Peanut (*Arachis hypogaea* L.) Response to Lactofen at Various Postemergence Timings[1]

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ABSTRACT

Field experiments were conducted at nine locations in Texas and Georgia in 2005 and 2006 to evaluate peanut tolerance to lactofen. Lactofen at 220 g ai/ha plus crop oil concentrate was applied to peanut at 6 leaf (lf), 6 lf followed by (fb) 15 days after the initial treatment (DAIT), 15 DAIT alone, 6 lf fb 30 DAIT, 30 DAIT alone, 6 lf fb 45 DAIT, 45 DAIT alone, 6 lf fb 60 DAIT, and 60 DAIT alone in weed-free plots. Lactofen caused visible leaf bronzing at all locations. Yield loss was observed when applications were made 45 DAIT, a timing that would correspond to plants in the R5 (beginning seed) to R6 (full seed) stage of growth. At all locations except the Texas High Plains, this application timing was within the 90 d preharvest interval. Growers who apply lactofen early in the peanut growing season to small weeds should have confidence that yields will not be negatively impacted despite dramatic above-ground injury symptoms; however, applications made later in the season, during seed fill, may adversely affect yield.

Key Words: *Arachis hypogaea* L., groundnut, herbicide injury, lactofen, peanut tolerance, postemergence-topical, tomato spotted wilt virus, visible injury, grade, yield.

Peanut (*Arachis hypogaea* L.) production decreased from 582,000 hectares in 1968 to a forecasted 451,170 hectares in 2011 (Anonymous, 2011a). Peanut yield nearly doubled over this period in part due to use of more effective herbicides, peanut genetics with improved disease resistance and greater yield potential, improved irrigation efficiencies, and more efficient cultural practices. However, weeds continue to be a major problem in all peanut growing regions. Weeds can reduce peanut yield 60 to 80% through competition and reduced harvest efficiency (Buchanan *et al.*, 1982; Wilcut *et al.*, 1995).

Peanut has several unique features that contribute to challenging weed management. First, peanut produced in the United States require a fairly long growing season (140 to 160 d), depending on cultivar and geographical region (Henning *et al.*, 1982; Wilcut *et al.*, 1995). Consequently, soil-applied herbicides do not provide season-long control and mid-to-late season weed problems are common. Secondly, peanut has a prostrate growth habit, a relatively shallow canopy, and is slow to shade inter-rows allowing weeds to be more competitive with the peanut plant (Walker *et al.*, 1989; Wilcut *et al.*, 1995). Additionally, peanut fruit develops underground on pegs originating from branches that grow along the soil surface. This prostrate growth habit and pattern of fruit development restricts cultivation to an early season control option (Brecke and Colvin, 1991; Wilcut *et al.*, 1995). With conventional row spacing (91 to 102 cm), complete ground cover may not be attained until 8 to 10 wk after planting. In some areas of the U.S. peanut growing region, complete canopy closure may never be attained.

Control of annual grasses and small-seeded broadleaf weeds can be achieved with a dinitroaniline herbicide applied preplant incorporated (PPI) (Wilcut *et al.*, 1994a); however, control of larger-seeded weeds such as ivyleaf morningglory (*Ipomoea hederacea* (L.) Jacq.) must occur with the addition of other herbicides such as imazethapyr and imazapic (Cole *et al.*, 1989, Grey *et al.*, 1995, Grichar *et al.*, 1994, Wilcut *et al.*, 1991a, 1994c, 1995). Imazethapyr applied postemergence (POST) provided broad-spectrum and most consistent control when applied within 10 d of weed emergence (Cole *et al.*, 1989; Grey *et al.*, 1995; Grichar *et al.*, 1992; Wilcut *et al.* 1991a, b; 1994b, c). Imazapic applied POST controls the same spectrum of weeds as imazethapyr (Nester and Grichar, 1993; Grichar *et al.*, 1994; Wilcut *et al.*, 1993, 1994c, 1995). In addition, imazapic provided control and suppression of Florida beggarweed [*Desmodium tortuosum* (S.W.) D.C.] and sicklepod

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[*Senna obtusifolia* (L.) Irwin & Barneby], which are not adequately controlled by imazethapyr (Grey *et al.*, 2001). The limiting factors on the use of imazethapyr and imazapic are the rotational restriction (18 mo.) to crops such as cotton (*Gossypium hirsutum* L.) and sorghum (*Sorghum bicolor* L. Moench) and the potential development of weeds resistant to the ALS-inhibiting class of herbicides (Grey *et al.*, 2005; Matocha *et al.*, 2003; Wilcut *et al.*, 1995; York and Wilcut, 1995).

Lactofen was registered for use POST in peanut in 2005 for control of several annual broadleaf weeds including annual morningglory. Lactofen is classified as a diphenyl ether (cell membrane disruptor) which interferes with protoporphyrinogen IX oxidase synthesis and causes accumulation of protoporphyrin IX (Duke *et al.*, 1991). Protoporphyrinogen IX is a potent photosensitizer that generates high levels of singlet oxygen in the presence of molecular oxygen and light, leading to light-induced oxidative breakdown of cell constituents (Duke *et al.*, 1991). In general, herbicides classified as cell membrane disruptors (contact inhibitors) must be applied to small weeds. In previous weed control studies, lactofen controlled 99% Palmer amaranth (*Amaranthus palmeri* S. Wats.) in two of three yrs, while controlling this weed 80% in the third yr (Grichar, 1997). Grichar (1994) reported that lactofen at 0.28 kg/ha controlled 92% spiny amaranth (*Amaranth spinosus* L.) when applied early postemergence (EPOST), but control was less than 80% when applied late postemergence (LPOST); however, Jordan *et al.*, (1993) reported that lactofen applied LPOST controlled prickly sida (*Sida spinosa* L.) and morningglory species (*Ipomoea* species) as well as lactofen applied EPOST. Lactofen controlled 86% common lambsquarters (*Chenopodium album* L.) when applied at ground-crack (GC), but control declined to 34% when applications were delayed 2 wks (Wilcut, 1991). Lactofen controlled 87 to 95% prickly sida and 83 to 86% morningglory species when applied at GC and 2 wks after GC, respectively, but control declined to 0% when applications were made at 4 wks after GC. Wilcut *et al.* (1990) reported that broadleaf weed control systems containing sequential lactofen systems control common lambsquarters 100% and morningglory species 86%.

Peanut and soybean (*Glycine max* L.) tolerance to lactofen is based on the plants ability to metabolize the herbicide, which often results in some leaf bronzing and spotting and plant growth is often temporarily reduced (Harris *et al.*, 1991). Since injury following paraquat plus bentazon is often viewed as unacceptable by peanut growers in the southwest, the potential phytotoxicity caused by lactofen may be considered unacceptable as well regardless of its effect on yield and grade. The objective of this research was to evaluate peanut response in weed-free conditions following lactofen applied in single and sequential applications over several environments.

Materials and Methods

Field experiments were conducted at four locations in 2005 and five locations in 2006. Locations included Lamesa (Texas High Plains, 2005–06), Lockett (Texas Rolling Plains, 2005–06), Yoakum (south Texas, 2005–06), Ty Ty (Tift County, GA, 2005–06), and Plains (Sumter County, GA, 2006). The experimental design was a randomized complete block with three or four replications depending on location. The plot size was two or four rows by 7.6 to 9 m. Lactofen at 220 g ai/ha plus crop oil concentrate[7] at 1% v/v was applied to peanut at 6-leaf (lf), 6 lf followed by (fb) 15 days after the initial 6 lf treatment (DAIT), 15 DAIT alone, 6 lf fb 30 DAIT, 30 DAIT alone, 6 lf fb 45 DAIT, 45 DAIT alone, 6 lf fb 60 DAIT, and 60 DAIT alone. Herbicides were applied using water as a carrier with a CO_2-pressurized backpack sprayer that delivered 93 L/ha at 206 kPa using 110015 TurboTee[8] flat fan nozzles (Lamesa), 117 L/ha at 177 kPa using 11002 XR flat fan nozzles (Lockett), 187 L/ha at 205 kPa using 11002 Drift Guard flat fan nozzles (Yoakum), 140 L/ha at 237 kPa using 11002 Drift Guard flat fan nozzles (Ty Ty), and 140 L/ha at 170 kPa using 11001 Drift Guard flat fan nozzles (Plains). Planting dates, varieties, spray timings, digging, and harvest dates are shown in Table 1. Peanut injury was estimated visually throughout the season using a scale of 0 = no peanut injury to 100 = complete injury or peanut plant death. Experimental sites received a dinitroaniline herbicide applied PPI (all locations), diclosulam PRE (Ty Ty, 2005), diclosulam plus flumioxazin PRE (Ty Ty, 2006), clethodim POST (Ty Ty), cultivation (Lamesa), and hand-weeding at all locations throughout the growing season to maintain weed-free conditions to prevent any stress due to competition. Peanut yield was determined by digging, air-drying in the field for 6 to 10 d, and harvesting individual plots with a mechanical

[7]Crop Oil Concentrate (85% mineral oil and 15% polyoxyethoxylated polyol fatty acid ester and polyol fatty acid ester), Helena Chemical Company, 225 Schilling Boulevard, Suite 300, Collierville, TN 38017.

[8]Spraying Systems Company, P.O. Box 7900, North Avenue, Wheaton, IL 60188.

Table 1. Planting, application, and harvest dates; and peanut cultivar used at 9 locations in Texas and Georgia in 2005 and 2006[a].

	Lamesa, TX		Lockett, TX		Yoakum, TX		Ty Ty, GA		Plains, GA
Event	2005	2006	2005	2006	2005	2006	2005	2006	2006
Planting	26 Apr	24 Apr	28 Apr	29 Apr	7 Jun	12 Jun	9 May	10 May	8 May
6 LF applic.	31 May	22 May	25 May	25 May	29 Jun	5 Jul	24 May	25 May	25 May
15 DAIT	16 Jun	5 Jun	9 Jun	8 Jun	14 Jul	20 Jul	8 Jun	9 Jun	7 Jun
30 DAIT	29 Jun	19 Jun	23 Jun	26 Jun	28 Jul	3 Aug	21 Jun	20 Jun	21 Jun
45 DAIT	15 Jul	3 Jul	8 Jul	7 Jul	11 Aug	15 Aug	6 Jul	9 Jul	7 Jul
60 DAIT	2 Aug	17 Jul	25 Jul	21 Jul	23 Aug	29 Aug	22 Jul	20 Jul	21 Jul
Digging	29 Oct	28 Oct	22 Sep	23 Sep	25 Oct	23 Oct	15 Sep	21 Sep	28 Sep
Harvest	8 Nov	1 Nov	28 Sep	2 Oct	31 Oct	26 Oct	20 Sep	26 Sep	3 Oct
Cultivar	Tamrun OL02[b]	Flavor-runner 458[c]	Jupiter[d]	Jupiter	Tamrun 96[e]	Tamrun OL01[f]	GA Green[g]	GA Green	GA Green

[a]Abbreviations: DAIT, days after initial treatment; LF = leaf.

[b]Simpson, C. E., M. R. Baring, A. M. Schubert, M. C. Black, H. A. Melouk, and Y. Lopez. 2006. Registration of 'Tamrun OL 02' peanut. Crop Sci. 46:1813–1814.

[c]Baughman, T.A. and P.A. Dotray. 2007. Texas Peanut Production Guide. http://vernon.tamu.edu/peanut/pdfs/D__peanut_pdfs_productionguide07_3.pdf. Accessed 4/9/10.

[d]Oklahoma Agricultural Experiment Station. 2000. Release of Jupiter peanut. Okla. State Univ., Coop. Ext. Service, Stillwater, OK.

[e]Smith, O. D., C. E. Simpson, M. C. Black, and B. A. Besler. 1998. Registration of 'Tamrun 96' peanut. Crop Sci. 38:1403.

[f]Simpson, C. E., M. R. Baring, A. M. Schubert, H. A. Melouk, M.C. Black, Y. Lopez, and K. A. Keim. 2003. Registration of 'Tamrun OL01' peanut. Crop Sci. 43:2298.

[g]Branch, W. D. 1996. Registration of 'Georgia Green' peanut. Crop Sci. 36:806.

combine. Yield samples were adjusted to 10% moisture. Pod, shell, and peanut kernel weight were determined from each sample. Grades were determined from a 250-g pod sample from each plot following procedures described by the Federal-State Inspection Service (USDA, 1986).

Results and Discussion

Statistical analysis.

All data were subjected to mixed models. Data were analyzed using the PROC MIXED procedure of SAS[9] as a two-way factorial (initial 6 lf application and the follow-up sequential application). Variances were partitioned into the random effects of environment (year-location combinations), blocks within environment, and their interactions with fixed effects (herbicide treatments). Tests of fixed effects used Satterthwaite option to adjust the error degrees of freedom. Significance of random effects was tested using a Z test of the variance estimate and fixed effects were tested using F tests. Error assumptions of the variance analyses (random, homogeneous, normal distribution of error) were confirmed using residual plots and the Shapiro-Wilk normality test. To meet assumptions of normality, all injury data were arcsine square-root transformed, but interpretation of results was similar to non-transformed data; therefore, means from ANOVA of non-transformed data are shown.

Visual injury.

Peanut injury from lactofen was characterized as small necrotic lesions and leaf bronzing. This injury was evident for several weeks after application on tissue that intercepted the herbicide at the time of the application. Subsequent new growth did not show the effects of the herbicide, but in severe cases plant stunting occurred. Visual injury was assessed from zero to eight times depending on locations, so injury was analyzed separately by location.

Lamesa. In 2005, lactofen applied at 6 lf injured Tamrun OL02 15 to 18% when evaluated on Jun 17 (17 days after treatment, DAT), 25 to 28% when evaluated on Jul 15 (45 DAT), and injury was still apparent late-season (6%) (Table 2). Lactofen applied at 6 lf fb 30 DAIT caused the greatest visual injury 2 wk after the sequential application (33%), which was greater than injury caused by single applications at 6 lf and 30 DAIT. Late-season injury was characterized as canopy stunt and was present in all treatments. In 2006, lactofen-induced injury following the 6 lf application was no greater than 5% 14 DAT, which appears less than what was observed in 2005. This injury difference could be due to differences in early season environmental conditions between the two years and differences in the varieties planted. Conditions

[9]SAS software for Windows, Version 9.2. SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513.

Table 2. Peanut injury as affected by lactofen at Lamesa, Lockett, and Yoakum, TX in 2005 and 2006[a].

	2005								2006									
	Lamesa				Lockett			Yoakum	Lamesa				Lockett			Yoakum		
Treatment	Jun 17	Jul 15	Aug 16	Sep 20	Jun 9	Jul 8	Aug 8	Jul 6	Jun 5	Jul 3	Jul 31	Sep 29	Jun 8	Jul 7	Aug 7	Jul 10	Aug 3	Sep 20
	(%)																	
Non-treated	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
6 LF	17	28	10	6	9	0	0	5	4	5	3	2	6	1	0	13	8	2
6 LF fb 15 DAIT	17	30	9	6	6	0	0	7	4	8	5	5	8	1	0	12	7	2
15 DAIT	0	22	5	4	8	0	0	0	0	7	4	3	0	0	0	0	5	3
6 LF fb 30 DAIT	17	33	10	7	6	9	0	8	5	10	6	5	6	19	10	11	7	12
30 DAIT	0	18	5	4	5	9	0	0	0	6	1	2	0	18	8	0	0	2
6 LF fb 45 DAIT	15	28	10	8	5	0	1	6	4	6	10	4	6	1	20	14	3	2
45 DAIT	0	0	7	6	4	0	5	0	0	0	11	5	0	0	19	0	0	2
6 LF fb 60 DAIT	18	25	9	7	8	0	6	7	4	5	15	3	6	1	10	13	0	2
60 DAIT	0	0	9	6	5	0	8	0	0	0	15	6	0	0	10	0	0	0
LSD (0.10)	23	11	14	29	45	65	70	3	21	19	25	56	55	45	37	29	92	105

[a]Abbreviations: 6 LF = 6 leaf; DAIT = days after initial treatment; fb = followed by.

were generally cooler in 2005, which may have slowed peanut growth and recovery following lactofen-induced leaf chlorosis and necrosis. Grichar *et al.* (2010) previously reported that there were no differences in the susceptibility of OL02 and Flavorrunner 458 following several POST herbicides including lactofen. Lactofen applied at 6 lf fb 60 DAIT and at 60 DAIT alone injured Flavorrunner 458 15% when evaluated 2 wk after the sequential application (Jul 31). No other treatment caused injury exceeding 10% (Table 2). Grichar (1994, 1997) also reported that peanut injury occurred following lactofen treatments, but injury never exceeded 15%.

Lockett. No injury exceeded 10% following any lactofen treatment in 2005 (Table 2). In 2006, lactofen applied at 6 lf fb 45 DAIT, 45 DAIT, 6 lf fb 60 DAIT, and 60 DAIT injured Jupiter 18 to 20%.

Yoakum. Lactofen injured Tamrun 96 up to 10% following the 6 lf application and up to 20% following other single and sequential applications in 2005 (authors personal observation). In 2006, lactofen applied at 6 lf injured Tamrun OL01 13% 5 days after application (Table 2). When evaluated in September, lactofen applied at 6 lf fb 30 DAIT injured peanut 12%, but no other treatment caused greater than 3% injury.

Ty Ty. Early-season lactofen applications (6 lf) caused peanut stunting and foliar injury up to 11%, whereas the 45 DAIT treatment injured peanut 8% when evaluated late August in 2006 (Table 3). Lactofen had no effect on the incidence of tomato spotted wilt virus in either year (data not shown).

Plains. Negligible visual injury was observed at this location over the course of the growing season (Table 3). Similar transient peanut injury with lactofen has been previously reported at Plains, Georgia for POST applications (Moore *et al.* 1990).

Peanut grade and yield.

No two-way factorial (initial 6 lf application and the follow-up sequential application) interaction was observed for yield and grade; therefore means within initial application timing pooled over sequential application timings and means within sequential application timing pooled over initial application timings were compared. There was no difference in peanut yield regardless of whether an initial 6-leaf application was made or not (Table 4). Peanut yield ranged from 4253 to 4314 kg/ha. There was a difference, however, in peanut yield depending on the timing of the sequential application. Yield loss was observed when applications were made 45 DAIT. This timing would correspond to when peanut plants were in the R5 to R6 (beginning seed to full seed) stage of growth. At all applications except the Texas High Plains, this application timing would be within the 90 d preharvest interval (PHI) label restriction (Anonymous, 2011b). Applications of acifluorfen caused similar yield reductions when applied at this same timing in previous research in Georgia (Baughman *et al.* 2002). In sicklepod control studies in Georgia, lactofen at 0.22 kg/ha produced similar yield when

Table 3. Peanut injury as affected by lactofen at Ty Ty and Plains, GA in 2006[a].

	Ty Ty			Plains	
Treatment	Jun 14	Jul 27	Aug 30	Jul 5	Aug 10
	(%)				
Non-treated	0	0	0	0	0
6 LF	4	0	0	0	0
6 LF fb 15 DAIT	11	11	0	0	0
15 DAIT	9	3	0	0	0
6 LF fb 30 DAIT	9	6	3	0	0
30 DAIT	4	0	3	0	0
6 LF fb 45 DAIT	4	0	0	1	0
45 DAIT	4	0	8	0	0
6 LF fb 60 DAIT	4	5	3	0	0
60 DAIT	0	0	3	0	0
LSD (0.10)	4	4	4	1	0

[a]Abbreviations: 6 LF = 6 leaf; DAIT = days after initial treatment; fb = followed by.

compared to the weed-free check (Moore and Banks, 1991). Grichar and Dotray (2011) reported that lactofen increased yield up to 22% over the weedy check. In studies where broadleaf weed pressure was virtually nonexistent, two applications of sethoxydim with lactofen or lactofen plus pyridate produced yield equal to or greater than the non-treated control (Grichar, 1991). There was no difference in peanut grade regardless of whether an initial 6-leaf application was made or not (Table 5). Peanut grade was 70%. There was no difference in peanut grade regardless of whether a sequential application was made or not and peanut grade ranged from 69 to 70%.

Conclusions

In 9 tests from Georgia and Texas in 2005 and 2006, lactofen caused visible peanut injury at all locations. Mature peanut leaves exposed to lactofen will exhibit bronzing and necrotic lesions, and growth of the next two true leaves may exhibit some cupping and crinkling of leaf margins. Subsequent growth should be normal and plants should quickly outgrow the initial temporary injury conditions. Yield reductions occurred when applications were made at 45 DAIT, which corresponded to beginning to full seed fill. No grade reductions were apparent in any of these studies. Thus, growers who apply lactofen according with manufacturer's label recommendations and prior to seed fill should have confidence that yields will not be negatively impacted despite dramatic aboveground injury symptoms; however, applications made during seed fill may adversely affect yield.

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Table 4. Peanut yield following lactofen application timings over 9 locations in Texas and Georgia in 2005 and 2006[a].

Initial 6-lf Application	Sequential Application (d after 6-lf application)					
	None	15	30	45	60	
	(kg/ha)					
No	4380	4384	4242	4157	4103	4253a
Yes	4384	4292	4357	4195	4340	4314a
	4382A	4338AB	4300AB	4176B	4222AB	

[a]Means within a column followed by the same lower case letter are not different at p=0.10 ($LSD_{0.10}$ = 105 kg/ha). Means within a row followed by the same upper case letter are not different at p=0.10 ($LSD_{0.10}$ = 200 kg/ha).

Table 5. Peanut grade following lactofen application timings over 5 locations in Texas in 2005 and 2006[a].

Initial 6-lf Application	Sequential Application (d after 6-lf application)					
	None	15	30	45	60	
	(%)					
No	69.4	69.2	70.7	69.8	70.1	69.8a
Yes	69.4	69.9	69.8	69.8	69.1	69.6a
	69.4A	69.6A	70.3A	69.8A	69.6A	

[a]Means within a column followed by the same lower case letter are not different at p=0.10 ($LSD_{0.10}$ = 1%). Means within a row followed by the same upper case letter are not different at p=0.10 ($LSD_{0.10}$ = 1%).

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