Grass Control in Peanut (*Arachis hypogaea*) with Clethodim and Selected Broadleaf Herbicide Combinations[1]

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ABSTRACT

Field studies were conducted to evaluate broadleaf signalgrass and southern crabgrass control and effect on peanut yield of clethodim alone and sequential applications with six broadleaf herbicides. When rated 9 wk after treatment (WAT), broadleaf signalgrass control with clethodim followed by (fb) acifluorfen, imazapic, or 2,4-DB 24 hr later did not differ from clethodim alone. When acifluorfen, acifluorfen plus bentazon, imazethapyr, imazapic, and lactofen were applied in a tank-mix with clethodim, broadleaf signalgrass control was less than 65%. Clethodim alone or clethodim plus 2,4-DB controlled 86 and 73% broadleaf signalgrass, respectively. When acifluorfen, acifluorfen plus bentazon, or imazethapyr was fb clethodim, signalgrass control was less than 72%. Southern crabgrass control was reduced in 2 of 3 yr from clethodim alone when acifluorfen was tank-mixed with clethodim. When other broadleaf herbicides were tank-mixed with clethodim, reduced crabgrass control was noted in only 1 of 3 yr. Where no POST herbicides were used, peanut yield was < 1600 kg/ha, while all plots which received a POST herbicide yielded over 2200 kg/ha.

Key Words: Antagonism, broadleaf signalgrass, groundnut, postemergence, southern crabgrass.

Graminicides are often applied in combination with broadleaf herbicides for convenience and to increase the spectrum of weed control. Antagonism of graminicide activity by broadleaf herbicides often occurs (Vidrine *et al.*, 1995; Snipes and Allen, 1996; Tredaway *et al.*, 1998; Corkern *et al.*, 1999). Unfavorable environmental conditions can further exacerbate herbicide efficacy when applied in mixture. Inadequate soil moisture has been reported to decrease grass control and increase antagonism by reducing foliar absorption (Godley and Kitchen, 1986; Vidrine, 1989; Holshouser and Coble, 1990).

Grass size also can affect the response of graminicide and broadleaf herbicide mixtures. Greater antagonism has been observed with mixtures applied to johnsongrass [*Sorghum halepense* (L.) Pers.] 40 cm and taller (Whitwell *et al.*, 1985; Jordan *et al.*, 1993). Rosales-Robles *et al.* (1999) reported that clethodim{(E,E)-(±)-2-[1-[[3-chloro-2(propenyl)oxy]imino] propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} at 35 g/ha controlled seedling johnsongrass at least 90% up to the eight-leaf stage while clethodim at 70 g/ha provided 90% or greater control of rhizome johnsongrass if applied at the three- to four-leaf stages.

Clethodim is registered for the control of grass weeds in cotton (*Gossypium hirsutum* L.), soybean [*Glycine max* (L.) Merr.], peanut (*Arachis hypogaea* L.), and several other dicotyledonous crops (Ahrens, 1994). Grichar (1991) reported clethodim at 0.11 kg/ha provided greater than 85% control of Texas panicum (*Panicum texanum* Buckl.) and southern crabgrass [*Digitaria ciliaris* (Retz.) Koel.] when applied to grasses less than 15 cm tall. In greenhouse studies, clethodim at 0.07 kg/ha reduced barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] fresh weight 81% when compared to the untreated check (Minton *et al.*, 1989).

However, tank mixes of broadleaf herbicides with clethodim are antagonistic. Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) antagonized efficacy of clethodim on annual and perennial grasses when applied in mixtures (Corkern *et al.*, 1998; Culpepper *et al.*, 1998, 1999). Vidrine *et al.* (1995) reported that lactofen {(±)-2-ethoxy-1-methyl-2-oxoethyl-5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate} tank-mixed with clethodim reduced johnsongrass and barnyardgrass control versus clethodim alone. In a greenhouse study, clethodim in combination with acifluorfen {5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid}, bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide], lactofen, or 2,4-DB [4-(2,4-dichlorophenoxy)butanic acid] did not reduce barnyardgrass fresh weight from clethodim alone. In contrast, fresh weights were decreased with tank mixes of clethodim and imazaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid} (Minton *et al.*, 1989).

Sequential application of a grass herbicide and broadleaf weed herbicide may result in less antagonism for grass control. Antagonism of sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} with bentazon can be avoided if bentazon is applied 48 hr after sethoxydim (Rhodes and Coble, 1984). The application of acifluorfen 3 d after fluazifop{(R)-2-[4-[[5-(triflyoromethyl)-2-pyridinyl]oxy]phenoxy] propanoic acid} did not affect large crabgrass [*Digitaria sanguinalis* (L.) Scop.], but control was antagonized when acifluorfen was applied 3 d before fluazifop (Godley and Kitchen, 1986).

Minton *et al.* (1989) reported the application of imazaquin, chlorimuron {ethyl 2-[[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoate}, or lactofen 24 hr after sethoxydim or quinzalofop did not affect barnyardgrass control. However, barnyardgrass control was antagonized by the application of imazaquin on lactofen 24 hr before sethoxydim or quizalofop {(R)-2-[4-[(6-chloro-2-quinoxalinyl)oxy]phenoxy] propanoic acid}.

The objective of this research was to evaluate the effect

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of tank mixes or 24-hr sequential applications of acifluorfen, acifluorfen + bentazon [Storm (a mixture of 159 g acifluorfen and 320 g bentazon/L) (BASF Corp., Parsippany, NJ)], imazethapyr {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid}, imazapic {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid}, lactofen, or 2,4-DB on broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash] and southern crabgrass control by clethodim. Also, the effect of three herbicide combinations and annual grass control on peanut yield was measured.

Materials and Methods

Experiments were conducted in 1996, 1997, and 1999 at the Texas Agric. Exp. Sta. located near Yoakum, TX on a Strabor loamy sand (fine, mixed, thermic Aquic Paleustalfs) with less than 1% organic matter and pH 7.0 to 7.2. The experimental design was a randomized complete block with four replications. Each plot contained two rows 97 cm apart and 6.1 m long. All field plots were naturally infested with broadleaf signalgrass (10 to 20 plants/m^2) and southern crabgrass (8 to 12 plants/m^2).

Clethodim at 0.11 kg/ha was applied alone, in tank mix, or sequentially with the broadleaf herbicides. Sequential applications included clethodim applied 24 hr before or after the broadleaf herbicides. The broadleaf herbicides and rates used were acifluorfen at 0.56 kg/ha, a premix of acifluorfen at 0.28 kg/ha with bentazon at 0.56 kg/ha, imazethapyr and imazapic at 0.07 kg/ha, lactofen at 0.22 kg/ha, and 2,4-DB at 0.28 kg/ha. Crop oil concentrate [Agridex (a mixture of 83% paraffin base petroleum oil and 17% surfactant blend) (Helena Chemical Co., Memphis, TN] at 1.25% (v/v) was added to all treatments. An untreated check was also included.

Herbicides were applied in water with a compressed air bicycle sprayer using Teejet 11002 (Spraying Systems, Co., Wheaton, IL) flat fan nozzles which delivered a spray volume of 190 L/ha at 180 kPa. Broadleaf signalgrass and southern crabgrass were less than 25 cm tall while peanuts were 13 to 18 cm tall at time of herbicide application. Herbicide applications were made 34 to 40 d after planting.

GK-7 peanut was planted in 1996 and 1997 while the cultivar Georgia Green was planted in 1999. Peanuts were planted 5 to 8 cm deep at 106 kg/ha in each year. Sprinkler irrigation was applied on an as-needed schedule throughout the growing season.

Visual ratings of annual grass control were recorded 3 to 4 wk after planting and every 4 wk afterward until harvest. Only the ratings taken prior to harvest are presented. Ratings were based on a scale of 0 (no control) to 100 (complete control) relative to the untreated check. Peanut yields were determined by digging the pods 135 to 146 d after planting, air-drying in the field 3 to 5 d, and harvesting individual plots with a combine. Weights were recorded after soil and trash were removed from the samples.

Data were subjected to analysis of variance with partitioning for a six (broadleaf herbicide) by three (herbicide application) factorial treatment arrangement. A separate ANOVA compared the yield of the untreated check with all herbicide treatments. Year by treatment interactions for broadleaf signalgrass and peanut yield were not observed; therefore, data are pooled. However, for southern crabgrass there was a treatment by year interaction and these data are presented by year. Efficacy data were transformed to the arcsine square root and means of nontransformed data were separated using Fisher's protected LSD test at P = 0.05. Nontransformed data are presented for weed control as the transformation did not change the order for presentation of results.

Results and Discussion

Broadleaf Signalgrass. Clethodim alone provided 86% control of broadleaf signalgrass (Table 1). All broadleaf herbicides when tank-mixed with clethodim reduced broadleaf signalgrass control. Similar results were noted in studies with other POST grass herbicides (Grichar and Boswell, 1987; York *et al.*, 1993; Snipes and Allen, 1996). Texas panicum and large crabgrass control was reduced 10 to 20% from the graminicide alone when fluazifop-P or haloxyfop was mixed with bentazon or 2,4-DB (Grichar and Bowell, 1987). When quizalofop-P, clethodim, sethoxydim, or fluazifop-P was applied alone, johnsongrass control was greater than 80%. However, when pyrithiobac was tank-mixed with each of these graminicides, control was usually less than 80% (Snipes and Allen, 1996). Mixing 2,4-DB with clethodim, fluazifop-P, quizalofop-P, or sethoxydim reduced annual grass control 8 to 15% (York *et al.*, 1993).

Table 1. Broadleaf signalgrass control using clethodim in combination with broadleaf herbicides.[a]

Broadleaf weed herbicide	Rate	Broadleaf signalgrass		
		Before[b]	With	After
	kg/ha	---------- % ----------		
Acifluorfen	0.56	76	38	61
Acifluorfen + bentazon[c]	0.28+0.56	72	48	67
Imazethapyr	0.07	55	51	71
Imazapic	0.07	83	62	79
Lactofen	0.22	70	64	81
2,4-DB	0.25	78	73	87
None[d]	---		86	
LSD (0.05)[e]			13	

[a]All treatments contained 1.25% (v/v) crop oil concentrate.

[b]'Before' indicates clethodim (0.11 kg/ha) followed 24 hr later by broadleaf weed herbicide; 'With' indicates a tank mixture of clethodim and broadleaf weed herbicide; 'After' indicates broadleaf weed herbicide followed 24 hr later by clethodim.

[c]A premix marketed as Storm.

[d]Clethodim alone at 0.11 kg/ha.

[e]Treatment comparison within time of clethodim application.

When clethodim was applied 24 hr prior to the application of the broadleaf herbicide, reduced broadleaf signalgrass control was noted with acifluorfen plus bentazon, imazethapyr, and lactofen. No differences in efficacy be-

tween clethodim alone and acifluorfen, imazapic, or 2,4-DB applied 24 hr after clethodim application were observed. While studies have shown that diphenylethers and the benzothiadiazinone herbicide bentazon reduce grass control by decreasing absorption and translocation of aromatic oxyphenoxypropanoate and cyclohexanone herbicides, research indicates that this is not the mechanism for antagonism with inhibitors of acetolactate synthase (e.g., imazapic or imazethapyr). It was postulated that this antagonistic interaction could result from a physiological linkage between the site of action of the grass herbicides and inhibition of acetolactate synthase (Rhodes and Coble, 1984; Gerwick *et al.*, 1988).

When clethodim followed the broadleaf herbicide, reduced broadleaf signalgrass control was noted with acifluorfen, the premix of acifluorfen plus bentazon, and imazethapyr (Table 1). Reduced signalgrass control was not noted when clethodim followed imazapic, lactofen, or 2,4-DB. In other studies, the sequential treatments in which sethoxydim or quizalofop was applied 24 hr before imazaquin, chlorimuron or lactofen did not affect barnyardgrass control (Minton *et al.*, 1989). However, a reduction in the efficacy of sethoxydim and quizalofop occurred when either was applied 24 hr after imazaquin or lactofen. Control was not antagonized by the application of sethoxydim or quizalofop 24 hr after chlorimuron (Minton *et al.*, 1989). Similar results were noted with 24-hr sequential applications of sethoxydim and bentazon on broadleaf signalgrass and fall panicum (*Panicum dichotomiflorum* Michx.) (Rhodes and Coble, 1984) and with 72-hr sequential applications of acifluorfen and fluazifop on large crabgrass and switchgrass (*Panicum virgatum* L.) (Godley and Kitchen, 1986).

Southern Crabgrass. In 1996, southern crabgrass control with clethodim was 95% while in 1997 and 1999 control was less than 80% (Table 2). When clethodim was applied 24 hr prior to the application of a broadleaf herbicide, antagonism was only noted in 1997. Clethodim fb acifluorfen plus bentazon or 2,4-DB reduced southern crabgrass control to less than 50%.

Tank mix combinations of clethodim and acifluorfen were antagonistic in 1996 and 1997, but not in 1999 (Table 2). In 1996, all other tank-mix combinations provided 80 to 98% control of southern crabgrass. In 1997, all tank-mix combinations of clethodim plus a broadleaf herbicide resulted in antagonism, while in 1999 no antagonism was noted with any tank-mix combinations.

When clethodim followed the broadleaf herbicides, antagonism was only noted in 1997. Acifluorfen or acifluorfen plus bentazon provided less than 50% southern crabgrass control while the other broadleaf herbicides fb clethodim showed 68 to 75% control.

The difference in antagonism between years may be explained by some variation in southern crabgrass size, but also by differences in soil moisture before and after time of application. Vidrine *et al.* (1995) reported inconsistent johnsongrass and barnyardgrass control with clethodim and lactofen when rainfall amounts varied between years and locations. Godley and Kitchen (1986) reported that fluazifop mixed with acifluorfen under different soil moisture conditions caused a lack of uniformity in response among years.

Peanut Yield. All herbicide treatments which included imazethapyr, imazapic, lactofen, or 2,4-DB increased peanut yield over the untreated check (1360 kg/ha) indicating a reduction in competitiveness from broadleaf signalgrass and southern crabgrass (Table 3). Acifluorfen applied with clethodim or the premix of acifluorfen plus bentazon applied in combination with clethodim or following clethodim did not result in a peanut yield increase over the untreated check. Peanuts with clethodim applied alone yielded 1510 kg/ha. Clethodim controlled > 70% broadleaf signalgrass and southern crabgrass; however, populations of these grasses were high enough at harvest to interfere with digging.

Table 2. Southern crabgrass control using clethodim in combination with broadleaf herbicides.[a]

Broadleaf weed herbicide	Rate	Before[b]			With			After		
		1996	1997	1999	1996	1997	1999	1996	1997	1999
	kg/ha	%			%			%		
Acifluorfen	0.56	93	66	66	68	33	83	99	44	85
Acifluorfen + bentazon[c]	0.28+0.56	99	38	60	80	46	63	94	40	75
Imazethapyr	0.07	91	71	68	84	55	81	86	70	71
Imazapic	0.07	100	81	97	95	51	90	78	68	94
Lactofen	0.22	96	58	55	96	40	56	99	71	83
2,4-DB	0.25	77	45	69	95	38	63	99	75	82
None[d]		95	78	71	95	78	71	95	78	71
LSD (0.05)		24	22	22		22[e]			22	

[a]All treatments contained 1.25% (v/v) crop oil concentrate.

[b]'Before' indicates clethodim followed 24 hr later by broadleaf weed herbicide; 'With' indicates a tank mixture of clethodim and broadleaf weed herbicide; 'After' indicates broadleaf weed herbicide followed 24 hr later by clethodim.

[c]A premix marketed as Storm.

[d]Clethodim applied alone at 0.11 kg/ha.

[e]Treatment comparison within time of clethodim application.

Table 3. Peanut yield as a result of using clethodim in combination with broadleaf herbicides.[a]

Broadleaf weed herbicide	Rate	Peanut yield[b]		
		Before[c]	With	After
	kg/ha	---------- kg/ha ---------		
Acifluorfen	0.56	3200	2520	3040
Acifluorfen+ bentazon[d]	0.28+0.56	3160	2300	2260
Imazethapyr	0.07	5840	2960	2660
Imazapic	0.07	3300	3220	3300
Lactofen	0.22	3160	3080	3040
2,4-DB	0.25	3260	3400	2940
None[e]		----	1510	----
LSD (0.05)[f]			1040	

[a]All treatments contained 1.25% (v/v) crop oil concentrate.

[b]Untreated check yield was 1360 kg/ha.

[c]'Before' indicates clethodim (0.11 kg/ha) followed 24 hr later by broadleaf weed herbicide; 'With' indicates a tank mixture of clethodim and broadleaf weed herbicide; 'After' indicates broadleaf weed herbicide followed 24 hr later by clethodim.

[d]A premix marketed as Storm.

[e]Clethodim applied alone at 0.11 kg/ha.

[f]Treatment comparison within time of clethodim application.

Although Palmer amaranth (*Amaranthus palmeri* S. Wats) and yellow nutsedge (*Cyperus esculentus* L.) were present in plots, they were never in numbers large enough to require a herbicide application. However, these weeds may have contributed to pod loss at digging and resulted in peanut yield reductions in clethodim only treated plots.

Implications of Results. This study clearly demonstrates that substantial antagonism may occur when clethodim is mixed with common broadleaf herbicides used in peanut. Generally, less antagonism of broadleaf signalgrass or southern crabgrass control was observed when clethodim was applied 24 hr before or after the application of a broadleaf herbicide. Other studies have noted similar results using fluazifop-P plus fenoxaprop-P, sethoxydim, or quizalofop with various broadleaf herbicides (Minton *et al.* 1989; Culpepper *et al.*, 1998).

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