Peanut Response to Carfentrazone-ethyl and Pyraflufen-ethyl Applied Postemergence[1]

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ABSTRACT

Field experiments were conducted at six locations in Texas in 2004 and 2005 to evaluate peanut tolerance to carfentrazone-ethyl and pyraflufen-ethyl. Carfentrazone-ethyl at 27 and 36 g ai/ha or pyraflufen-ethyl at 2.6 and 3.5 g ai/ha were applied early postemergence (EP) 28 to 51 days after planting (DAP) or late postemergence (LP) 93 to 121 DAP in weed-free plots. In the Texas High Plains, carfentrazone-ethyl and pyraflufen-ethyl applied EP resulted in 62 and 48% visual injury, respectively, when rated 14 days after treatment (DAT). With the exception of the low rate of carfentrazone-ethyl at one location, this injury was greater than the injury caused by paraquat at 210 g ai/ha plus bentazon at 280 g ai/ha. All injury declined over time, but was still apparent at harvest (up to 3%). Peanut injury from applications made late postemergence did not exceed 16%. In the Rolling Plains, peanut injury did not exceed 12% at Lockett and 25% at Rochester regardless of herbicide, rate, or timing. In south Texas, peanut injury ranged from 14 to 19% and 6 to 8% following EP and LP applications, respectively. At this location, carfentrazone-ethyl and pyraflufen-ethyl at the low rate caused less injury than paraquat plus bentazon when applied EP. Peanut yield was reduced by herbicide treatment at two of six locations. Greatest yield losses were observed at Lamesa in 2004, where all carfentrazone-ethyl treatments, except the lowest rate applied LP, and all pyraflufen-ethyl treatments caused a yield reduction when compared to the non-treated control. No reduction in grade from the non-treated control was observed at the five locations where grade analysis was performed.

Key Words: *Arachis hypogaea* L., carfentrazone-ethyl, groundnut, herbicide injury, peanut tolerance, postemergence-topical, pyraflufen-ethyl, visible injury, yield.

Peanut (*Arachis hypogaea* L.) production increased from 582,000 hectares in 1968 to 610,000 hectares in 2008 (Anonymous, 2008a). Peanut yield nearly doubled over this 40-year period in part due to effective herbicides, improved genetics with disease resistance, and cultural practices. However, weeds continue to be a major pest 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. Most peanut cultivars grown in the United States require a 135 to 160 d growing season, depending on cultivar and geographical region (Henning *et al.*, 1982; Wilcut *et al.*, 1995). Because of this extensive growing season, soil-applied herbicides may not provide season-long control and mid-to-late season weed problems are common. 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.

Weeds compete with the peanut plant for sunlight, moisture, and nutrients throughout the growing season. However, harvesting efficiency can also be reduced by weeds, which are particularly troublesome during digging and inverting procedures (Young *et al.*, 1982). Weed biomass slows field-drying of peanut vines and pods and increases the likelihood of exposure to rainfall, which can also increase harvest losses (Young *et al.*, 1982; Wilcut *et al.*, 1995). The fibrous root system of annual grasses is extremely difficult to separate from the peanut (Wilcut *et al.*, 1994a).

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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 by other means. 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; 1994 b,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 [*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 months) 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).

Herbicides with different modes of action which are as efficacious as the imidazolinone herbicides without the rotation restrictions would be useful in peanut. In 2004, sulfentrazone was registered for use in peanut in the southeast (Alabama, Georgia, North Carolina, South Carolina, Virginia, and Mississippi) due to lack of peanut injury (Grey *et al.*, 2004), but this label excluded states like Texas because significant injury has been observed (Grichar *et al.*, 2006; Grichar, 2006). Since 2004, peanut has been removed from the label (Anonymous, 2008c). Carfentrazone has a Federal label for use in peanut, which is efficacious on several annual broadleaf weeds including morningglory, but only as a burndown treatment prior to planting and as a directed (hooded) application in-crop any time during the growing season (Anonymous, 2008b). Both sulfentrazone and carfentrazone belong in the protoporphyrinogen oxidase (PPO) family of herbicides. Pyraflufen-ethyl, another PPO inhibitor, may be effective if used POST in peanut. This herbicide, utilized primarily in cereal crops, is registered for use in cotton as a harvest aid/defoliant and POST-directed spray, with potato (*Solanum tuberosum* L.) as a harvest aid/defoliant, and as a burndown/preplant herbicide for cotton, soybean (*Glycine max* L.), and corn (*Zea mays* L.) (Anonymous, 2004).

Until 2004, previous research on the use of carfentrazone-ethyl or pyraflufen-ethyl in peanut was lacking. Therefore, the objective of this research was to evaluate peanut tolerance to carfentrazone-ethyl and pyraflufen-ethyl applied POST-topical at different timings at various locations across the peanut growing regions of Texas.

Materials and Methods

Peanut tolerance experiments were conducted in the Texas High Plains near Denver City (2004) and Lamesa (2004 and 2005), in south Texas near Yoakum (2004), and in the Texas Rolling Plains near Rochester (2004) and Lockett (2005). The soil at Denver City was a Brownfield fine sand (loamy, mixed, superactive, thermic Arenic Aridic Paleustalf, 0.1% organic matter, pH 7.8), at Lamesa, an Amarillo fine sandy loam (fine-loamy, mixed, superactive, thermic Aridic Paleustalf, 0.4% organic matter, pH 7.8), at Yoakum, a Denhawken sandy clay loam (fine, smectitic, hyperthermic, Vertic Haplustepts, 1.6% organic matter, pH 7.6), at Rochester, a Miles fine sandy loam (fine-loamy, mixed, superactive, thermic Typic Paleustalf, 0.1% organic matter, pH 8.1), and at Lockett, a Miles fine sandy loam (fine-loamy, mixed, superactive, thermic Typic Paleustalf, 0.1% organic matter, pH 7.9). Peanut variety, planting date, application dates, and harvest date for each experiment are presented in Table 1.

At all locations, carfentrazone-ethyl at 27 or 36 g ai/ha and pyraflufen-ethyl at 2.6 or 3.5 g ai/ha were topically applied either 28 to 51 DAP (EP), or 93 to 121 DAP (LP). At Denver City, Lamesa, Lockett, and Rochester, crop oil concentrate (COC)[5] at 1 and 0.5% v/v was used with carfentrazone-ethyl and pyraflufen-ethyl, respectively; and at Yoakum, COC at 1.25% v/v was used with both. The rate of COC used for each herbicide was based on recommendations from representatives of each herbicide manufacturer and the COC used at Yoakum was based on previous research experience. Paraquat at 210 g ai/ha plus bentazon at 280 g ai/ha plus nonionic surfactant at 0.25% v/v was applied EP and 2,4-DB at 448 g ai/ha plus COC at 1% v/v was applied LP as standards for comparison purposes. Individual plot size was 2 by 9 m at Denver City, Lockett, Lamesa, and Rochester, and 2 by 6 m at Yoakum. All plots received a dinitroaniline herbicide applied preplant incorporated (PPI) and were cultivated and hand-weeded

[5]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.

Table 1. Peanut variety, planting date, application date, and harvest date at each location[a].

Site location/year	Variety	Planting date	Application date		Harvest date
			EP	LP	
Denver City, 2004	Fl Runner 458[b]	27 Apr	26 May	24 Aug	19 Oct
Lamesa, 2004	Fl Runner 458	26 Apr	27 May	24 Aug	8 Nov
Lamesa, 2005	Tamrun OL 02[c]	26 Apr	16 Jun	23 Aug	8 Nov
Lockett, 2005	Tamrun OL 02	30 Apr	2 Jun	29 Aug	24 Oct
Rochester, 2004	Tamrun 96[d]	7 May	4 Jun	1 Sep	8 Nov
Yoakum, 2004	Tamrun 96	24 May	23 Jun	25 Aug	8 Nov

[a]Abbreviations: EP, early postemergence; Fl, Flavor; LP, late postemergence.

[b]Beasley, J. and J. Baldwin. 2009. Peanut cultivars and descriptions. http://www.uga/commodities/fieldcrops/peanuts/production/cultivardescription.html. Accessed 2/19/09.

[c]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.

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

throughout the growing season to maintain weed-free conditions. Production practices including fertilizer, irrigation, fungicides, and insecticides were applied following local crop management practices.

Herbicides were applied using water as a carrier with a CO_2-pressurized backpack sprayer that delivered 140 L/ha at 207 kPa (Denver City and Lamesa), 187 L/ha at 103 kPa (Lockett and Rochester), or 190 L/ha at 180 kPa (Yoakum). Peanut injury was estimated visually 6 to 14 d and 28 to 36 d after EP applications and 7 to 19 d and 24 to 28 d after the LP applications using a scale of 0 (no injury) to 100 (peanut death). Peanut yield was determined by digging, air-drying in the field for 6 to 10 d, and harvesting individual plots with a tractor pull-type thresher. 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).

At each location, the experimental design was a randomized complete block with treatments replicated three or four times. Data were subjected to analysis of variance (SAS 9.1). Means were compared using Fisher's Protected LSD test at $P \leq 0.10$.

Results and Discussion

Statistical Analysis

There was a location by treatment interaction for peanut injury, yield, and grade across years and location. Therefore, data for these variables are presented separately by location and year.

Visual Injury

Peanut injury from carfentrazone-ethyl, pyraflufen-ethyl, and paraquat plus bentazon resulted in rapid damage to plant tissue after application and manifested as small necrotic lesions. This injury was evident for several weeks after application on older tissue. Subsequent new growth did not show the effects of the carfentrazone-ethyl, pyraflufen-ethyl, or paraquat plus bentazon applications. Similar injury symptoms were noted by Lyon *et al.* (2007) who described injury as localized spotting of treated foxtail millet leaves.

Denver City. Visual injury ranged from 22 to 47% following carfentrazone-ethyl treatments and 33 to 48% following pyraflufen-ethyl treatments 14 days after EP applications (Table 2). When compared to paraquat plus bentazon (a common EP treatment), carfentrazone-ethyl at the high rate and pyraflufen-ethyl caused more injury. At 28 DAT, peanut injury was at least 18% following EP treatments. There was no difference between paraquat plus bentazon and the low rates of either carfentrazone-ethyl or pyraflufen-ethyl; however peanut injury increased as herbicide rate increased. All injury declined over time, but was still apparent at harvest (2 to 3%, data not shown). Carfentrazone-ethyl or pyraflufen-ethyl applied LP caused less peanut injury than at the EP timing. Visual injury from LP applications of carfentrazone-ethyl or pyraflufen-ethyl did not exceed 7% at either 14 or 28 DAT while peanut injury following 2,4-DB was 5% or less (Table 2).

Lamesa 2004. Visual injury 14 DAT ranged from 47 to 62% following carfentrazone-ethyl treatments and 35 to 40% following pyraflufen-ethyl applied EP (Table 2). Injury 28 DAT was at least 32% and 28% following applications of carfentrazone-ethyl and pyraflufen-ethyl, respectively. When compared to paraquat plus bentazon, both herbicides caused more peanut injury 14 and 28 DAT except pyraflufen-ethyl at the low rate 28 DAT. Injury decreased over time but was still apparent at

Table 2. Visual peanut injury 14 and 28 days after carfentrazone-ethyl and pyraflufen-ethyl applied early- and late-postemergence in Texas[a].

			Denver City		Lamesa, 2004		Lamesa, 2005		Lockett	Rochester	Yoakum
Herbicide	Rate	Timing	14	28	14	28	14	28	28	14	14
	g ai/ha		(%)								
Carfen	27	EP	22	18	47	32	17	20	3	18	15
Carfen	36	EP	47	35	62	38	30	31	7	25	16
Pyraflu	2.6	EP	33	23	35	28	27	31	5	13	14
Pyraflu	3.5	EP	48	35	40	37	38	38	3	23	19
Paraquat plus bentazon	210 + 280	EP	23	22	28	27	10	23	0	11	20
Carfen	27	LP	3	2	3	3	9	0	8	5	7
Carfen	36	LP	5	4	4	3	13	3	12	3	8
Pyraflu	2.6	LP	6	5	5	5	12	0	7	18	6
Pyraflu	3.5	LP	7	6	5	5	16	5	2	20	8
2,4-DB	448	LP	5	4	0	0	7	0	0	0	4
$LSD_{(0.10)}$			5	5	5	5	5	2	6	5	5
P value			0.0001	0.0001	0.001	0.001	0.0001	0.0001	0.0708	0.0001	0.001

[a]Abbreviations: Carfen, carfentrazone-ethyl; EP, early postemergence; LP, late postemergence; Pyraflu, pyraflufen-ethyl.

harvest (2 to 7%, data not shown). Visual injury following LP treatments of carfentrazone-ethyl or pyraflufen-ethyl did not exceed 5% while there was no injury following 2,4-DB.

Lamesa 2005. Peanut injury 14 DAT from carfentrazone-ethyl applied EP ranged from 17 to 30% and 27 to 38% following pyraflufen-ethyl applications (Table 2). Peanut injury 14 DAT was greater following carfentrazone-ethyl and pyraflufen-ethyl compared to paraquat plus bentazon regardless of rate. Carfentrazone-ethyl at the low rate caused less injury than paraquat plus bentazon 28 DAT; however, peanut injury with carfentrazone-ethyl at 36 g/ha and pyraflufen-ethyl was greater than paraquat plus bentazon. All peanut injury decreased over time, but was still visible at harvest (2 to 6%, data not shown). Peanut injury 14 DAT following carfentrazone-ethyl and pyraflufen-ethyl applied LP ranged from 9 to 13% and 12 to 16%, respectively, while injury following an application of 2,4-DB was 7%. Carfentrazone-ethyl and pyraflufen-ethyl at the low rate and 2,4-DB caused no peanut injury 28 DAT, while the high rates of carfentrazone-ethyl and pyraflufen-ethyl resulted in 3 to 5% injury.

Lockett. Peanut injury at 28 DAT did not exceed 7% following EP applications or 12% following LP applications regardless of herbicide and rate (Table 2). Carfentrazone-ethyl at the high rate LP was the only treatment that caused greater than 10% injury. This injury was greater than the injury observed following pyraflufen-ethyl and 2,4-DB applied LP.

Rochester. Peanut injury at 14 DAT ranged from 11 to 25% following EP applications and 0 to 20% following LP applications. The high rate of carfentrazone-ethyl and pyraflufen-ethyl applied EP injured peanut 23 to 25% 14 DAT, respectively (Table 2). This injury was greater than that observed following paraquat plus bentazon (11%). All injury decreased to less than 5% at the end of the season (data not shown). Carfentrazone-ethyl and pyraflufen-ethyl applied LP caused 3 to 5% and 18 to 20% injury, respectively. There was no visual injury following 2,4-DB applied LP.

Yoakum. Visual injury following carfentrazone-ethyl and pyraflufen-ethyl applied EP ranged from 15 to 19% while injury from paraquat plus bentazon applied at EP was 20% (Table 2). Injury was lower with carfentrazone-ethyl and pyraflufen-ethyl at the low rates compared to paraquat plus bentazon. Injury following carfentrazone-ethyl and pyraflufen-ethyl applied LP ranged from 6 to 8% while injury from 2,4-DB applied LP was 4%. There was no difference among LP treatments.

Research has indicated that crop injury can vary with carfentrazone-ethyl and pyraflufen-ethyl. Durgan *et al.* (1997) observed wheat (*Triticum aestivum* L.) injury from 1 to 67% 3 to 5 DAT with carfentrazone-ethyl at 26 or 35 g/ha. Injury varied among tank-mix partner, location, and year, but tended to increase when crop oil concentrate or nitrogen-containing adjuvants were used as compared to non-ionic surfactants. The addition of either non-ionic surfactant or methylated vegetable oil to carfentrazone-ethyl and urea ammonium nitrate was necessary to achieve effective weed control when the spray volume was reduced from 94 or 190 L/ha to 47 L/ha (Ramsdale and Messersmith, 2001). Crop injury or weed control has been closely correlated with metabolism of carfentra-

Table 3. Peanut yield and grade following carfentrazone-ethyl and pyraflufen-ethyl applications made early- and late-postemergence in Texas[a].

			Denver City		Lamesa, 2004		Lamesa, 2005		Lockett		Rochester		Yoakum
Herbicide	Rate	Timing	yield	grade	yield	grade	yield	grade	yield	grade	yield	grade	yield
	g/ha		kg/ha	(%)	kg/ha	(%)	kg/ha	(%)	kg/ha	(%)	kg/ha	(%)	kg/ha
Carfen	27	EP	4647	74	6799	73	5358	70	7722	77	3983	77	3039
Carfen	36	EP	4663	74	5856	73	5308	70	6704	77	3726	77	2754
Pyraflu	2.6	EP	5449	73	6496	73	4617	69	6010	77	4378	78	2724
Pyraflu	3.5	EP	5149	73	6395	73	4971	68	7265	75	3909	77	2439
Paraquat plus bentazon	210 + 280	EP	5035	73	7421	72	5223	70	7193	75	4506	78	3100
Carfen	27	LP	4626	73	7018	74	5156	69	6666	76	4536	78	2866
Carfen	36	LP	4619	74	6782	72	4482	68	6716	76	4968	77	2826
Pyraflu	2.6	LP	4420	75	6715	72	4869	69	6262	75	4165	78	2724
Pyraflu	3.5	LP	4210	74	6580	74	4600	69	6214	75	4159	77	3344
2,4-DB	448	LP	4522	73	6900	73	4332	68	6813	75	4445	77	2724
NTC	—	—	5052	74	7387	72	4769	69	6149	76	4476	77	2978
$LSD_{(0.10)}$	—	—	NS	NS	562	NS	NS	NS	NS	NS	607	NS	NS
P value	—	—	0.460	0.963	0.006	0.459	0.270	0.402	0.846	0.348	0.082	0.299	0.731

[a]Abbreviations: Carfen, carfentrazone-ethyl; EP, early postemergence; LP, late postemergence; NTC, non-treated control; Pyraflu, pyraflufen-ethyl.

zone-ethyl (Dayan *et al.*, 1997; Thompson and Nissen, 2002). The effect of crop oil concentrate or nitrogen adjuvants may be related to the metabolic capacity of wheat (Howatt, 2005). Thompson and Nissen (2002) demonstrated that low light intensity immediately before carfentrazone-ethyl application resulted in increased crop response. Typically, herbicide applications at Yoakum were made early in the morning, within a couple of hours of daybreak so the south Texas location should have shown greater injury.

Scroggs *et al.* (2006) reported on soybean, where pyraflufen-ethyl was applied in combination with glyphosate, that as the rate of pyraflufen-ethyl increased, injury increased. At one location, pyraflufen-ethyl at 45 g/ha plus glyphosate resulted in greater soybean injury (32%) than all other rates. Carfentrazone-ethyl applied in tank mix improved weed control when weeds were under drought stress (Lyon *et al.*, 2007).

Peanut Grade and Yield

No difference between the non-treated control and any herbicide treatment was noted with respect to peanut grade at any location (Table 3).

With respect to peanut yield, at the Denver City, Lamesa in 2005, Lockett, and Yoakum locations, no difference in peanut yield was observed between the non-treated control and any herbicide treatment (Table 3). At Lamesa in 2004, only the standard herbicide treatments and carfentrazone-ethyl at the low rate applied LP were not different from the non-treated control. The greatest reduction in yield from the non-treated control was noted with carfentrazone-ethyl at the high rate applied EP. At Rochester, none of the herbicide treatments with the exception of carfentrazone-ethyl at the high rate applied EP resulted in a reduction in yield from the non-treated control. Yields from this herbicide treatment were reduced when compared to the non-treated control. Howatt (2005) reported that carfentrazone-ethyl caused 21% wheat injury 3 d after treatment, but did not affect yield.

Conclusions

These experiments indicate that peanut injury following carfentrazone-ethyl and pyraflufen-ethyl applied early season is more severe than applications made late season. Substantial peanut visual injury was observed from EP applications at all locations, and yield loss was observed at two of six locations. Yield losses were only observed at 1 of 6 locations with LP applications. Except for the low rate of carfentrazone-ethyl at Yoakum and Lamesa (2005) and the low rate of pyraflufen-ethyl at Yoakum, injury observed with these EP applications was equal to or greater than injury observed following paraquat plus bentazon at the same application timing. Since injury following paraquat plus bentazon is often viewed as unacceptable by peanut growers in the southwest, it is likely that injury following carfentrazone-ethyl and pyraflufen-ethyl will be unacceptable as well. These herbicides may provide a tool for late season weed control, especially where morningglories are a problem and a rescue treatment is needed.

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