Glufosinate Application Timing and Rate Affect Peanut Yield

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ABSTRACT

Field studies were conducted at 13 locations across the US peanut belt during 2010–2012 to evaluate peanut response to postemergence applications of glufosinate. Glufosinate was applied at 0, 41, 82, 164, 328 and 656 g ai/ha 30, 60, and 90 days after planting (DAP). There was a significant interaction for peanut yield between application time and glufosinate rate; peanut yield data were regressed on rate of glufosinate and fit to a log-logistic dose response curve by application timing. At 30 DAP, peanut yield ranged from 16 to 92% of the non-treated control, with glufosinate at 266 g/ha causing an estimated 50% reduction in yield (Y_{50}). At 60 DAP, peanut yield ranged from 16 to 82% of the nontreated control, with Y_{50} = 266 g/ha of glufosinate. Peanut yield when glufosinate was applied at 90 DAP ranged from 20 to 78% of the non-treated control; Y_{50} = 187 g/ha of glufosinate, which was lower than that at 30 DAP and indicated greater peanut sensitivity. Peanut plants treated at 30 DAP had more time to recover from glufosinate injury at the lower rates and/or were in a less susceptible stage of growth relative to 90 DAP. These data provide peanut growers across the US with an estimate of potential yield losses associated with mis-application, off-target movement, or sprayer contamination of glufosinate.

Key Words: *Arachis hypogaea* L., crop tolerance, drift, herbicide injury, sprayer contamination.

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The threat of glyphosate-resistant (GR) weeds, especially Palmer amaranth (*Amaranthus palmeri* S. Wats.), has motivated growers to consider the use of herbicides with alternative modes of action in cotton (*Gossypium hirsutum* L.) and soybean [*Glycine max* (L.) Merr.]. Glufosinate is a non-selective, broad-spectrum, postemergence herbicide that inhibits glutamine synthetase (Senseman 2007). Thus, it can be used to effectively control GR-Palmer amaranth in glufosinate-resistant crops if applied to plants less than 8 cm in height (Norsworthy et al. 2008; Wilson et al. 2007).

Glufosinate-resistant crops (Liberty-Link®) were developed by insertion of the bar gene isolated from the soil bacterium *Streptomyces hygroscopicus* (Duke 2005). The bar gene expresses the phosphinothricin acetyltransferase (*pat*) enzyme that acetylates *L*-phosphinothricin, and confers tolerance to glufosinate (Herouet *et al.* 2005; Lydon and Duke 1999). Liberty-Link® cotton cultivars were commercialized in 2004 (Duke 2005). Additionally, WideStrike® cotton cultivars, which also contain the *pat* gene, are commercially available but offer lower levels of resistance to glufosinate (Culpepper *et al.* 2009, Steckel *et al.* 2012). In soybean, regulatory approval for glufosinate-resistance in soybean occurred in 1996 (Duke 2005). However, wide-spread commercialization of LibertyLink® soybean cultivars did not occur until 2009. Glufosinate-resistant field corn (*Zea mays* L.) hybrids were commercialized in 1997 (Duke 2005).

Since peanut is grown in close proximity to field corn, cotton, and soybean in the US peanut belt, drift or sprayer contamination problems are likely to occur. Previous research has evaluated the unintentional effects of glyphosate and dicamba on peanut yield. When glyphosate was applied to peanut plants at 28 days after planting (DAP), rates of 280 g/ha or higher caused significant yield reductions (Lassiter *et al.* 2007). When applied between 75 to 105 DAP, glyphosate at 240, 320, and 470 g/ha reduced peanut yield by 12%, 24%, and 36%, respectively (Grey and Prostko 2010). Estimated peanut yield losses for dicamba applied at rates between 40 to 560 g/ha at 30, 60, or 90 DAP ranged between 2 and 100% (Prostko *et al.* 2011).

Limited studies have addressed the effects of glufosinate on peanut. In Texas, glufosinate applied at 470 to 580 g/ha provided 100% control

Table 1. Locations, cultivars, and planting dates for the peanut-glufosinate tolerance studies in 2010 to 2012.

Year	Location	Cultivar	Planting date
2010	Blackville, SC	Georgia Greener	May 25
2010	Lamesa, TX	FlavorRunner 458	April 28
2010	Yoakum, TX	Florida-07	May 27
2010	Citra, FL	Georgia-06G	April 26
2010	Jay, FL	Florida-07	May 6
2010	Plains, GA	Georgia-06G	May 26
2010	Ty Ty, GA	Georgia-06G	May 11
2011	Plains, GA	Georgia-06G	May 31
2011	Ty Ty, GA	Georgia-06G	May 9
2011	Lewiston-Woodville, NC	Phillips	May 16
2011	Rocky Mount, NC	Phillips	May 8
2011	Jay, FL	Florida-07	May 19
2012	Jay, FL	Georgia-06G	May 17

of simulated volunteer runner peanut cultivars (Grichar and Dotray 2007). Early tests conducted in North Carolina indicated that peanut yield was reduced 14 to 74% when glufosinate was applied at rates ranging between 135 to 538 g/ha (Jordan *et al.* 2011). Subsequent North Carolina tests reported peanut yield was reduced 33 to 75% by 302 g/ha of glufosinate in 4 out of 4 site-years and 25% by 123 g/ha in 1 of 4 site-years (Johnson *et al.* 2012). However, both of these tests were conducted using only one application timing, approximately 25 to 28 DAP. Therefore, the objective of our research was to evaluate peanut yield response to glufosinate at 0, 41, 82, 164, 328, 656 g ai/ha applied 30, 60, or 90 DAP.

Materials and Methods

Small-plot field trials were conducted at 13 locations across the US peanut belt during 2010 to 2012. A complete description of these locations is presented in Table 1. Production and pest management practices were followed according to local Cooperative Extension recommendations.

At all locations, herbicide treatments were arranged in a split-plot design. Time of application was the main plot with glufosinate rate as the sub-plot. Application timings were 30, 60, and 90 DAP and glufosinate rates were 0, 41, 82, 164, 328, 656 g ai/ha. A logarithmic scale with a common multiplier (e.g. 2) is recommended to evaluate herbicide dose response relationships (Seefeldt *et al.* 1995). The typical use rate of glufosinate in cotton and and soybean is 656 g ai/ha (Anonymous 2013). Generally, peanut plants were in the R1, R4-R5, and R6 stages of growth at 30, 60, and 90 DAP timings, respectively (Boote 1982). All treatments were replicated four to six times. Glufosinate was applied using a CO_2-pressurized sprayer calibrated to deliver 94 to 140 L/ha. All plot areas were maintained weed-free throughout the season using a combination of herbicides (clethodim, diclosulam, flumioxazin, imazapic, pendimethalin, and 2,4-DB) and hand-weeding. Peanut yield data were obtained by mechanical harvesting at maturity.

Data were analyzed using a mixed model ANOVA. Rate and timing of glufosinate were fixed effects, while site-years, replications, and interactions with these factors were considered random effects. Peanut yield data were regressed on rate of glufosinate and fit to a log-logistic curve (Seefeldt *et al.* 1995). The mathematical expression relating peanut yield to glufosinate rate was:

$$y = c + \left[\frac{d - c}{1 + \left(\frac{x}{Y_{50}} \right)^{b}} \right]$$

where c = the mean yield response at very high glufosinate doses, d = mean yield response of the nontreated control, Y_{50} = the glufosinate rate causing a 50% reduction in yield, and b = slope of the curve around Y_{50}. Differences in parameter estimates from the regression models were evaluated using t-tests with an alpha of 0.05 and $t_{critical}$ = 1.96 (Glantz and Slinker 2001). Similar to Askew and Wilcut (2001) and Jasieniuk *et al.* (1999), the nonlinear coefficient of determination ($R^2_{nonlinear}$) was calculated as:

$$R^2_{nonlinear} = 1 - \left(\frac{\textit{Residual sum of squares}}{\textit{Corrected total sum of squares}} \right)$$

Results and Discussion

There were significant interactions between time of application and glufosinate rate. Therefore, yield data were regressed on glufosinate rate by time of application.

30 DAP. Peanut yield as a percentage of the non-treated control at 30 DAP ranged from to 92 to 16% at 41 and 656 g/ha, respectively (Figure 1). This supports previous findings from North Carolina, where no major reductions in peanut yield were observed when glufosinate was applied 21 days after peanut emergence at rates ≤ 67 g/ha (Jordan *et al.* 2011). Additionally, in North Carolina peanut yield losses ranged from 33 to 75% when applied at 302 g/ha of glufosinate (Johnson *et al.* 2012). At higher rates in Texas (470 to 580 g/ha glufosinate), peanut death resulted when applied to plants that were 8 to 10 cm tall (Grichar and Dotray 2007).

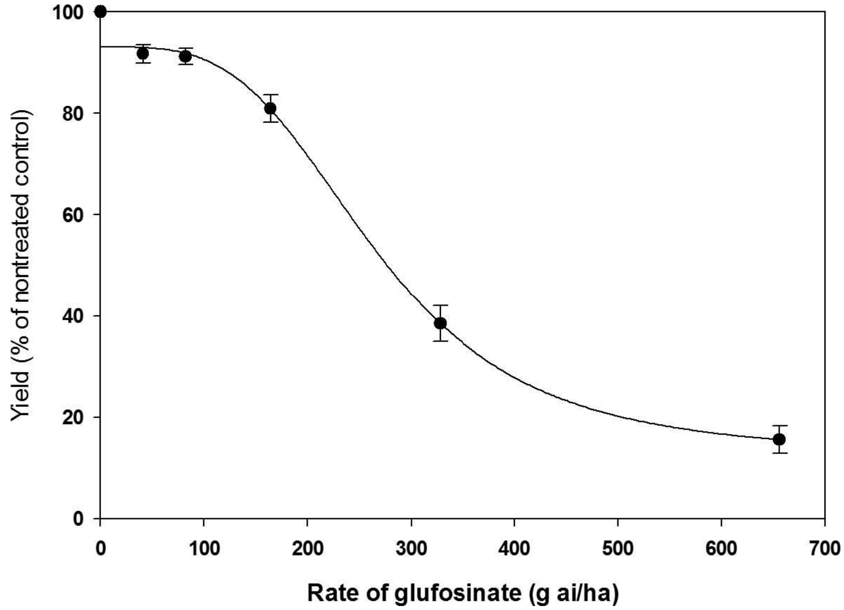

Fig. 1. Peanut yield loss response to glufosinate applied 30 days after planting averaged over 13 locations. $y=12.3+\left(\frac{80.8}{1+\left(\frac{x}{266}\right)^{8.14}}\right)$, $R^2_{nonlinear}=0.75$.

Peanut yield declined with increasing glufosinate rate, with the relationship described ($R^2_{nonlinear}$ = 0.75) by a log-logistic curve. This particular function is frequently used to evaluate plant sensitivity across a range of herbicide doses, with biologically relevant parameters (Knezevic *et al.* 2007; Seefeldt *et al.* 1995). The estimate of the Y_{50} parameter was 266 g/ha, which is the amount of glufosinate needed to reduce peanut yield 50%. This value is often used to compare plant sensitivity to an herbicide across plant types. For instance, the rate of glufosinate needed to reduce seedling biomass 50% (GR_{50}) ranged from 63 to 160 g/ha for seven different weeds, including common ragweed (*Ambrosia artemisiifolia* L.), common lambsquarters (*Chenopodium album* L.), and velvetleaf (*Abutilon theophrasti* Medik.) (Tharp *et al.* 1999). However, established common bermudagrass had a GR_{50} of 990 g/ha of glufosinate (Webster *et al.* 2004). Lassiter *et al.* (2007)

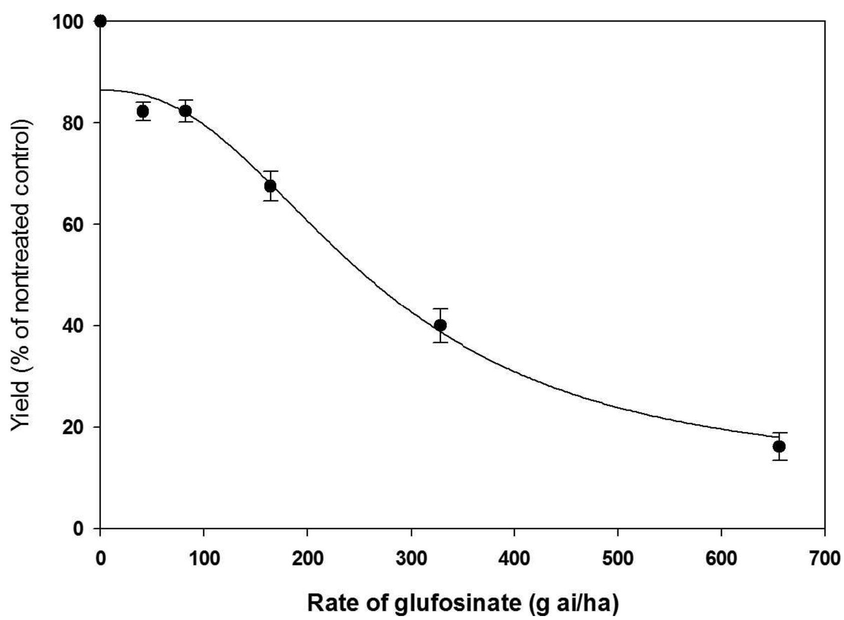

Fig. 2. Peanut yield response to glufosinate applied 60 days after planting averaged over 13 locations. $y=10.0+\left(\frac{76.4}{1+\left(\frac{x}{266}\right)^{5.48}}\right)$, $R^2_{nonlinear}=0.66$.

Table 2. Parameter estimates and the standard errors (s.e.) from the log-logistic regression equations from Figures 1, 2, and 3.

Timing	*c* (s.e.)		*d* (s.e.)		*b* (s.e.)		Y_{50} (s.e.)		$R^2_{nonlinear}$
30 DAP	12.3	3.64	93.1	1.95	8.14	1.20	266	13.8	0.75
60 DAP	10.0	6.80	86.4	2.50	5.48	1.20	266	27.8	0.66
90 DAP	15.0	8.00	88.0	4.40	3.60	0.89	187	32.0	0.61

c = the mean yield response at very high glufosinate doses; d = mean yield response of the non-treated control; b = slope of the curve around Y_{50}; and Y_{50} = the glufosinate rate causing a 50% reduction in yield.

evaluated glyphosate drift on peanut and determined that Y_{50} values ranged from 244 to 788 g/ha.

60 DAP. At this application timing, peanut yield ranged from to 82 to 16% of the non-treated control at 41 and 656 g/ha, respectively (Figure 2). The relationship was described by a log-logistic regression ($R^2_{nonlinear} = 0.66$). The Y_{50} was 266 g/ha of glufosinate, with $b = 5.48$ (Table 2); based on t-tests, both values were equivalent to those parameter estimates at 30 DAP.

90 DAP. Peanut yield ranged from to 78 to 20% of the non-treated control at glufosinate rates of 41 and 656 g/ha, respectively (Figure 3). The Y_{50} from the log-logistic regression model was 187 g/ha, which was lower ($t = 2.28$) than the Y_{50} at 30 DAP (266 g/ha). This suggests that glufosinate applied at 90 DAP was more sensitive to glufosinate than when applied at 30 DAP. The slope of the regression curve around the Y_{50} ($b = 3.6$) at 90 DAP was less ($t = 3.02$) than that at 30 DAP ($b = 8.14$), with each of these similar to the slope at 60 DAP. Peanut yield at the highest glufosinate rate was between 15 and 20% of the nontreated control for all application dates. As a result, the smaller slope at 90 DAP and the convergence of peanut yield at the maximum glufosinate rates suggests that peanut at 90 DAP was more sensitive to lower glufosinate rates than those applied at 30 DAP. One potential explanation is that the 30 DAP treatment may have had more time during the growing season before harvest to recover from glufosinate injury. Additionally, there may have been differences in peanut sensitivity to glufosinate among plant growth stages at the time of application.

Summary and Conclusions

These results provide growers across the U.S. Peanut Belt with an estimate of potential yield losses caused by a range of rates of glufosinate applied at three different growth stages. Consequently, decisions can be made to determine if a peanut crop that is unintentionally treated with glufosinate should be managed for production or terminated.

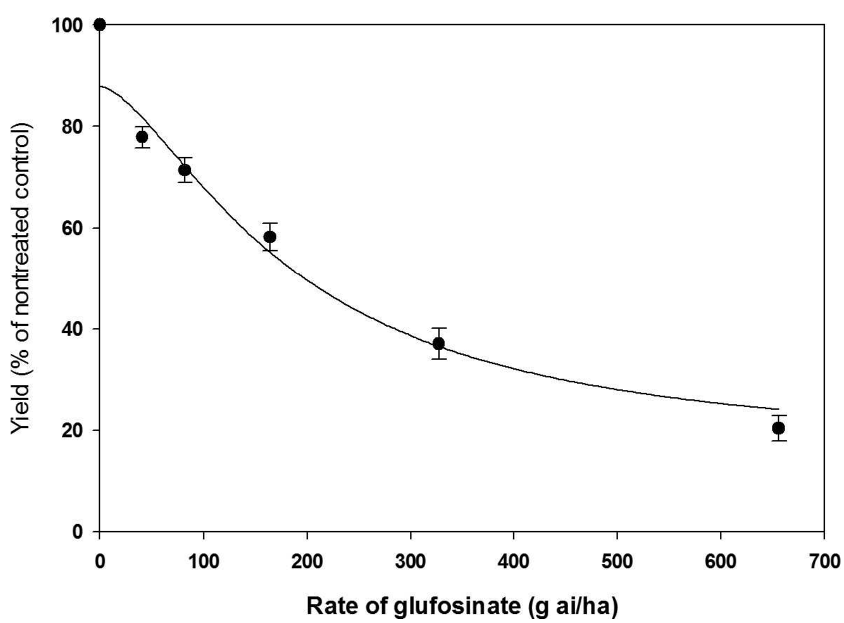

Fig. 3. Peanut yield response to glufosinate applied 90 days after planting averaged over 13 locations. $y=15.0+\left(\frac{73}{1+\left(\frac{x}{187}\right)^{3.6}}\right)$, $R^2_{nonlinear} = 0.61$.

Acknowledgments

This research was partially supported through grants provided by the Georgia Peanut Commission, North Carolina Peanut Grower's Association, Texas Peanut Producer's Board, and the Florida Peanut Producer's Association. The technical support of Peter Eure, Charlie Hilton, Rand Merchant, Jesse Parker, Dewayne Johnson, and Lyndell Gilbert was greatly appreciated.

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