Effect of Residual Herbicides Used in the Last POST-Directed Application on Weed Control and Cotton Yield in Glyphosate- and Glufosinate-Resistant Cotton

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Field experiments were conducted to evaluate weed control and cotton response to glyphosate or glufosinate applied alone or with residual herbicides applied in the last POST-directed application (LAYBY) in glyphosate- and glufosinate-resistant cotton. Glyphosate (0.86 kg ae/ha) or glufosinate (0.47 kg ai/ha) were applied alone over the top of glyphosate- or glufosinate-resistant cotton early POST (EPOST) followed by (fb) late POST (LPOST) fb one of the herbicides applied either alone or with a residual herbicide at LAYBY. Glyphosate- and glufosinate-based treatments were applied only to glyphosate- and glufosinate-resistant cotton, respectively. Residual herbicides evaluated included prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), diuron (1.12 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), pendimethalin (1.0 kg ai/ha), prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha), or linuron + diuron (0.56 + 0.56 kg ai/ha). Glyphosate-and glufosinate-based weed management systems with and without residual LAYBY herbicides resulted in little to no injury to cotton. Three applications of glyphosate or glufosinate alone provided better full-season control of most species when compared to two applications of either herbicide. The addition of a residual herbicide to glyphosate or glufosinate at LAYBY did not improve cotton yields, but did improve overall control of barnyardgrass and yellow nutsedge and reduced weed dry biomass present at time of cotton harvest when compared to three applications of glyphosate or glufosinate alone.
Nomenclature: Diuron; fluometuron; glufosinate; glyphosate; linuron; oxyfluorfen; pendimethalin; prometryn; trifloxysulfuron; barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. ECHCG; yellow nutsedge, *Cyperus esculentus* L. CYPES; cotton, *Gossypium hirsutum* L. 'DPL 555BG/RR', 'Fibermax 958LL, 966LL, and 989RR'.
Key words: CGA-362622, crop injury, glyphosate-resistant cotton, Liberty Link® cotton, residual weed control, Roundup Ready® cotton, transgenic crops.

Glyphosate and glufosinate are nonselective herbicides that provide broad-spectrum POST control of broadleaf, grass, and sedge weeds. Glyphosate's mechanism of action is specific to an enzyme found only in plants and certain bacteria, resulting in minimal toxicological and environmental impacts (Franz et al. 1997). Adoption of glyphosate-resistant crops (GRC) such as soybean [*Glycine max* (L.), Merr], cotton (*Gossypium hirsutum* L.), and corn (*Zea mays* L.) has been wide-scale by U.S. growers. In 2004, more than 80 and 60% of the hectares grown to soybean and cotton were planted in GRC varieties, respectively (Gianessi 2005).

Glyphosate controls most weed species in GRC (Askew and Wilcut 1999; Corbett et al. 2004; Faircloth et al. 2001; Koger et al. 2005; Wilcut and Askew 1999) and has no carryover restrictions to subsequently planted crops because glyphosate does not have soil residual activity. The expiration of patent rights for glyphosate in 2000 was followed by broadscale production of generic glyphosate formulations and a subsequent decline in glyphosate price and increase in glyphosate usage in GRC.

Glufosinate controls a wide range of weed species and is especially effective on some species such as morningglories (*Ipomoea* spp.) that can be difficult to control with glyphosate alone (Askew et al. 1997; Corbett et al. 2004; Hydrick and Shaw 1995; Norris et al. 2002). Crop varieties resistant to glufosinate have not been adopted by growers to the degree of GRC; however, increases in adoption are likely as glyphosate-tolerant or -resistant weed populations increase over time. Glufosinate-resistant cotton has been planted on a considerable hectarage in parts of the southeastern United States because of glufosinate's enhanced efficacy on species difficult to control with glyphosate and the fact that glufosinate is capable of controlling glyphosate-resistant horseweed [*Conyza canadensis* (L.) Cronq.] (CDMS 2007). Glufosinate is similar to glyphosate in that it has no residual carryover activity on crops planted the following growing season.

Many growers have shifted toward total POST weed control programs utilizing glyphosate and glufosinate systems on a wide-scale basis. However, the need for residual and season-long weed control in cotton may be warranted in some cases because of the extended time period needed for closure of row middles, for control of some weed species that are difficult to control with glyphosate or glufosinate alone, and/or for control of weeds capable of germinating late in the growing season and having multiple emergence periods. In Mississippi alone, pitted morningglory (*Ipomoea lacunosa* L. IPOLA) has become more common and difficult to control concurrently with the broadscale adoption of glyphosate-

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resistant cotton according to surveys conducted in 1995 and 2001 (Anonymous 1995, 2001). Shifts toward weed species, specifically grasses such as barnyardgrass and browntop millet [*Brachiaria ramosa* (L.) Stapf.], that are capable of emerging after LAYBY or the last POST application have been reported in cotton and soybean (C. E. Snipes and D. H. Poston, personal communication). Soil temperatures late in the growing season are conducive to germination of some weed species. Germination of goosegrass [*Eleusine indica* (L.) Gaertn. ELEIN] increases as soil temperature increases (Nishimoto and McCarty 1997). Askew et al. (2002) reported lack of residual control by glyphosate allowed for late-season seedling growth of goosegrass.

Information is needed on weed control efficacy of residual LAYBY herbicides applied with glyphosate and glufosinate in glyphosate- and glufosinate-resistant cotton. The objectives of this research were to investigate the effects of residual herbicides applied with glyphosate and glufosinate at LAYBY on weed control and cotton response in glyphosate- and glufosinate-based weed management systems.

Materials and Methods

Field experiments were conducted in 2004 at the U.S. Department of Agriculture Southern Weed Science Research Farm, Stoneville, MS; the Alabama Agricultural Experiment Station's E. V. Smith Research and Extension Center, Shorter, AL; the Upper Coastal Plain Research Station located near Rocky Mount, NC; the Caswell Research Station located in Kinston, NC; and the Tidewater Agricultural Research and Extension Center located in Suffolk, VA. Soils were a Dundee silt loam (fine-silty, mixed, thermic Aeric Ochraqualfs) with 1.1% organic matter (OM) and pH 7.0 at Stoneville, a Dothan Fine sandy loam (fine-loamy, siliceous, thermic Plinthic Paleudults) with 0.5% OM and pH 5.0 at Shorter, a Norfolk loamy sand (fine, loamy, siliceous thermic Typic Paleudults) with 1.5% OM and pH 6.2 at Rocky Mount, a Goldsboro sandy loam (loamy, mixed, thermic Arenic Hapludults) with 1.3% OM and pH 5.9 at Kinston, and a fine sandy loam (coarse-loamy, siliceous, thermic, Aquic Hapludults) with 1.2% OM and pH 6.2 at Suffolk.

The field at Stoneville was disked twice and 100-cm-wide beds were prepared in the fall of 2003. Two weeks prior to planting cotton at Stoneville existing vegetation was controlled with 1.12 kg ae/ha glyphosate.[1] At Shorter, the seedbed contained a 'SoilSaver' black oat (*Avena strigosa* Schreb.) cover crop that was drill-seeded in November 2003, terminated with 1.12 kg/ha glyphosate in early May 2004, rolled 3 d prior to planting cotton with a mechanical roller–crimper (Ashford and Reeves 2003) to flatten residue on the soil surface, and in-row subsoiled with a narrow-shanked parabolic subsoiler prior to planting. Seedbeds in fields at Rocky Mount and Kinston, NC, and Suffolk, VA, locations were conventionally tilled prior to planting cotton.

Plots, depending on location, ranged from 6 to 7.6 m long and 3 to 4 m wide and were arranged in a split block design with three to four replications of treatments at each location. The main plot was cotton variety and the subplot was herbicide treatment. The glyphosate- and glufosinate-resistant cotton varieties 'DPL 555BG/RR' and 'Fibermax 966LL', respectively, were planted 2.5 cm deep at 15 seed/m row in separate plots consisting of four 102-cm-wide rows on May 3, 2004, at Stoneville and May 26, 2004, at Shorter. The glyphosate- and glufosinate-resistant cotton varieties 'Fibermax 989RR' and 'Fibermax 958LL' were planted 2 cm deep at 13 seed/m row in plots consisting of four 96-cm-wide rows at Rocky Mount and Kinston and four 91-cm-wide rows at Suffolk. Cotton was planted on May 10, May 11, and May 18 of 2004 at the Suffolk, Rocky Mount, and Kinston locations, respectively. Aldicarb at 0.6 kg ai/ha was applied in-furrow for early season insect control. Cultural practices, including fertilization, insect and plant growth management, and defoliation chemicals were applied to cotton at each location according to state Cooperative Extension Service recommendations.

Herbicide treatments were applied at EPOST, LPOST, and LAYBY timings. EPOST treatments were applied over the top of one-to-two–leaf cotton and weeds in the cotyledon-to-eight–leaf growth stage. LPOST treatments were applied over the top of three-to-five–leaf cotton and cotyledon-to-eight–leaf weeds. LAYBY treatments were applied postdirected to 10-to-12–leaf cotton and cotyledon-to-10–leaf weeds. Glyphosate was applied at 0.86 kg/ha in treatments requiring glyphosate. Glufosinate[2] was applied at 0.47 kg ai/ha in treatments requiring glufosinate. Treatments in glyphosate-resistant cotton included the following: (1) no herbicide, (2) glyphosate EPOST fb glyphosate LPOST, (3) glyphosate EPOST fb glyphosate LPOST fb glyphosate LAYBY, and (4–10) glyphosate EPOST fb glyphosate LPOST fb glyphosate plus residual herbicide at LAYBY. Treatments in glufosinate-resistant cotton included the following: (1) no herbicide, (2) glufosinate EPOST fb glufosinate LPOST, (3) glufosinate EPOST fb glufosinate LPOST fb glufosinate LAYBY, and (4–10) glufosinate EPOST fb glufosinate LPOST fb glufosinate plus residual herbicide at LAYBY. LAYBY treatments consisted of either glyphosate or glufosinate plus prometryn[3] (1.12 kg ai/ha), fluometuron[4] (1.12 kg ai/ha), diuron[5] (1.12 kg ai/ha), oxyfluorfen[6] (1.12 kg ai/ha), pendimethalin[7] (1.0 kg ai/ha), prometryn[8]+ trifloxysulfuron[9] (1.33 kg ai/ha + 12 g ai/ha), or linuron[10] + diuron (0.56 + 0.56 kg ai/ha).

Herbicides were applied with either a compressed-CO_2 backpack or tractor-mounted sprayer calibrated to deliver 140 to 233 L/ha at 138 to 220 kPa depending on location. Herbicides were delivered using 11002 to 8004 standard flat-fan spray nozzles[11] depending on location and herbicide application timing.

Cotton injury and control of individual weed species was estimated visually 2 wk after EPOST and LPOST treatments and 3 to 5 wk after LAYBY treatments depending on location. Visual estimates of cotton injury and weed control were based on a summation of plant stunting, discoloration, and stand reduction ranging from 0% (no cotton injury or no weed control) to 100% (cotton death or complete weed control) (Frans et al. 1986). In order to measure overall effect of herbicide treatments, only cotton injury and weed control data collected 3 to 5 wk after LAYBY herbicide application are presented here. Weed control evaluations were recorded for barnyardgrass and pitted morningglory in Mississippi; yellow nutsedge, large crabgrass [*Digitaria sanguinalis* (L.)

Table 1. Visual control of barnyardgrass (ECHCG), pitted morningglory (IPOLA), yellow nutsedge (CYPES), large crabgrass (DIGSA), and Palmer amaranth (AMAPA) 2 wk after LAYBY in glyphosate- and glufosinate-resistant cotton in Mississippi and Alabama.[a]

		Mississippi		Alabama			
Herbicide treatments[b]	Application timing[c]	ECHCG	IPOLA	CYPES	DIGSA	AMAPA	IPOLA
		% Visual control					
Nontreated		0	0	0	0	0	0
Glyph fb glyph	EPOST fb LPOST	45	50	51	74	74	79
Glyph fb glyph fb glyph	EPOST fb LPOST fb LAYBY	69	85	75	96	96	94
Gluf fb gluf	EPOST fb LPOST	38	60	64	52	42	82
Gluf fb gluf fb gluf	EPOST fb LPOST fb LAYBY	70	80	97	90	80	97
Glyph fb glyph fb glyph + residual herb or gluf fb gluf fb gluf + residual herb[d]	EPOST fb LPOST fb LAYBY	88	86	92	90	94	95
LSD (0.05)[e]		12	10	16	15	16	14

[a] Abbreviations: EPOST, early POST; fb, followed by; glyph, glyphosate; gluf, glufosinate; herb, herbicide; LAYBY, last POST-directed application; LPOST, late POST.

[b] Glyphosate was applied at 0.86 kg ae/ha and glufosinate was applied at 0.47 kg ai/ha in all treatments. Residual herbicides included the following: prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), diuron (1.12 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), pendimethalin (1.0 kg ai/ha), prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha), and linuron + diuron (0.56 + 0.56 kg ai/ha).

[c] EPOST treatments were applied over the top of two-to-three–leaf cotton and weeds in the cotyledon-to-eight–leaf growth stage; LPOST treatments were applied over the top of six-to-seven–leaf cotton and cotyledon-to-eight–leaf weeds; LAYBY treatments were applied postdirected to 10-to-12–leaf cotton and cotyledon-to-10–leaf weeds.

[d] Data were averaged across glyphosate and glufosinate mixed with residual LAYBY herbicide treatments because there were no differences between residual herbicides or between glyphosate or glufosinate when mixed with residual herbicide.

[e] Means within a column are separated according to LSD value at P = 0.05.

Scop. DIGSA], Palmer amaranth (*Amaranthus palmeri* S. Wats AMAPA), and pitted morningglory in Alabama; goosegrass, large crabgrass, ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq. IPOHE], pitted morningglory, and Palmer amaranth in North Carolina; and goosegrass, large crabgrass, and entireleaf morningglory [*Ipomoea hederacea* var. *integriuscula* Gray IPOHG] in Virginia.

Total aboveground weed biomass was harvested from one randomly placed 1-m^2 quadrat per plot just prior to cotton harvest at the Mississippi and Alabama locations. Weed biomass samples were oven dried at 30 C. Cotton yields were measured by harvesting the center two rows of each plot with a spindle picker modified for small-plot harvesting.

Statistical Analysis. Cotton injury and weed control data were subjected to arcsine square-root transformations. Interpretations were not different from nontransformed data; therefore, nontransformed data are presented. Nontreated control data of all studies were deleted prior to statistical analysis to stabilize variance. Data were subjected to ANOVA using the general linear models procedure of SAS (SAS 1998), and sums of squares were partitioned to evaluate effects of location, glyphosate- and glufosinate-resistant cotton, and herbicide treatments (McIntosh 1983). Means were separated using Fisher's Protected LSD test at $P \leq 0.05$. When interactions were significant, LSD tests were performed separately across the levels of a given factor within levels of other factors. Data are presented by location because of location effect and differences in weed species composition.

Results and Discussion

The specific residual herbicide added to glyphosate or glufosinate at LAYBY did not affect cotton injury, weed control, weed dry biomass, or cotton yield at all locations. Additionally, when a residual herbicide was added to glyphosate or glufosinate at LAYBY there were no differences between glyphosate or glufosinate. Thus, data were averaged across glyphosate or glufosinate plus a residual herbicide at LAYBY treatments for all parameters measured and presented.

Cotton Injury. Glyphosate- and glufosinate-based weed management systems with and without residual LAYBY herbicides resulted in little to no injury to cotton across all locations (data not shown). Injury was less than 2% by 2 wk after EPOST and LPOST treatments at all locations. Injury was less than 10% at all locations by 2 wk after all LAYBY treatments except glufosinate or glyphosate plus oxyfluorfen, which resulted in 15% injury at the Virginia location.

Weed Control. *Mississippi.* Glyphosate or glufosinate applied EPOST fb LPOST fb LAYBY (three applications) improved control of barnyardgrass and pitted morningglory compared to EPOST fb LPOST applications (two applications) of either herbicide (Table 1). Glyphosate and glufosinate provided similar levels of control of barnyardgrass and pitted morningglory. Glyphosate or glufosinate EPOST fb LPOST fb either of the two herbicides plus a residual herbicide at LAYBY improved control of barnyardgrass when compared to three applications of glyphosate or glufosinate applied alone. However, the specific residual herbicide added to glyphosate or glufosinate at LAYBY was not significant, because all residual herbicides added to glyphosate or glufosinate produced similar results with respect to control of barnyardgrass and pitted morningglory.

Alabama. Three applications of glyphosate or glufosinate improved control of yellow nutsedge, large crabgrass, Palmer amaranth, and pitted morningglory when compared to two applications of either herbicide (Table 1). Glufosinate provided better control of yellow nutsedge compared to glyphosate. Inconsistent and inadequate control of yellow nutsedge with glyphosate has been reported previously (Fischer and Harvey 2002; Nelson et al. 2002). Glyphosate was more efficacious on

Table 2. Visual control of pitted morningglory (IPOLA), entireleaf morningglory (IPOHG), ivyleaf morningglory (IPOHE), large crabgrass (DIGSA), Palmer amaranth (AMAPA), and goosegrass (ELEIN) 2 wk after LAYBY herbicide application in glyphosate- and glufosinate-resistant cotton in North Carolina and Virginia.[a]

Herbicide treatments[b]	Application timing[c]	North Carolina					Virginia		
		ELEIN	DIGSA	IPOHE	IPOLA	AMAPA	ELEIN	DIGSA	IPOHG
		% Visual control							
Nontreated		0	0	0	0	0	0	0	0
Glyph fb glyph	EPOST fb LPOST	88	90	94	93	94	50	100	100
Glyph fb glyph fb glyph	EPOST fb LPOST fb LAYBY	97	98	97	96	98	100	100	100
Gluf fb gluf	EPOST fb LPOST	69	91	98	98	79	40	88	80
Gluf fb gluf fb gluf	EPOST fb LPOST fb LAYBY	97	99	99	99	96	100	100	100
Glyph fb glyph fb glyph + residual herb or gluf fb gluf fb gluf + residual herb[d]	EPOST fb LPOST fb LAYBY	99	99	99	99	99	100	100	100
LSD (0.05)[e]		4	2	2	2	5	8	6	5

[a] Abbreviations: EPOST, early POST; fb, followed by; glyph, glyphosate; gluf, glufosinate; herb, herbicide; LAYBY, last POST-directed application; LPOST, late POST.

[b] Glyphosate was applied at 0.86 kg ae/ha and glufosinate was applied at 0.47 kg ai/ha in all treatments. Residual herbicides included the following: prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), diuron (1.12 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), pendimethalin (1.0 kg ai/ha), prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha), and linuron + diuron (0.56 + 0.56 kg ai/ha).

[c] EPOST treatments were applied over the top of two-to-three–leaf cotton and weeds in the cotyledon-to-eight–leaf growth stage; LPOST treatments were applied over the top of six-to-seven–leaf cotton and cotyledon-to-eight–leaf weeds; LAYBY treatments were applied postdirected to 10-to-12–leaf cotton and cotyledon-to-10–leaf weeds.

[d] Data were averaged across glyphosate and glufosinate mixed with residual LAYBY herbicide treatments because there were no differences between residual herbicides or between glyphosate or glufosinate when mixed with residual herbicide.

[e] Means within a column are separated according to LSD value at $P = 0.05$.

Palmer amaranth than was glufosinate. Coetzer et al. (2002) and Jones et al. (2001) have shown Palmer amaranth to be difficult to control with glufosinate.

Glyphosate or glufosinate applied EPOST fb LPOST fb either of the two herbicides plus a residual herbicide at LAYBY improved control of yellow nutsedge compared to three applications of glyphosate alone. LAYBY herbicides controlled all weed species at least 90%. All residual herbicides added to either glyphosate or glufosinate at LAYBY resulted in similar levels of control of all weed species evaluated.

North Carolina. Three applications of glyphosate or glufosinate alone were more effective at controlling all weed species evaluated (goosegrass, large crabgrass, ivyleaf morningglory, pitted morningglory, and Palmer amaranth) when compared to two applications of either herbicide (Table 2). Three applications of glyphosate or glufosinate were also as effective at controlling all weed species as the two herbicides applied EPOST fb LPOST fb either of the two herbicides plus a residual herbicide at LAYBY. All weeds were controlled better than 95% with three applications of glyphosate or glufosinate applied alone or with a residual herbicide at LAYBY.

Virginia. Glyphosate or glufosinate applied three times alone or with a residual herbicide at LAYBY controlled goosegrass, large crabgrass, and entireleaf morningglory 100%, and were more effective than glufosinate applied EPOST fb LPOST (40 to 88% control of all weed species) (Table 2). Two applications of glyphosate (EPOST fb LPOST) were just as effective as three with respect to control of large crabgrass and entireleaf morningglory.

All locations. Three applications of glyphosate or glufosinate provided better control of most species when compared to two applications of either herbicide at all locations. Glyphosate or glufosinate applied alone or with a residual herbicide at LAYBY provided similar levels of weed control at all locations. The addition of a residual herbicide to glyphosate or glufosinate at LAYBY improved the control of barnyardgrass in Mississippi, whereas the addition of a residual herbicide to glyphosate improved control of yellow nutsedge in Alabama when compared to applying three applications of glyphosate or glufosinate alone. Barnyardgrass is capable of multiple emergence flushes throughout a growing season (Leblanc et al. 2002). Late-season emergence of grasses such as barnyardgrass after the final herbicide application is the most prominent challenge to season-long weed control in cotton (C. E. Snipes, personal communication) and soybean (D. Poston, personal communication) in Mississippi, and typically requires a residual herbicide to improve late-season control.

Weed Dry Biomass. All herbicide treatments reduced weed biomass at harvest when compared to the nontreated check (Table 3). Weed biomass was reduced more with three applications of glyphosate or glufosinate compared to two applications of either herbicide. Glyphosate and glufosinate were equally effective at reducing weed biomass at both locations. The addition of a residual herbicide at LAYBY to glyphosate or glufosinate resulted in less weed biomass at both locations when compared to three applications of glyphosate or glufosinate applied alone. The improved reduction in weed biomass with the addition of a residual LAYBY herbicide can be attributed to reduced control of barnyardgrass at Mississippi and yellow nutsedge at Alabama when glyphosate or glufosinate were applied alone vs. applying these herbicides with a residual herbicide at LAYBY.

Seed-Cotton Yield. Overall cotton yields were lower at the North Carolina location because of extremely dry growing conditions (Table 4). Cotton yields were higher for all herbicide treatments when compared to yields for the nontreated check at all locations. Minimal differences were observed within glyphosate- or glufosinate-resistant variety

Table 3. Dry biomass of weeds just prior to cotton harvest in glyphosate- and glufosinate-resistant cotton in Alabama and Mississippi.[a]

Herbicide treatments[b]	Application timing[c]	Weed dry biomass	
		Alabama	Mississippi
	Number of weeks after planting	kg/ha	
Nontreated		1238	3558
Glyph fb glyph	EPOST fb LPOST	527	903
Glyph fb glyph fb glyph	EPOST fb LPOST fb LAYBY	370	260
Gluf fb gluf	EPOST fb LPOST	685	549
Gluf fb gluf fb gluf	EPOST fb LPOST fb LAYBY	320	210
Glyph fb glyph fb glyph + residual herb or gluf fb gluf fb gluf + residual herb[d]	EPOST fb LPOST fb LAYBY	95	42
LSD (0.05)[e]		180	95

[a] Abbreviations: EPOST, early POST; fb, followed by; glyph, glyphosate; gluf, glufosinate; herb, herbicide; LAYBY, last POST-directed application; LPOST, late POST.

[b] Glyphosate was applied at 0.86 kg ae/ha and glufosinate was applied at 0.47 kg ai/ha in all treatments. Residual herbicides included the following: prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), diuron (1.12 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), pendimethalin (1.0 kg ai/ha), prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha), and linuron + diuron (0.56 + 0.56 kg ai/ha).

[c] EPOST treatments were applied over the top of two-to-three–leaf cotton and weeds in the cotyledon-to-eight–leaf growth stage; LPOST treatments were applied over the top of six-to-seven–leaf cotton and cotyledon-to-eight–leaf weeds; LAYBY treatments were applied postdirected to 10-to-12–leaf cotton and cotyledon-to-10–leaf weeds.

[d] Data were averaged across glyphosate and glufosinate mixed with residual LAYBY herbicide treatments because there were no differences between residual herbicides or between glyphosate or glufosinate when mixed with residual herbicide.

[e] Means within a column are separated according to LSD value at P = 0.05.

between herbicide treatments with respect to cotton yields at all locations. Cotton yields were often similar for glyphosate- and glufosinate-resistant cotton. Cotton yields were often similar when two or three applications of glyphosate or glufosinate alone were applied. The lack of differences in cotton yield when two or three applications of either glyphosate or glufosinate were applied vs. the differences in cotton yield for multiple glyphosate or glufosinate applications compared to no herbicide emphasizes the importance of early season weed control on overall crop vigor and subsequent high crop yield (Bryson 1990; Knezevic et al. 1994; Rajcan et al. 2004; Swanton et al. 1999). The addition of residual herbicide to glyphosate or glufosinate at LAYBY did not improve cotton yield when compared to three applications of glyphosate or glufosinate alone.

Overall, cotton injury was minimal and weed control levels were similar for glyphosate- and glufosinate-based weed management systems at all locations. Three applications of glyphosate or glufosinate alone were often more effective at all locations for season-long weed control when compared to two applications of either herbicide alone. The addition of a residual herbicide to glyphosate or glufosinate at LAYBY did not improve cotton yields, but did improve overall control of certain weed species at some locations. The addition of

Table 4. Seed-cotton yield in glyphosate- and glufosinate-resistant cotton in Alabama, Mississippi, North Carolina, and Virginia.[a]

Herbicide treatments[b]	Application timing[c]	Seed cotton yield			
		Alabama	Mississippi	North Carolina	Virginia
	Number of weeks after planting	kg/ha			
Nontreated		1535	138	0	0
Glyph fb glyph	EPOST fb LPOST	2460	2449	1163	2225
Glyph fb glyph fb glyph	EPOST fb LPOST fb LAYBY	2365	2676	1072	1954
Gluf fb gluf	EPOST fb LPOST	2237	2120	852	2808
Gluf fb gluf fb gluf	EPOST fb LPOST fb LAYBY	2544	2288	1002	3317
Glyph fb glyph fb glyph + residual herb or gluf fb gluf fb gluf + residual herb[d]	EPOST fb LPOST fb LAYBY	2438	2393	1116	2544
LSD (0.05)[e]		530	466	175	588

[a] Abbreviations: EPOST, early POST; fb, followed by; glyph, glyphosate; gluf, glufosinate; herb, herbicide; LAYBY, last POST-directed application; LPOST, late POST.

[b] Glyphosate was applied at 0.86 kg ae/ha and glufosinate was applied at 0.47 kg ai/ha in all treatments. Residual herbicides included the following: prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), diuron (1.12 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), pendimethalin (1.0 kg ai/ha), prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha), and linuron + diuron (0.56 + 0.56 kg ai/ha).

[c] EPOST treatments were applied over the top of two-to-three–leaf cotton and weeds in the cotyledon-to-eight–leaf growth stage; LPOST treatments were applied over the top of six-to-seven–leaf cotton and cotyledon-to-eight–leaf weeds; LAYBY treatments were applied postdirected to 10-to-12–leaf cotton and cotyledon-to-10–leaf weeds.

[d] Data were averaged across glyphosate and glufosinate mixed with residual LAYBY herbicide treatments because there were no differences between residual herbicides or between glyphosate or glufosinate when mixed with residual herbicide.

[e] Means within a column are separated according to LSD value at P = 0.05.

a residual herbicide to glyphosate or glufosinate at LAYBY reduced total weed dry biomass present at time of cotton harvest when compared to three applications of glyphosate or glufosinate alone at both locations where weed biomass just prior to cotton harvest was measured. Reducing weed presence and biomass by time of cotton harvest should help to reduce foreign matter in harvested cotton and subsequently maintain cotton quality. The addition of a residual herbicide at LAYBY should also help to reduce the potential for development of glyphosate and glufosinate resistance in weed populations and weed species shifts in transgenic cropping systems such as glyphosate- and glufosinate-resistant cotton. These findings are applicable across a wide range of growing conditions and cultural practices as weed control levels and cotton yields were similar across given treatments for most locations.

Sources of Materials

[1] Roundup WeatherMax™, Monsanto Company, 800 North Linbergh Boulevard, St. Louis, MO 63167.

[2] Ignite herbicide®, Bayer CropScience, 2 T.W. Alexander Drive, RTP, NC 27709.

[3] Caparol herbicide®, Syngenta Crop Protection, P.O. Box 18300, Greensboro, NC 27419.

[4] Cotoran®, Griffin LLC/Dupont Crop Protection, 2509 Rocky Ford Road, Valdosta, GA 31601.

[5] Direx®, Griffin LLC/Dupont Crop Protection, 2509 Rocky Ford Road, Valdosta, GA 31601.

[6] Goal, Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268.

[7] Prowl®, BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

[8] Suprend™, Syngenta Crop Protection, PO Box 18300, Greensboro, NC 27419.

[9] Envoke™, Syngenta Crop Protection, PO Box 18300, Greensboro, NC 27419.

[10] Dupont™ Layby™ Pro, Dupont Crop Protection, Wilmington, DE 19898.

[11] TeeJet, Spraying Systems Co., PO Box 7900, Wheaton, IL 60189.

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