant cotton was developed by insertion of a gene coding for expression of glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthase (Nida et al., 1996). Glyphosate can be applied postemergence over-the-top from emergence through the four-leaf stage of glyphosate-tolerant cotton (Welch et al., 1997). After the four-leaf stage, glyphosate must be applied as a directed spray to avoid potential fruit abortion (Kalaher et al., 1997).

Glyphosate controls a broad spectrum of annual and perennial grasses, sedges, and broadleaf weeds (Wilcut et al., 1996) and may be a viable alternative to other commonly used herbicides now that glyphosate-tolerant cotton is commercially available. The objective of our research was to compare weed control, cotton yield, and net returns from conventionally tilled glyphosate-tolerant cotton treated with various glyphosate and standard herbicide systems.

MATERIALS AND METHODS

The experiment was conducted on the Cherry Farm Unit at Goldsboro, NC, in 1996 and on the Central Crops Research Station at Clayton, NC, in 1996 and 1997. Soil at Goldsboro was a Kinston loam (fine-loamy, siliceous, nonacid thermic Typic Fluvaquents) with 2.5% organic matter and pH 5.3. Soils at Clayton included a Goldsboro loamy sand (fine-loamy, siliceous, thermic Aquic Paleudults) with 2.1% organic matter and pH 6.0 in 1996 and a Dothan loamy sand (fine-loamy, siliceous, thermic Plinthic Paleudults) with 2.7% organic matter and pH 6.1 in 1997. Cultural practices, including fertilization, insect management, plant growth management, and defoliation, were standard for North Carolina.

Cotton cv. Coker 312-1445RR and Paymaster 1220RR were planted in conventionally prepared seedbeds in 1996 and 1997, respectively. Planting dates were 3 and 9 May at Clayton and Goldsboro, respectively, in 1996 and 16 May 1997 at Clayton. Plots were four 91-cm rows by 11 m. The experimental design was a randomized complete block with treatments replicated four times.

Treatments consisted of a factorial arrangement of four soil-applied and five postemergence herbicide options. Soil-applied herbicide options were no herbicide, trifluralin preplant incorporated at 0.6 kg a.i. ha^{-1}, fluometuron preemergence at 1.4 kg a.i. ha^{-1}, and trifluralin preplant incorporated plus fluometuron preemergence at 0.6 plus 1.4 kg ha^{-1}. Trifluralin was incorporated with a power-driven, vertical-action tiller at Clayton and with two passes of a field cultivator at Goldsboro. Postemergence herbicide options included the following: glyphosate (Roundup Ultra from Monsanto Co., St. Louis, MO) applied early postemergence over-the-top; glyphosate applied mid-postemergence directed; glyphosate applied early postemergence over-the-top and mid-postemergence directed; glyphosate applied early postemergence over-the-top, mid-postemergence directed, and late postemergence directed; and glyphosate applied early postemergence over-the-top followed by cyanazine plus MSMA applied mid-postemergence directed. Glyphosate and cyanazine plus MSMA were applied at 0.56 kg a.i. ha^{-1} and 1.1 plus 2.2 kg a.i. ha^{-1}, respectively. The postemergence-directed herbicides were applied to the lower 5 to 7 cm of the cotton plants. In addition to treatments within the factorial, the experiment included herbicide systems with trifluralin preplant incorporated plus fluometuron preemergence at 0.6 plus 1.4 kg ha^{-1} applied alone or in conjunction with the following: pyrithiobac early postemergence over-the-top followed by cyanazine plus MSMA mid-postemergence directed; fluometuron plus MSMA early postemergence directed followed by cyanazine plus MSMA mid-postemergence directed; and cyanazine plus MSMA mid-postemergence directed. Pyrithiobac was applied at 0.07 kg a.i. ha^{-1}, and fluometuron plus MSMA at 1.1 plus 2.2 kg ha^{-1} was directed to the lower 3 to 5 cm of the cotton plants. A nontreated check also was included.

Early postemergence over-the-top and postemergence-directed herbicides were applied 3 to 4 weeks after planting when cotton was 7 to 10 cm tall with two to three leaves. Mid-postemergence-directed herbicides were applied 6 to 7 weeks after planting when cotton was 20 to 26 cm with seven to eight leaves. Late postemergence-directed herbicides were applied 10 to 11 weeks after planting when cotton was 60 to 70 cm tall and blooming. Weed species, densities in the nontreated checks, and sizes at time of postemergence herbicide applications are listed in Table 1.

A nonionic surfactant (X-77 Spreader, alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol from Valent USA Corp., Walnut Creek, CA) at 0.25% (v v^{-1}) was included with all postemergence herbicides except glyphosate. Herbicides were broadcast, and plots were not cultivated. Soil-applied and postemergence over-the-top herbicides were applied using a CO_2-pressurized backpack sprayer equipped with flat fan nozzles and calibrated to deliver 160 L ha^{-1} at 170 kPa. The postemergence-directed herbicides were applied using a CO_2-pressurized backpack sprayer equipped with three equally spaced flat fan nozzles per row middle and calibrated to deliver 250 L ha^{-1} at 170 kPa.

Weed control was estimated visually 14 days after each postemergence herbicide application and late in the season (about 1 month prior to harvest). Crop injury was estimated visually immediately prior to and at 5 and 14 days after each postemergence application. Visual estimates of weed control and cotton injury were based on a scale of 0 to 100 where 0 = no weed control or cotton injury and 100 = complete weed control or cotton death. The center two rows of each plot were harvested with a spindle picker. A 200 g sample of harvested seed cotton was collected and used for percentage lint and fiber quality determinations. Fiber length, fiber length uniformity, fiber strength,

Table 1. Weed densities and growth stages at time of early, mid-, and late postemergence (POST) applications.

Location and weed species	Density†	Growth stage†			
		Early POST	Mid POST‡	Mid POST§	Late POST¶
	No. m^{-2}	No. of leaves			
Clayton, 1996					
Palmer amaranth	182	1–7	1–6	4–10	–#
Large crabgrass	35	1–4	1–4	6–10	--
Common cocklebur	16	1–3	1–3	2–8	--
Common lambsquarters	13	2–6	1–6	6–10	--
Common ragweed	12	2–5	1–5	5–8	--
Pitted morningglory	2	1–3	1–3	2–8	2–8
Goldsboro, 1996					
Palmer amaranth	5	2–4	1–6	5–10	--
Common lambsquarters	2	3–4	1–5	8–10	--
Common ragweed	1	2–4	1–4	5–6	--
Pitted morningglory	6	2–5	1–3	1–8	7–10
Prickly sida	6	1–4	2–4	4–10	--
Sicklepod	49	1–3	1–3	1–6	2–4
Clayton, 1997					
Common lambsquarters	1	1–3	1–6	4–18	5–6
Common ragweed	1	1–2	1–4	6–8	2–4
Large crabgrass	185	1–3	1–4	8–10	5–6
Tall morningglory	14	1–3	1–3	1–10	1–5
Smooth pigweed	225	1–4	1–5	2–15	2–6

† Growth stage and weed density in nontreated check.
‡ Following early POST herbicide application.
§ In absence of early POST herbicide.
¶ Following two POST applications of glyphosate.
# Weed species not present after soil-applied, early POST, and mid-POST treatments.

and micronaire were determined by High Volume Instrumentation testing at Cotton Incorporated in Raleigh, NC (Sasser, 1981).

An enterprise budget reflecting input costs, cotton yield, and average cotton price was calculated for each plot to determine net returns to land, overhead, and management (Brown et al., 1997). Market prices used for lint were \$1.56 kg^{-1} in 1996 and \$1.43 kg^{-1} in 1997. These prices were based on seasonal averages at the New York Cotton Exchange minus average discounts for cotton grown in North Carolina (J. Cooper, 1997, personal communication). Market prices for seed were \$0.11 kg^{-1}. Glyphosate-tolerant seed and technology fee costs were \$1.98 kg^{-1} and \$19.76 ha^{-1}, respectively. Herbicide costs per hectare were as follows: cyanazine plus MSMA, \$29.74; fluometuron, \$22.73; fluometuron plus MSMA, \$36.01; glyphosate, \$21.34; pyrithiobac, \$62.24; and trifluralin \$8.82. Nonionic surfactant costs per hectare for postemergence over-the-top and postemergence-directed applications were \$1.28 and \$2.49, respectively. These costs reflect average prices quoted by two major dealers for the 1997 growing season. Input costs, except those associated with cultivar selection and weed management, were based upon a budget prepared by the North Carolina Cooperative Extension Service (Brown et al., 1997).

Statistical Analyses

Data for the soil-applied and postemergence herbicide options within the factorial were subjected to analysis of variance with basic partitioning for the factorial treatment arrangement. However, conclusions from the factorial analysis did not differ from an analysis including those treatments in the factorial arrangement plus the additional treatments. Results are therefore presented using the combined treatment analysis. Nontransformed data for visual estimations are presented as arcsin square root transformation did not affect data interpretation. Residual plots were examined for homogeneity of error variance, and data were pooled when appropriate. Means were separated using the appropriate Fisher's Protected LSD at $P = 0.05$. A separate analysis of variance compared the nontreated check with all herbicide systems.

RESULTS AND DISCUSSION

Weed Control

Lack of herbicide treatment by location interaction allowed pooling of data for species present at multiple locations. Data from the late-season evaluation are presented. Except for sicklepod, tall morningglory [*Ipomoea purpurea* (L.) Roth], and common cocklebur in systems with only trifluralin plus fluometuron, weed control was greater with all herbicide systems than in the nontreated check.

Trifluralin plus fluometuron did not adequately control weeds. This treatment controlled large crabgrass greater than 90% 5 to 6 weeks after planting (data not shown), but control declined to 73% late in the season (Table 2). Cyanazine plus MSMA mid-postemergence directed increased late-season control to 83%, and pyrithiobac early postemergence over-the-top or fluometuron plus MSMA early postemergence directed further increased control to 98%. Large crabgrass was in the one- to four-leaf stage at time of early postemergence-directed application (Table 1). MSMA controls small annual grasses (Byrd and York, 1987). Although pyrithiobac did not control large crabgrass, it did suppress its growth such that it was still small enough to be controlled by MSMA at the late postemergence-directed application (Culpepper and York, 1997; Jordan et al., 1993c).

Trifluralin plus fluometuron controlled common lambsquarters, Palmer amaranth (*Amaranthus palmeri* S. Wats.), and common ragweed 94, 81, and 76%, respectively, whereas late-season control of prickly sida, smooth pigweed (*Amaranthus hybridus* L.), common cocklebur, sicklepod, pitted morningglory (*Ipomoea lacunosa* L.), and tall morningglory ranged from 0 to 60% (Tables 2, 3, and 4). Cyanazine plus MSMA applied mid-postemergence directed increased late-season control of prickly sida, sicklepod, pitted morningglory, and tall morningglory to 90 to 94% and common ragweed and common lambsquarters to at least 99%. Because of this high level of control, adding pyrithiobac early postemergence over-the-top or fluometuron plus MSMA early postemergence directed did not further improve late-season control of these species. Control of common cocklebur and the *Amaranthus* species by

Table 2. Late-season control of large crabgrass, common lambsquarters, and common ragweed in glyphosate-tolerant cotton by herbicide systems using glyphosate and traditional herbicides.†

Herbicide applications‡,§				Large crabgrass	Common lambsquarters	Common ragweed
PPI and PRE	Early POST	Mid-POST	Late POST			
					%	
Trif./fluom.	None	None	None	73 ef	94 b	76 c
Trif./fluom.	None	Cyan. + MSMA	None	83 cd	100 a	99 a
Trif./fluom.	Pyrithiobac	Cyan. + MSMA	None	98 a	100 a	100 a
Trif./fluom.	Fluom. + MSMA	Cyan. + MSMA	None	98 a	100 a	100 a
None	Glyphosate	None	None	68 fg	74 d	86 b
None	None	Glyphosate	None	61 g	47 f	52 d
None	Glyphosate	Glyphosate	None	93 ab	100 a	100 a
None	Glyphosate	Glyphosate	Glyphosate	96 ab	100 a	100 a
None	Glyphosate	Cyan. + MSMA	None	96 ab	100 a	100 a
Trifluralin	Glyphosate	None	None	77 de	85 c	85 b
Trifluralin	None	Glyphosate	None	85 c	64 e	70 c
Trifluralin	Glyphosate	Glyphosate	None	96 ab	100 a	100 a
Trifluralin	Glyphosate	Glyphosate	Glyphosate	98 a	100 a	100 a
Trifluralin	Glyphosate	Cyan. + MSMA	None	97 ab	100 a	100 a
Fluometuron	Glyphosate	None	None	77 de	100 a	100 a
Fluometuron	None	Glyphosate	None	90 bc	100 a	100 a
Fluometuron	Glyphosate	Glyphosate	None	97 ab	100 a	100 a
Fluometuron	Glyphosate	Glyphosate	Glyphosate	98 a	100 a	100 a
Fluometuron	Glyphosate	Cyan. + MSMA	None	97 ab	100 a	100 a
Trif./fluom.	Glyphosate	None	None	93 ab	100 a	100 a
Trif./fluom.	None	Glyphosate	None	96 ab	98 ab	98 a
Trif./fluom.	Glyphosate	Glyphosate	None	98 a	100 a	100 a
Trif./fluom.	Glyphosate	Glyphosate	Glyphosate	98 a	100 a	100 a
Trif./fluom.	Glyphosate	Cyan. + MSMA	None	99 a	100 a	100 a

† Data pooled over locations. Means within a species followed by the same letter are not different according to Fisher's Protected LSD test at $P = 0.05$.

‡ Abbreviations: Cyan. + MSMA = cyanazine plus MSMA; Fluom. + MSMA = fluometuron plus MSMA; POST = postemergence; PPI = preplant incorporated; PRE = preemergence; Trif./fluom. = trifluralin followed by fluometuron.

§ Trifluralin, fluometuron, glyphosate, pyrithiobac, fluometuron plus MSMA, and cyanazine plus MSMA were applied at 0.6, 1.4, 0.56, 0.07, 1.1 + 2.2, and 1.1 + 2.2 kg ha^{-1}, respectively. Trifluralin and fluometuron were applied PPI and PRE, respectively. Fluometuron plus MSMA, cyanazine plus MSMA, and glyphosate at mid-POST and late POST were applied as directed sprays.

trifluralin plus fluometuron followed by cyanazine plus MSMA was no better than control by trifluralin plus fluometuron alone. Lack of control of these species by cyanazine plus MSMA was due primarily to the large size of the weeds at time of mid-postemergence-directed application (Table 1) and the resulting poor coverage by the directed spray. However, Palmer amaranth, smooth pigweed, and common cocklebur were controlled 99 to 100% late in the season in systems that included trifluralin preplant incorporated, fluometuron preemergence, pyrithiobac early postemergence over-the-top or fluometuron plus MSMA early postemergence directed, and cyanazine plus MSMA late postemergence directed. Other researchers have reported good control of common cocklebur and *Amaranthus* species by fluometuron plus MSMA and pyrithiobac (Culpepper and York, 1997; Hair et al., 1996; Jordan et al., 1993d).

Glyphosate applied once did not adequately control large crabgrass or the broadleaf weeds (Tables 2, 3, and 4). However, glyphosate applied early postemergence over-the-top was 13, 20, 26, 27, 28, 34, and 48% more effective on pitted morningglory, Palmer amaranth, smooth pigweed, common lambsquarters, tall morningglory, common ragweed, and common cocklebur, respectively, than glyphosate applied mid-postemergence directed. Weeds were larger at mid- postemergence directed (Table 1), and larger weeds are more difficult to control with glyphosate (Jordan et al., 1997). Additionally, poorer control by glyphosate at mid-postemergence directed was at least partially due to less coverage on the larger weeds by the directed spray. Sicklepod and prickly sida were more effectively controlled late in the season by glyphosate applied mid-postemergence directed (Table 4). Glyphosate applied early postemergence over-the-top initially controlled both species greater

Table 3. Late-season control of Palmer amaranth, smooth pigweed, and common cocklebur in glyphosate-tolerant cotton by herbicide systems using glyphosate and traditional herbicides.†

Herbicide applications‡,§				Palmer amaranth	Smooth pigweed	Common cocklebur
PPI and PRE	Early POST	Mid-POST	Late POST			
					%	
Trif./fluom.	None	None	None	81 c	60 c	3 d
Trif./fluom.	None	Cyan. + MSMA	None	79 cd	64 c	15 d
Trif./fluom.	Pyrithiobac	Cyan. + MSMA	None	100 a	100 a	99 a
Trif./fluom.	Fluom. + MSMA	Cyan. + MSMA	None	99 a	100 a	100 a
None	Glyphosate	None	None	63 e	41 d	63 bc
None	None	Glyphosate	None	43 f	15 f	15 d
None	Glyphosate	Glyphosate	None	99 a	98 a	100 a
None	Glyphosate	Glyphosate	Glyphosate	99 a	100 a	90 a
None	Glyphosate	Cyan. + MSMA	None	98 a	99 a	93 a
Trifluralin	Glyphosate	None	None	82 bc	80 b	45 c
Trifluralin	None	Glyphosate	None	69 de	30 d	15 d
Trifluralin	Glyphosate	Glyphosate	None	100 a	99 a	97 a
Trifluralin	Glyphosate	Glyphosate	Glyphosate	100 a	100 a	100 a
Trifluralin	Glyphosate	Cyan. + MSMA	None	100 a	100 a	100 a
Fluometuron	Glyphosate	None	None	76 cd	81 b	62 bc
Fluometuron	None	Glyphosate	None	83 bc	76 b	56 bc
Fluometuron	Glyphosate	Glyphosate	None	100 a	100 a	98 a
Fluometuron	Glyphosate	Glyphosate	Glyphosate	100 a	100 a	88 a
Fluometuron	Glyphosate	Cyan. + MSMA	None	100 a	100 a	100 a
Trif./fluom.	Glyphosate	None	None	86 bc	94 a	54 bc
Trif./fluom.	None	Glyphosate	None	93 ab	83 b	68 b
Trif./fluom.	Glyphosate	Glyphosate	None	99 a	98 a	100 a
Trif./fluom.	Glyphosate	Glyphosate	Glyphosate	100 a	100 a	100 a
Trif./fluom.	Glyphosate	Cyan. + MSMA	None	100 a	100 a	100 a

† Data pooled over locations. Means within a species followed by the same letter are not different according to Fisher's Protected LSD test at $P = 0.05$.

‡ Abbreviations: Cyan. + MSMA = cyanazine plus MSMA; Fluom. + MSMA = fluometuron plus MSMA; POST = postemergence; PPI = preplant incorporated; PRE = preemergence; Trif./fluom. = trifluralin followed by fluometuron.

§ Trifluralin, fluometuron, glyphosate, pyrithiobac, fluometuron plus MSMA, and cyanazine plus MSMA were applied at 0.6, 1.4, 0.56, 0.07, 1.1 + 2.2, and 1.1 + 2.2 kg ha^{-1}, respectively. Trifluralin and fluometuron were applied PPI and PRE, respectively. Fluometuron plus MSMA, cyanazine plus MSMA, and glyphosate at mid-POST and late POST were applied as directed sprays.

than 90% (data not shown), but continued germination resulted in poor late-season control. The mid-postemergence-directed application was somewhat less effective initially but more effective late in the season because fewer sicklepod and prickly sida germinated following the later application.

Large crabgrass and prickly sida were controlled similarly by trifluralin preplant incorporated plus fluometuron preemergence and by glyphosate early postemergence over-the-top (Tables 2 and 4). Glyphosate applied early postemergence over-the-top was less effective on common lambsquarters and both *Amaranthus* species late in the season than trifluralin plus fluometuron because of continued germination after the early postemergence over-the-top application (Tables 2 and 3). However, glyphosate early postemergence over-the-top was more effective than trifluralin plus fluometuron on common ragweed, common cocklebur, pitted morningglory, tall morningglory, and sicklepod (Tables 2, 3, and 4).

Glyphosate applied twice controlled all species at least 93% late in the season, and glyphosate applied three times was no more effective than glyphosate applied twice (Tables 2, 3, and 4). All species were controlled similarly by glyphosate applied twice and by glyphosate early postemergence over-the-top followed by cyanazine plus MSMA. Most importantly, glyphosate applied twice or glyphosate early postemergence over-the-top followed by cyanazine plus MSMA mid-postemergence directed controlled all species as well as the traditional systems consisting of trifluralin preplant incorporated, fluometuron preemergence, pyrithiobac early postemergence over-the-top or fluometuron plus MSMA early postemergence directed, and cyanazine plus MSMA mid-postemergence directed. Each of these treatments controlled all species at least 93% late in the season.

The soil-applied herbicides generally increased late-season weed control in systems with glyphosate applied once. Fluometuron and trifluralin plus fluometuron increased control of more species than trifluralin alone (Tables 2, 3, and 4). For example, trifluralin increased control of large crabgrass, common lambsquarters, common ragweed, Palmer amaranth, and smooth pigweed in systems with glyphosate applied once but did not increase control of common cocklebur, pitted morningglory, tall morningglory, sicklepod, or prickly sida. Trifluralin plus fluometuron increased control of all species except sicklepod and prickly sida. Trifluralin plus fluometuron followed by glyphosate early postemergence over-the-top was as effective on large crabgrass, common lambsquarters, common ragweed, prickly sida, and smooth pigweed as glyphosate applied twice. Trifluralin plus fluometuron followed by glyphosate mid-postemergence directed was as effective as glyphosate applied twice on large crabgrass, common lambsquarters, common ragweed, prickly sida, Palmer amaranth, pitted morningglory, and sicklepod. Trifluralin plus fluometuron followed by glyphosate at early postemergence over-the-top or mid-postemergence directed was less effective than glyphosate applied twice on common cocklebur and tall morningglory. In no case was trifluralin plus fluometuron followed by glyphosate applied once more effective than glyphosate applied twice. Soil-applied herbicides did not increase control of any species in systems with glyphosate applied twice or with glyphosate early postemergence over-the-top followed by cyanazine plus MSMA mid-postemergence directed. Similar results have been reported (Isgett et al., 1997).

Table 4. Late-season control of pitted morningglory, tall morningglory, sicklepod, and prickly sida in glyphosate-tolerant cotton by herbicide systems using glyphosate and traditional herbicides.†

Herbicide applications‡,§				Morningglory			
PPI and PRE	Early POST	Mid-POST	Late POST	Pitted	Tall	Sicklepod	Prickly sida
				%			
Trif./fluom.	None	None	None	23 g	13 f	0 f	60 d
Trif./fluom.	None	Cyan. + MSMA	None	94 a	94 a	94 ab	90 ab
Trif./fluom.	Pyrithiobac	Cyan. + MSMA	None	99 a	99 a	98 ab	100 a
Trif./fluom.	Fluom. + MSMA	Cyan. + MSMA	None	99 a	100 a	99 a	98 a
None	Glyphosate	None	None	50 e	43 d	50 e	73 bcd
None	None	Glyphosate	None	37 f	15 ef	84 bc	92 a
None	Glyphosate	Glyphosate	None	93 ab	95 a	96 ab	95 a
None	Glyphosate	Glyphosate	Glyphosate	99 a	100 a	100 a	100 a
None	Glyphosate	Cyan. + MSMA	None	98 a	97 a	96 ab	98 a
Trifluralin	Glyphosate	None	None	48 ef	52 cd	57 e	70 cd
Trifluralin	None	Glyphosate	None	47 ef	28 e	88 ab	91 ab
Trifluralin	Glyphosate	Glyphosate	None	92 ab	93 a	99 a	96 a
Trifluralin	Glyphosate	Glyphosate	Glyphosate	99 a	100 a	99 a	100 a
Trifluralin	Glyphosate	Cyan. + MSMA	None	98 a	99 a	99 a	99 a
Fluometuron	Glyphosate	None	None	67 d	77 b	73 cd	82 abc
Fluometuron	None	Glyphosate	None	76 cd	58 c	98 ab	98 a
Fluometuron	Glyphosate	Glyphosate	None	93 ab	95 a	97 ab	98 a
Fluometuron	Glyphosate	Glyphosate	Glyphosate	99 a	100 a	100 a	99 a
Fluometuron	Glyphosate	Cyan. + MSMA	None	99 a	98 a	98 ab	100 a
Trif./fluom.	Glyphosate	None	None	73 cd	78 b	64 de	92 ab
Trif./fluom.	None	Glyphosate	None	81 bc	74 b	96 ab	98 a
Trif./fluom.	Glyphosate	Glyphosate	None	96 a	94 a	95 ab	97 a
Trif./fluom.	Glyphosate	Glyphosate	Glyphosate	98 a	100 a	99 a	100 a
Trif./fluom.	Glyphosate	Cyan. + MSMA	None	99 a	100 a	99 a	100 a

† Data pooled over locations. Means within a species followed by the same letter are not different according to Fisher's Protected LSD test at $P = 0.05$.

‡ Abbreviations: Cyan. + MSMA = cyanazine plus MSMA; Fluom. + MSMA = fluometuron plus MSMA; POST = postemergence; PPI = preplant incorporated; PRE = preemergence; Trif./fluom. = trifluralin followed by fluometuron.

§ Trifluralin, fluometuron, glyphosate, pyrithiobac, fluometuron plus MSMA, and cyanazine plus MSMA were applied at 0.6, 1.4, 0.56, 0.07, 1.1 + 2.2, and 1.1 + 2.2 kg ha^{-1}, respectively. Trifluralin and fluometuron were applied PPI and PRE, respectively. Fluometuron plus MSMA, cyanazine plus MSMA, and glyphosate at mid-POST and late POST were applied as directed sprays.

Cotton Response

Crop Injury

Glyphosate did not visibly injure cotton nor cause noticeable fruit abortion (Kalaher et al., 1997). Fluometuron plus MSMA, pyrithiobac, and cyanazine plus MSMA injured cotton 7, 4, and 5%, respectively, 5 days after application and less than 2% 14 days after application (data not shown).

Fiber Quality

Micronaire, fiber strength, fiber length, and fiber length uniformity were not affected by herbicide programs. Micronaire, fiber strength, fiber length, and fiber length uniformity averaged 4.6, 288 kN m kg^{-1}, 25.6 mm, and 84.4%, respectively (data not shown).

Lint Yield and Net Returns

Lack of herbicide by location interactions allowed pooling of yield and net returns over locations. Nontreated checks were assigned yields of zero as mechanical harvest was not possible because of severe weed infestations. Relative to the nontreated check, which returned -\$705 ha^{-1}, all herbicide systems except trifluralin plus fluometuron with no postemergence herbicides increased yields and net returns (Table 5).

Trends in cotton yield and the resulting net returns correlated well with weed control. Among the 24 herbicide systems, the lowest yield and net returns were in the system consisting of only trifluralin plus fluometuron (Table 5). Cotton in this system yielded 265 kg ha^{-1} for a net loss of \$405 ha^{-1}. Addition of cyanazine plus MSMA applied mid postemergence directed to this system increased yield 855 kg ha^{-1}, or 323%, and increased net returns \$1245 ha^{-1}. Yields and net returns were similar in systems containing pyrithiobac early postemergence over-the-top or fluometuron plus MSMA early postemergence directed. Adding either of these early postemergence treatments to a

Table 5. Cotton lint yield and net returns from glyphosate-tolerant cotton with herbicide systems using glyphosate and traditional herbicides.†

Herbicide applications‡,§					
PPI and PRE	Early POST	Mid-POST	Late POST	Lint yield	Net returns
				-- kg ha^{-1} --	-- \$ ha^{-1} --
Trif./fluom.	None	None	None	265 j	-405 i
Trif./fluom.	None	Cyan. + MSMA	None	1120 fgh	840 fgh
Trif./fluom.	Pyrithiobac	Cyan. + MSMA	None	1950 ab	2020 ab
Trif./fluom.	Fluom. + MSMA	Cyan. + MSMA	None	1865 ab	1905 abc
None	Glyphosate	None	None	1410 def	1345 def
None	None	Glyphosate	None	795 i	445 h
None	Glyphosate	Glyphosate	None	1815 abc	1910 abc
None	Glyphosate	Glyphosate	Glyphosate	1810 abc	1865 abc
None	Glyphosate	Cyan. + MSMA	None	1760 abc	1815 a-d
Trifluralin	Glyphosate	None	None	1260 efg	1095 efg
Trifluralin	None	Glyphosate	None	975 ghi	670 gh
Trifluralin	Glyphosate	Glyphosate	None	1860 ab	1950 ab
Trifluralin	Glyphosate	Glyphosate	Glyphosate	1785 abc	1810 a-d
Trifluralin	Glyphosate	Cyan. + MSMA	None	1805 abc	1865 abc
Fluometuron	Glyphosate	None	None	1495 cde	1435 cde
Fluometuron	None	Glyphosate	None	1495 cde	1425 cde
Fluometuron	Glyphosate	Glyphosate	None	1790 abc	1835 a-d
Fluometuron	Glyphosate	Glyphosate	Glyphosate	1830 abc	1865 abc
Fluometuron	Glyphosate	Cyan. + MSMA	None	1890 ab	1990 ab
Trif./fluom.	Glyphosate	None	None	1685 bcd	1700 bcd
Trif./fluom.	None	Glyphosate	None	1920 ab	2045 ab
Trif./fluom.	Glyphosate	Glyphosate	None	1745 bcd	1755 bcd
Trif./fluom.	Glyphosate	Glyphosate	Glyphosate	1745 bcd	1735 bcd
Trif./fluom.	Glyphosate	Cyan. + MSMA	None	2095 a	2285 a

† Data pooled over locations. Means within a species followed by the same letter are not different according to Fisher's Protected LSD test at $P = 0.05$. Yield and net returns of the nontreated check were 0 kg ha^{-1} and -\$705 ha^{-1}, respectively.

‡ Abbreviations: Cyan. + MSMA = cyanazine plus MSMA; Fluom. + MSMA = fluometuron plus MSMA; POST = postemergence; PPI = preplant incorporated; PRE = preemergence; Trif./fluom. = trifluralin followed by fluometuron.

§ Trifluralin, fluometuron, glyphosate, pyrithiobac, fluometuron plus MSMA, and cyanazine plus MSMA were applied at 0.6, 1.4, 0.56, 0.07, 1.1 + 2.2, and 1.1 + 2.2 kg ha^{-1}, respectively. Trifluralin and fluometuron were applied PPI and PRE, respectively. Fluometuron plus MSMA, cyanazine plus MSMA, and glyphosate at mid-POST and late POST were applied as directed sprays.

system with trifluralin preplant incorporated, fluometuron preemergence, and cyanazine plus MSMA mid postemergence directed increased yield 67 to 74% and increased net returns \$1065 to \$1180 ha^{-1}.

Yields and net returns from systems with glyphosate applied once in the absence of soil-applied herbicides were less than with most other systems (Table 5). However, similar to observations with weed control, greater yield and net returns were obtained when glyphosate was applied early postemergence over-the-top as compared with mid-postemergence directed. Trifluralin applied preplant incorporated did not increase yield or net returns in systems with glyphosate applied early postemergence over-the-top or mid-postemergence directed. Similarly, fluometuron and trifluralin plus fluometuron did not increase yield or net returns in systems with glyphosate applied early postemergence over-the-top. However, both fluometuron and trifluralin plus fluometuron increased yield and net returns in systems with glyphosate applied mid-postemergence directed. Apparently there was sufficient weed competition to adversely affect cotton when glyphosate application was delayed to mid-postemergence directed in the absence of fluometuron. Soil-applied herbicides did not affect yield or net returns in systems with glyphosate applied two or three times or in systems with glyphosate applied early postemergence over-the-top followed by cyanazine plus MSMA mid-postemergence directed. However, there was no evidence of adverse effects from use of the soil-applied herbicides.

Yields and net returns from systems with glyphosate applied twice or with glyphosate applied early postemergence over-the-top followed by cyanazine plus MSMA mid-postemergence directed were similar (Table 5). Yield and net returns from either of these systems were similar to yields and net returns from standard herbicide systems consisting of trifluralin preplant incorporated, fluometuron preemergence, pyrithiobac early postemergence over-the-top or fluometuron plus MSMA early postemergence directed, and cyanazine plus MSMA mid- postemergence directed. A third application of glyphosate was of no benefit.

Results from this and other experiments in North Carolina (Culpepper and York, 1997) demonstrate that excellent weed control can be obtained in cotton with traditional herbicide programs. Our results also demonstrate that glyphosate applied to glyphosate-tolerant cotton is an effective alternative to traditional herbicide programs. Yields and net returns were no greater with the glyphosate systems than with the more effective traditional systems. However, fewer herbicide applications and less total herbicide were required to produce equivalent yields and net returns in the glyphosate systems. Additionally, glyphosate systems give the added benefit of crop rotational flexibility (Batts et al., 1998; York, 1993).

It must be noted that although our study included many of the weeds commonly found in cotton (Dowler, 1995), no weeds tolerant of glyphosate or particularly difficult to control by glyphosate were present. A benefit from use of soil-applied herbicides or pyrithiobac in the glyphosate systems may have been observed if species such as Florida pusley (*Richardia scabra* L.), spreading dayflower (*Commelina diffusa* Burm. f.), Asiatic dayflower (*Commelina communis* L.), or hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. ex A.W. Hill] had been present (York and Culpepper, 1998).

ACKNOWLEDGMENT

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

REFERENCES

Batts, R.B., A.L. Bradley, Jr., F.H. Yelverton, and A.C. York. 1998. Potential for Cotoran to carry over to flue-cured tobacco. p. 873. *In* P. Dugger and D.A. Richter (ed.) Proc. Beltwide Cotton Conf., San Diego, CA. 5–9 Jan. 1998. Natl. Cotton Council Am., Memphis, TN.

Batts, R.B., and A.C. York. 1997. Weed management in no-till cotton (*Gossypium hirsutum*) with thiazopyr. Weed Technol. 11:580–585.

Brown, B., T. Cole, and K. Edmisten. 1997. North Carolina farm enterprise budget guidelines. Misc. Publ. North Carlina Coop. Ext. Serv., Raleigh.

Buchanan, G.A. 1992. Trends in weed control methods. p. 47–72. *In* C.G. McWhorter and J.R. Abernathy (ed.) Weeds of cotton: Characterization and control. The Cotton Foundation, Memphis, TN.

Byrd, J.D., Jr., and A.C. York. 1987. Interaction of fluometuron and MSMA with sethoxydim and fluazifop. Weed Sci. 35:270–276.

Culpepper, A.S., and A.C. York. 1997. Weed management in no-tillage bromoxynil-tolerant cotton (*Gossypium hirsutum*). Weed Technol. 11:335–345.

Devine, M.D., S.O. Duke, and C. Fedtke. 1993. Inhibition of amino acid biosynthesis. p. 252–263. *In* Physiology of herbicide action. Prentice Hall, Englewood Cliffs, NJ.

Dowler, C.C. 1995. Weed survey - southern states. p. 290–325. *In* J.E. Street (ed.) 48th Proc. South. Weed Sci. Soc., Memphis, TN. 16–18 Jan. 1995. South. Weed Sci. Soc., Champaign, IL.

Ferreira, K.L., J.D. Burton, and H.D. Coble. 1995. Physiological basis for antagonism of fluazifop-P by DPX-PE350. Weed Sci. 43:184–191.

Franz, J.E. 1985. Discovery, development and chemistry of glyphosate. p. 3–14. *In* E. Grossbard and D. Atkinson (ed.) The herbicide glyphosate. Butterworth and Co., Ltd., London.

Franz, J.E., M.K. Mao, and J.A. Sikorski. 1997. Toxicology and environmental properties of glyphosate. p. 103–141. *In* Glyphosate: A unique global herbicide. Am. Chem. Soc. Monogr. 189. Am. Chem. Soc., Washington, DC.

Guthrie, D.S., and A.C. York. 1989. Cotton (*Gossypium hirsutum*) development and yield following fluometuron postemergence applied. Weed Technol. 3:501–504.

Hair, W. M., E.C. Murdock, A. Keeton, and T.D. Isgett. 1996. Broadleaf weed control in cotton with Staple—1995. p. 1527. *In* P. Dugger and D.A. Richter (ed.) Proc. Beltwide Cotton Conf., Nashville, TN. 9–12 Jan. 1996. Natl. Cotton Council Am., Memphis, TN.

Isgett, T.D., E.C. Murdock, and A. Keeton. 1997. Weed control in Roundup Ready® cotton. p. 47–48. *In* J. A. Dusky (ed.) 50th Proc. South. Weed Sci. Soc., Houston, TX. 20–22 Jan. 1997. South. Weed Sci. Soc., Champaign, IL.

Jordan, D.L., R.E. Frans, and M.R. McClelland. 1993a. Cotton (*Gossypium hirsutum*) response to DPX-PE350 applied postemergence. Weed Technol. 7:159–162.

Jordan, D.L., R.E. Frans, and M.R. McClelland. 1993b. Influence of application rate and timing on efficacy of DPX-PE350 applied postemergence. Weed Technol. 216–219.

Jordan, D.L., R.E. Frans, and M.R. McClelland. 1993c. Interactions of DPX-PE350 with fluazifop-P, sethoxydim, clethodim, and quizalofop-P. Weed Technol. 7:605–610.

Jordan, D.L., R.E. Frans, and M.R. McClelland. 1993d. Total postemergence herbicide programs in cotton (*Gossypium hirsutum*) with sethoxydim and DPX-PE350. Weed Technol. 7:196–201.

Jordan, D.L., A.C. York, J.L. Griffin, P.A. Clay, P.R. Vidrine, and D.B. Reynolds. 1997. Influence of application variables on efficacy of glyphosate. Weed Technol. 11:354–362.

Kalaher, C.J., H.D. Coble, and A.C. York. 1997. Morphological effects of Roundup application timings on Roundup-Ready® cotton. p. 780. *In* P. Dugger and D. A. Richter (ed.) Proc. Beltwide Cotton Conf., New Orleans, LA. 6–10 Jan. 1997. Natl. Cotton Council Am., Memphis, TN.

Nida, D.L., K.H. Kolacz, R.E. Guehler, W.R. Deaton, W.R. Schuler, T.A. Armstrong, M.L. Taylor, C.C. Ebert, G.J. Rogan, S.R. Padgette, and R.L. Fuchs. 1996. Glyphosate-tolerant cotton: genetic characterization and protein expression. J. Agric. Food Chem. 44:1960–1966.

Sasser, P.E. 1981. The basics of high volume instruments for fiber testing. p. 191–193. *In* J.M. Brown (ed.) Proc. Beltwide Cotton Conf., New Orleans, LA. 4–8 Jan. 1981. Natl. Cotton Council Am., Memphis, TN.

Smith, J.D., E.C. Murdock, A.C. York, H.P. Wilson, and T.D. Isgett. 1997. Growers' perceptions following Staple's first year. p. 54. *In* J.A. Dusky (ed.) 50th Proc. South. Weed Sci. Soc., Houston, TX. 20–22 Jan. 1997. South. Weed Sci. Soc., Champaign, IL.

Snipes, C.E., and J.D. Byrd, Jr. 1994. The influence of fluometuron and MSMA on cotton yield and fruiting characteristics. Weed Sci. 42:210–215.

Tredaway, J.A., M.G. Patterson, and G.R. Wehtje. 1998. Interaction of clethodim with pyrithiobac and bromoxynil applied in low volume. Weed Technol. 12:185–189.

Turner, R.G., and D.A. Allison. 1997. Staple performance in cotton weed control programs. p. 766–770. *In* P. Dugger and D.A. Richter (ed.) Proc. Beltwide Cotton Conf., New Orleans, LA. 6–10 Jan. 1997. Natl. Cotton Council Am., Memphis, TN.

Welch, A.K., P.R. Rahn, R.D. Voth, J.A. Mills, and C.R. Shumway. 1997. Evaluation of preplant and preemergence herbicides in Roundup Ready® cotton. p. 784–785. *In* P. Dugger and D.A. Richter (ed.) Proc. Beltwide Cotton Conf., New Orleans, LA. 6–10 Jan. 1997. Natl. Cotton Council Am., Memphis, TN.

Wilcut, J.W., H.D. Coble, A.C. York, and D.W. Monks. 1996. The niche for herbicide-resistant crops in U. S. agriculture. p. 213–230. *In* S.O. Duke (ed.) Herbicide-resistant crops: Agricultural, environmental, economic, regulatory, and technical aspects. CRC Press, Boca Raton, FL.

Wilcut, J.W., D.L. Jordan, W.K. Vencill, and J.S. Richburg, III. 1997. Weed management in cotton (*Gossypium hirsutum*) with soil-applied and post-directed herbicides. Weed Technol. 11:221–226.

Wilcut, J.W., A.C. York, and D.L. Jordan. 1995. Weed management systems for oil seed crops. p. 343–400. *In* A.E. Smith (ed.) Handbook of weed management systems. Marcel-Dekker, New York.

York, A.C. 1993. Peanut response to fluometuron applied to a preceding cotton crop. Peanut Sci. 20:111–114.

York, A.C., and A.S. Culpepper. 1998. Weed management in cotton. p. 74–118. *In* K.L. Edmisten (ed.) 1998 Cotton information. Publ. AG-417. North Carolina Coop. Ext. Serv., Raleigh.