Influence of Adjuvants on Peanut (*Arachis hypogaea* L.) Response to Prohexadione Calcium

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ABSTRACT

Research has demonstrated that prohexadione calcium (calcium salt of 3,5-dioxo-4-propionylcyclohexanecarboxylic acid) retards vegetative growth of peanut (*Arachis hypogaea* L.) and in some cases increases pod yield, the percentage of extra large kernels, market value ($/kg), and gross value ($/ha). Spray adjuvants such as crop oil concentrate and nitrogen solution most likely will be recommended for application with prohexadione calcium. However, efficacy of prohexadione calcium applied with adjuvants has not been conclusively determined. Twelve experiments were conducted in North Carolina and Virginia during 1997 and 1998 to determine peanut response to prohexadione calcium applied with crop oil concentrate, urea ammonium nitrate, or a mixture of these adjuvants. Applying prohexadione calcium with urea ammonium nitrate, either alone or with crop oil concentrate, increased row visibility and shorter main stems compared with nontreated peanut or prohexadione calcium applied with crop oil concentrate. Prohexadione calcium increased pod yield, the percentage of extra large kernels, and gross value of peanut in seven of 12 experiments regardless of adjuvant when compared with nontreated peanut. Pod yield, the percentage of extra large kernels, and gross value of peanut were not affected in the other experiments. Prohexadione calcium did not affect the percentage of total sound mature kernels, the percentage of other kernels, or market value in any of the experiments regardless of adjuvant.

Key Words: Additives, canopy architecture, crop oil concentrate, nitrogen solution, plant growth regulator, row visibility, urea ammonium nitrate.

Excessive growth of peanut (*Arachis hypogaea* L.) vines can make digging peanut a challenge because of poor row visibility and the need to precisely dig without cutting pods (Beasley, 1970). Mitchem *et al.* (1996) reported that the top of the peanut canopy is nearly level across rows and row middles in years where conditions are favorable for plant growth. Excessive vine growth can contribute to enhanced disease (Bauman and Norden, 1971; Henning *et al.*, 1982) and poor coverage of foliar-applied fungicides (Henning *et al.*, 1982; Maloy, 1993). Several virginia-market type cultivars exhibit vine growth which often deters growers from planting these cultivars

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(Jordan, 1999). Ability to reduce vine growth by using a plant growth regulator may increase utility of these cultivars.

Research suggests that prohexadione calcium may be an effective replacement for daminozide [butanoic acid mono (2,2-dimethylhydrazide)] (Mitchem *et al.*, 1996; Evans *et al.*, 1997; McKemie and Evans, 1998). Prohexadione calcium has been shown to reduce vine growth regardless of cultivar (Culpepper *et al.*, 1997). Additionally, pod yield, percentage of extra large kernels, market value, and gross value often increased when prohexadione calcium was applied to peanut (Mitchem *et al.*, 1996; Culpepper *et al.*, 1997). These yield and quality responses were dependant upon cultivar and environmental conditions.

Efficacy of foliarly applied agrichemicals can be influenced by adjuvants (Hatzios and Penner, 1985). These changes can be associated with a number of factors, including alteration of spray solution pH, interactions with ions in the spray solution, decreased surface tension, and enhanced penetration through the cuticle (McWhorter, 1982; Hatzios and Penner, 1985; Wanamarta and Penner, 1989). Adjuvants also can affect photodecomposition of herbicides (Campbell and Penner, 1985). Environmental conditions such as temperature, relative humidity, and soil moisture can affect response to adjuvants (Hull *et al.*, 1982). Interactions of these factors make predicting response of agrichemicals to adjuvants challenging. However, applying agrichemicals with the most effective adjuvant is critical in order to optimize product performance.

Crop oil concentrate (COC) and ammonium sulfate are often applied with herbicides to increase weed control (York *et al.*, 1990; Jordan *et al.*, 1996). Increased herbicide efficacy can be associated with the adjuvants ability to increase herbicide absorption (Wanamarta and Penner, 1989). Evans *et al.* (1997) suggested that urea ammonium nitrate (UAN) increases foliar uptake of prohexadione calcium. Determining the most efficacious adjuvant for use with prohexadione calcium is important for optimizing performance.

Prohexadione calcium is applied shortly before row closure (Mitchem *et al.*, 1996; McKemie *et al.*, 1998). Fungicides used to control *Cercospera arachidicola* Hori, *Sclerotium rolfsii* Sacc., *Sclerotinia minor* Jagger, and *Rhizoctonia solani* Kuhn are often applied during this time period. Appropriate timing of application for prohexadione calcium and fungicides may coincide. Determining if COC is needed with prohexadione calcium will be important when considering compatibility with other agrichemicals. The manufacturers of tebuconazole {a-[2-(4-chlorophenyl)-ethyl]-alpha-(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol} and iprodione [3-(3,5-dichlorophenyl)-*N*-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboxamide] recommend a surfactant rather than COC when these fungicides are applied to peanut (Anonymous, 1997). Manufacturers of chlorothalonil (tetrachloroisophthalonitrile) recommend that adjuvants not be included in the spray solution (Anonymous, 1997). These restrictions may limit feasibility of tank mixing prohexadione calcium with fungicides if COC is necessary for adequate performance of prohexadione calcium. Also, the effect of UAN on prohexadione calcium and fungicide performance has not been thoroughly evaluated.

Determining efficacy of prohexadione calcium applied with UAN, COC, or COC + UAN will be important in optimizing performance of prohexadione calcium. Therefore, research was conducted to compare response of vegetative and reproductive growth of peanut to prohexadione calcium when applied with these adjuvants.

Materials and Methods

Experiments were conducted in North Carolina at four locations in 1997 and six locations in 1998. Experiments also were conducted in 1997 and 1998 at the Tidewater Agric. Res. and Ext. Center, Suffolk, VA. Experiments, locations, soil series, irrigation practices, cultivars, and dates of planting, prohexadione application, digging, and combining are presented in Table 1. Peanut was planted in conventionally prepared seedbeds at all locations. Cultural and pest management practices were based on Cooperative Extension Service recommendations for the region. Plot size was four rows spaced 91 to 102 cm wide by 10 to 15 m long.

Treatments consisted of prohexadione calcium at 140 g ai/ha applied with COC at 2.3 L/ha, UAN at 2.3 L/ha, or the combination of COC and UAN at these rates. Treatments were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha at 220 kPa using flat fan nozzles. Treatments were applied when approximately 50% of vines from adjacent rows were touching, followed by a repeat application 2 to 3 wk later (Table 1).

Main stem height of four plants from each plot was determined 3 wk before digging in Experiment 1 at Gatesville during 1997 and in all experiments in North Carolina during 1998. Main stem height was not determined in Virginia during either year. However, peanut row visibility was determined at all locations both years in late August using the scale developed by Mitchem *et al.* (1996) where 1 = no row visibility to 10 = a triangular peanut canopy. Peanuts in the center two rows of each plot were dug in late September or October (Table 1).

Peanuts were combined using conventional harvesting equipment. A 500-g sample from each plot was collected to determine the percentage of extra large kernels (ELK), the percentage of total sound mature kernels (SMK), and the percentage of other kernels (OK) using USDA Grading Service Guidelines. Market value of farmer stock peanut ($/kg) and gross value ($/ha) were determined based on grade factors and pod yield.

Data were subjected to analyses of variance. The interaction of experiment by treatment was significant for row visibility, pod yield, the percentage of ELK, and gross value. In an effort to simplify data, additional analyses were performed on these parameters to determine which experiments could be pooled. Initially, experiments were organized by year, cultivar, or irrigation. However, experiment by treatment interactions were noted in each of these analyses which prevented pooling of data for similar years, cultivars, or irrigation practices. Additional analyses were conducted to determine if data from experiments without a common cultivar, not within the same year, or with different irrigation practices responded similarly to the treatments. Pooled data

Table 1. Experiments; locations; soil series and texture; cultivars; and dates of planting, prohexadione calcium applications, digging, and harvesting.

						Dates				
							Prohexadione calcium appl.			
Exp.	Location[a]	Year	Soil series[b]	Cultivar	Irrigation	Planting	First	Second	Digging	Harvest
1	Gatesville	1997	Wando FS	NC-V11[c]	Yes	3 May	21 July	8 Aug.	6 Oct.	9 Oct.
2	Woodard	1997	Conetoe LS	NC 12C	Yes	8 May	8 Aug.	28 Aug.	15 Oct.	17 Oct.
3	Belvedere	1997	Arapahoe FSL	VA-C 92R	No	9 May	22 July	8 Aug.	6 Oct.	13 Oct.
4	Lewiston	1997	Raines LS	NC 10C	Yes	8 May	21 July	8 Aug.	15 Oct.	23 Oct.
5	Bladenboro	1998	Norfolk LS	NC-V11	No	18 May	14 July	28 July	28 Sep.	5 Oct.
6	Windsor	1998	Conetoe LS	NC 12C	Yes	29 April	21 July	8 Aug.	22 Sep.	28 Sep.
7	Tyner	1998	Wando FS	NC-V11[c]	No	4 May	29 July	12 Aug.	25 Sep.	29 Sep.
8	Halifax	1998	Goldsboro LS	NC-V11	No	15 May	18 July	3 Aug.	11 Oct.	16 Oct.
9	Lewiston	1998	Raines LS	NC 12C	Yes	1 May	17 July	3 Aug.	14 Oct.	20 Oct.
10	Rocky Mount	1998	Goldsboro LS	NC-V11	No	15 May	29 July	12 Aug.	16 Oct.	19 Oct.
11	Suffolk	1997	Goldsboro LS	NC-V11	No	12 May	11 Aug.	2 Sep.	7 Oct.	12 Oct.
12	Suffolk	1998	Goldsboro LS	NC-V11	No	20 May	21 July	10 Aug.	15 Oct.	21 Oct

[a]Suffolk location in Virginia, all other locations in North Carolina.
[b]LS, loamy sand; FSL, fine loamy sand; FS, fine sand.
[c]Planted in twin rows.

for row visibility, pod yield, the percentage of ELK, and gross value will be discussed based on these analyses. Main effects of experiment and treatment and the interaction of these factors were not significant for the percentage of TSMK or the percentage of OK. Means were separated using Fisher's Protected LSD Test at P = 0.05.

Results and Discussion

The treatment by experiment interaction was not observed in the combined analysis that included Experiments 1, 3, 5, 6, 7, 8, 9, 10, and 11 (Table 2). Additionally, a treatment by experiment interaction was not observed when Experiments 2, 4, and 12 were combined (Table 2). Prohexadione calcium applied with UAN or UAN + COC increased row visibility in all of the experiments compared with nontreated peanut. This response was consistent across 2 yr, four cultivars, and presence or absence of irrigation. In nine of 12 experiments, prohexadione calcium + UAN was as effective as prohexadione calcium applied with UAN + COC. This response was consistent although considerable variation in cultivar selection and irrigation existed. Prohexadione calcium applied with COC alone improved row visibility in all experiments compared with nontreated peanut.

Response to adjuvants could not be easily explained by cultivar selection or environmental conditions. In Group 1 (Experiments 1, 3, 5, 6, 7, 8, 9, 10, and 11), where COC + UAN and UAN were equally effective adjuvants, the cultivars NC-V11, VA-C 92R, and NC 12C were included (Table 1). In Group 2 (Experiments 2, 4, and 12), where COC + UAN was more effective than UAN or COC alone, the cultivars NC 12C, NC 10C, and NC-V11 were grown. Culpepper *et al.* (1997) reported differences in cultivar response to prohexadione calcium. They noted that prohexadione calcium increased row visibility of the cultivar NC-V11 more than the cultivars VA-C 92R or NC 12C. Results from our study suggest that UAN is the more critical component of the adjuvant system than COC.

Table 2. Influence of COC and UAN on efficacy of prohexadione calcium.[a]

Treatment	Row visibility Group 1[b]	Row visibility Group 2[c]	Main stem ht[d]	Pod yield[e]	Gross value[e]
	----------%---------		cm	kg/ha	$/ha
None	3.3 c	2.9 d	46 a	4980 c	3750 b
Prohexadione calcium:					
+COC + UAN	6.1 a	8.4 a	38 c	5460 ab	4104 a
+UAN	5.9 a	6.7 b	38 c	5690 a	4284 a
+COC	4.2 b	4.7 c	43 b	5400 b	4066 a

[a]Means within a column followed by the same letter are not statistically different according to Fisher's Protected LSD Test at P = 0.05.
[b]Data are pooled over Experiments 1, 3, 5, 6, 7, 8, 9, 10, and 11.
[c]Data are pooled over Experiments 2, 4, and 12.
[d]Data are pooled over Experiments 1, 5, 6, 7, 8, 9, and 10.
[e]Data are pooled over Experiments 1, 2, 4, 5, 6, 8, and 9.

The interaction of experiment by treatment was not significant for main stem height. However, the main effect of treatment was significant. Main stem height decreased when prohexadione calcium was applied regardless of adjuvant when compared with nontreated peanut (Table 2). Main stem height was the same when prohexadione calcium was applied with UAN or COC + UAN. The combination of COC + UAN and UAN alone was more effective than COC alone. Differences in main stem height appeared to correlate with differences in row visibility noted for Group 1. Both parameters suggest that UAN alone is as effective as COC + UAN.

The interaction of experiment by treatment was significant for pod yield. Two distinct responses to prohexadione calcium were noted. In seven of the 12 experiments (Experiments 1, 2, 4, 5, 6, 8, and 9), prohexadione calcium increased pod yield regardless of the adjuvant treatment when compared with nontreated peanut (Table 2). Pod yield increased 9.6, 14.3, or 8.4% when prohexadione calcium was applied with COC + UAN, UAN, or COC, respectively. Pod yield was similar when prohexadione calcium was applied with COC + UAN or UAN. Additionally, pod yield was similar when prohexadione calcium was applied with COC + UAN or COC. Urea ammonium nitrate alone was a more effective adjuvant in increasing pod yield with prohexadione calcium than was COC. In contrast, prohexadione calcium did not affect pod yield in the other experiments (Experiments 3, 7, 10, 11, and 12) regardless of adjuvant treatment (data not presented).

Culpepper *et al.* (1997) reported that pod yield of NC 12C and NC-V11 was increased 9 to 15% at two of four locations when prohexadione calcium was applied with COC + UAN. A yield response was not observed at the other two locations. They also reported no yield response of the cultivar VA-C 92R at two of four locations and a yield decrease of 8% at the other two locations. The cultivars NC 12C and NC-V11 were present in both groups of experiments in our study, with only one of the groups showing a yield increase when prohexadione calcium was applied (Tables 2 and 3). Additionally, peanut was grown with or without irrigation in both sets of experiments (Table 1). Consistent with results reported by Culpepper *et al.* (1997), prohexadione calcium did not increase pod yield of VA-C 92R (Table 3). Beasley *et al.* (1998) reported variation in yield response of four runner market-type peanuts with prohexadione calcium use in Georgia.

The percentage of TSMK and market value ($/kg) were not affected by prohexadione calcium (data not presented). However, the percentage of ELK increased from 46 to 49% when prohexadione calcium was applied compared with nontreated peanut in eight of 12 experiments (Experiments 1, 2, 3, 4, 5, 6, 8, and 9) regardless of adjuvant (data not presented). In contrast to differences in pod yield noted among adjuvants, prohexadione calcium increased gross value ($/ha) similarly compared with nontreated peanut regardless of adjuvant (Table 2). Although the percentage of ELK was increased by prohexadione calcium, there was no difference in market value ($/kg) when comparing prohexadione calcium-treated peanut to nontreated peanut. These data suggest that increased gross value was associated with increased pod yield rather than increased market value. In contrast, Culpepper *et al.* (1997) reported that prohexadione calcium often increased both the percentage of ELK and market value. They also suggested that prohexadione calcium enhanced earliness as demonstrated by pod mesocarp color determination and by the increased percentage of ELK. A higher percentage of ELK suggests that peanut kernels were larger and likely more mature at digging. However, a higher percentage of ELK could have been associated with greater retention of mature pods. The mechanism of increased percentage of ELK when prohexadione calcium is applied has not been elucidated. In five experiments in our study (Experiments 3, 7, 10, 11, and 12), prohexadione calcium did not affect the percentage of ELK or gross value (data not presented).

The increase in pod yield following prohexadione calcium application with UAN alone ranged from 350 to 1,130 kg/ha over nontreated peanut in Experiments 1, 2, 4, 5, 6, 8, and 9 (Table 3). In experiments where pod yield was not statistically different among prohexadione calcium-treated and nontreated peanuts (Experiments 3, 7, 10, 11, and 12), pod yield ranged from 310 kg/ha lower when prohexadione calcium was applied to 50 kg/ha higher when compared with nontreated peanut (Table

Table 3. Comparison of differences in pod yield and gross value of peanut treated with prohexadione calcium + UAN to nontreated peanut.

Exp.	Location[b]	Year	Soil series[c]	Cultivar	Irrigation	Statistical significance[d]	Difference between treated and nontreated peanut[a]: Pod yield	Gross value
							kg/ha	$/ha
1	Gatesville	1997	Wando FS	NC-V11[e]	Yes	Yes	+ 870	+ 579
2	Woodard	1997	Conetoe LS	NC 12C	Yes	Yes	+ 1130	+ 795
3	Belvedere	1997	Arapahoe FSL	VA-C 92R	No	No	- 350	- 295
4	Lewiston	1997	Raines LS	NC 10C	Yes	Yes	+ 460	+ 321
5	Bladenboro	1998	Norfolk LS	NC-V11	No	Yes	+ 350	+ 329
6	Windsor	1998	Conetoe LS	NC 12C	Yes	Yes	+ 760	+ 619
7	Tyner	1998	Wando FS	NC-V11[e]	No	No	- 150	- 110
8	Halifax	1998	Goldsboro LS	NC-V11	No	Yes	+ 650	+ 629
9	Lewiston	1998	Raines LS	NC 12C	Yes	Yes	+ 410	+ 378
10	Rocky Mount	1998	Goldsboro LS	NC-V11	No	No	+ 50	+ 68
11	Suffolk	1997	Goldsboro LS	NC-V11	No	No	- 210	- 270
12	Suffolk	1998	Goldsboro LS	NC-V11	No	No	- 100	- 83

[a]Positive value indicates that pod yield or gross value of peanut treated with prohexadione calcium exceeded that of nontreated peanut.
[b]Suffolk location in Virginia; all other locations in North Carolina.
[c]LS, loamy sand; FSL, fine loamy sand; FS, fine sand.
[d]Yes indicates significance at P = 0.05 based on pooled data.
[e]Planted in twin rows.

3). Similarly, gross value of peanut treated with prohexadione calcium ranged from 321 to 795 \$/ha higher than nontreated peanut (Table 3). In experiments where statistical differences between treated and nontreated peanut were not observed, gross value ranged from 295 \$/ha lower when prohexadione calcium was applied to 68 \$/ha higher when compared with nontreated peanut (Table 3).

When pooled over adjuvant treatments, the increase in pod yield over nontreated peanut ranged from 410 to 1,130 kg/ha when the cultivar NC 12C was grown under irrigation (Table 3). The range of increase in gross value for this cultivar under irrigation was 378 to 795 \$/ha. The cultivar NC-V11 yielded 870 kg/ha higher and provided 579 \$/ha higher gross value when grown in twin rows under irrigation and treated with prohexadione calcium at Gatesville in 1997 (Table 3). This cultivar also responded positively to prohexadione calcium at Bladenboro (optimum moisture conditions) and Halifax (relatively dry conditions). In contrast, prohexadione calcium did not affect pod yield or gross value at Suffolk during either years and at Tyner and Rocky Mount when applied to the cultivar NC-V11 (Table 3). Growing conditions in these experiments were relatively dry, and excessive vegetative growth was not apparent (data not presented). The cultivar VA-C 92R did not respond favorably to prohexadione calcium (Table 3). Culpepper *et al.* (1997) reported no increase in pod yield or gross value when prohexadione calcium was applied to this cultivar. They also reported a decrease in pod yield and gross value in two of four experiments when prohexadione calcium was applied to VA-C 92R. Pod yield of NC 10C was increased by 460 kg/ha and gross value increased by 321 kg/ha when prohexadione calcium was applied (Table 3).

Collectively, these data indicate that UAN often is as effective as the combination of COC + UAN in optimizing performance of prohexadione calcium. Prohexadione calcium consistently improved row visibility. Additionally, main stem height was shorter when prohexadiane was applied. These data suggest that prohexadione calcium will not need COC to be effective which may improve compatibility of prohexadione calcium with the fungicides tebuconazole or chlorthalonil. However, the influence of UAN on efficacy of fungicides as well as compatibility in mixtures with prohexadione calcium needs to be addressed in more detail.

These studies suggest that pod yield and gross value were not always increased by prohexadione calcium and that increases in these parameters could not be entirely associated with cultivars, environmental conditions, or cultural practices. Although a yield increase of at least 410 to 1130 kg/ha was noted when prohexadione calcium was applied to irrigated peanut, prohexadione calcium also increased pod yield and gross value in two experiments where peanut was not irrigated (Table 3). A relatively small fraction of peanuts are irrigated in the Virginia-Carolina peanut production area. Additional research is needed to further define situations when prohexadione calcium will enhance pod yield and gross value, especially under nonirrigated conditions.

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