Peanut (*Arachis hypogaea* L.) Response to Cyclanilide and Prohexadione Calcium

D.L. Jordan*, J.B. Beam, J.E. Lanier, S.H. Lancaster, and P.D. Johnson[1]

ABSTRACT

Excessive growth of virginia market-type peanut affects row visibility and pod yield of peanut. Ten experiments were conducted from 2000 to 2002 in North Carolina to compare peanut response to cyclanilide and prohexadione calcium applied at 50% row closure followed by a repeat application 2 wk later. Cyclanilide and prohexadione calcium increased row visibility in all experiments. Main stem height was shorter at the end of the season when cyclanilide and prohexadione calcium were applied compared with non-treated peanut in all experiments except one. Prohexadione calcium improved row visibility compared with cyclanilide in three experiments and equaled cyclanilide in seven experiments. Main stem height was similar following application of cyclanilide and prohexadione calcium in eight of the 10 experiments. When pooled over experiments, pod yield ranged from 4210 to 4480 kg/ha and did not differ between non-treated peanut and peanut treated with either plant growth regulator. However, prohexadione calcium did increase pod yield of peanut compared with cyclanilide. Results indicate that cyclanilide is not as effective as prohexadione calcium in managing peanut vine growth because of inconsistent enhancement of row visibility and possible negative impacts on pod yield.

Key Words: Cyclanilide, plant growth regulator, prohexadione calcium, row visibility.

Excessive vine growth of peanut (*Arachis hypogaea* L.) can reduce efficiency of digging and inverting vines. Reduction in efficiency is often attributed to poor row visibility. Additionally, pods often shed from plants in the digging process and can lead to substantial yield loss, especially when soil conditions are not conducive for separation of pods from soil. Prohexadione calcium (calcium salt of 3,5-dioxo-4 propionylcyclohexane-carboxylic acid) (Apogee®) is registered for management of vegetative growth of peanut and other crops (Yamaji *et al.*, 1991; Nakayama *et al.*, 1992; Grossman *et al.*, 1994; Lee *et al.*, 1998; Byers and Yoder, 1999; Anon., 2003a). Culpepper *et al.* (1997) and Mitchem *et al.* (1996) reported that prohexadione calcium improved row visibility of peanut and increased pod yield. Beam *et al.* (2002) reported that increased pod yield of peanut by prohexadione calcium was attributed to increased pod retention. Although the benefits of prohexadione calcium have been established in the literature, the current price of prohexadione calcium is cost prohibitive in many circumstances, especially in light of changes in 2002 Federal farm legislation that reduced value of peanut at the farm level (Brown, 2003). Developing alternatives to prohexdione calcium might allow growers to control vine growth more economically.

Cyclanilide [1-(2,4-dichlorophenylaminocarbonyl)-cyclopropane carboxylic acid] and ethylene are the active ingredients found in the cotton (*Gossypium hirsutum* L.) defoliant Finish® (Anon., 2003b). Cyclanilide inhibits auxin transport in cotton (Pederson *et al.*, 1997). When applied with ethylene, cyclanilide enhances cellulase activity and contributes to greater leaf abscission during the cotton defoliation process (Pederson *et al.*, 1997). Stewart *et al.* (2000) reported that boll opening of cotton by ethylene was enhanced when ethylene and cyclanilide were applied simultaneously compared with ethylene applied alone. These properties may also contribute to vine management and maturation of peanut, although research has not been conducted to address this issue (J. Sanderson, Bayer CropScience, personal comm.). Comparing peanut response to prohexadione calcium and cyclanilide is important in determining utility of cyclanilide to manage vine growth of peanut. Therefore, research was conducted in North Carolina with virginia market-type peanut to compare row visibility, main stem height, and pod yield following application of cyclanilide and prohexadione calcium.

Materials and Methods

Ten experiments were conducted from 2000 through 2002 in northeastern North Carolina in conventionally-tilled peanut to compare efficacy of cyclanilide and prohexadione calcium (Table 1). Soils were a Norfolk sandy loam (fine-loamy, siliceous, thermic, Aquic Paleudults) with pH 5.7 to 6.1 and 1.5 to 2.1% organic matter, a Goldsboro sandy loam (fine-loamy, mixed, thermic, Arenic Hapludults) with pH 5.8 and 2.0% organic matter, and a Roanoke silt loam (clayey, mixed, thermic, Typic Ochraquepts) with pH 6.2 and 2.1% organic matter. Plot size was four rows (96-cm spacing) by 9 to 12 m. Seed of the peanut cultivars NC-V 11 and NC 12C were seeded in early to mid May of each year at rates designed to achieve a final in-row plant population of 12 seed/m

[1]Assoc. Prof., former Grad. Res. Asst., former Grad. Res. Asst., former Grad Res. Asst., and Ext. Tech., respectively, Dept. Crop Sci., North Carolina State Univ., Box 7620, Raleigh, NC 27695.

*Corresponding author (e-mail: david_jordan@ncsu.edu).

Table 1. Year, location, soil series, and cultivars in experiments comparing peanut response to cyclanilide and prohexadione calcium.

Experiment	Year	Location	Soil series	Cultivar
1	2000	Lewiston-Woodville	NSL[a]	NC 12C
2	2001	Lewiston-Woodville	NSL	NC 12C
3	2002	Lewiston-Woodville	NSL	NC 12C
4	2000	Edenton	RSL[b]	NC-V 11
5	2001	Lewiston-Woodville	NSL	NC 12C
6	2001	Rocky Mount	GSL[c]	NC-V 11
7	2002	Lewiston-Woodville	GSL	NC-V 11
8	2002	Lewiston-Woodville	GSL	NC-V 11
9	2002	Lewiston-Woodville	NSL	NC-V 11
10	2002	Rocky Mount	GSL	NC-V 11

[a]NSL = Norfolk sandy loam.
[b]RSL = Roanoke silt loam.
[c]GSL = Goldsboro sandy loam.

(Jordan, 2003). These peanut cultivars are among the most popular cultivars grown in North Carolina (Spears, 2002).

Cyclanilide at 0.05 kg ai/ha and prohexadione calcium at 0.14 kg ai/ha were applied when 50% of vines from adjacent peanut rows were touching. A repeat application was made 2 wk later to the same plots. Cyclanilide was also applied at 0.025 and 0.10 kg/ha in Experiments 1, 2, and 3. An adjuvant was not applied with cyclanilide. A non-treated control was included as a comparison. Crop oil concentrate (Agri-Dex, 83% paraffin-based petroleum oil and 17% surfactant; Helena Chemical Co., Memphis, TN) and 28% urea ammonium nitrate, each at 1.2 L/ha, were applied with prohexadione calcium. Plant growth regulators were applied in 140 L/ha aqueous solution using a CO_2-pressurized backpack sprayer equipped with 8002 regular flat fan spray nozzles (Teejet nozzles, Spraying Systems Co., Wheaton, IL). Production and pest management practices, other than plant growth regulator applications, were held constant over the entire test based on North Carolina Cooperative Extension Service recommendations (Jordan, 2003).

Visual estimates of row visibility were recorded in early September using a scale of 1 to 10 where 1 = a peanut canopy that is flat with indistinguishable rows and 10 = a peanut canopy with triangular-shaped rows that are clearly visible. Height of main stems from ground level to the uppermost free standing point of three randomly selected plants from each plot were recorded in early September. The average of the three measurements was used as the experimental unit for each plot. Peanut vines were inverted in late September or early October depending upon location using pod mesocarp color for determination of maturity. Vines and pods were allowed to air dry for a period of 4 to 10 d prior to harvesting.

The experimental design was a randomized complete block with four replications. Data for row visibility, main stem height, and pod yield were subjected to analysis of variance. Means were separated using Fisher's Protected LSD test at $P \leq 0.05$.

Results and Discussion

The interaction of experiment by treatment was significant for row visibility and main stem height when all experiments were included in the analysis. An additional analysis was performed on these parameters to determine if groups of experiments could be pooled. Experiments 1, 3, 5, 6, 7, 8, and 10 were pooled and labeled Group 1, and experiments 2, 4, and 9 were pooled as Group 2. In Group 1, cyclanilide and prohexadione calcium increased row visibility similarly (Table 2). In Group 2, cyclanilide increased row visibility compared to non-treated peanut, but did not increase row visibility as effectively as prohexadione calcium (Table 2). Row visibility was similar with all rates of cyclanilide and prohexadione calcium in Experiment 1 and greater with prohexadione calcium compared with all rates of cyclanilide in Experiments 2 and 3 (Table 3). A rate response to cyclanilide was noted in Experiment 3, but not in Experiments 1 and 2. In Experiment 3, row visibility following cyclanilide at 0.05 and 0.1 kg/ha exceeded that of cyclanilide at 0.025 kg/ha.

When main stem height was compared in all 10 experiments, a similar response to both plant growth regulators was noted in 7 of 10 experiments (Experiments 1, 2, 4, 5, 6, 7, and 10) (Table 2). In Experiment 3, cyclanilide did not affect mainstem height when compared with non-treated peanut. Main stem height was shorter when prohexadione calcium was applied in this experiment. In Experiment 8, main stem height was similar among all treatments including non-treated peanut while in Experiment 10, main stem height was shorter following application of prohexadione calcium than following application of cyclanilide. When pooled over all experiments, peanut main stem height was shorter when prohexadione calcium was applied when compared to non-treated peanut.

As was noted for row visibility in two of the experiments, cyclanilide at 0.025 kg/ha did not affect main stem height compared with non-treated peanut (Table 3). Main stem height was similar for all rates of cyclanilide and prohexadione calcium in Experiments 1 and 2. In Experiment 3, main stem height was reduced similarly when cyclanilide was applied at 0.1 kg/ha or when prohexadione calcium was applied. These results are consistent with previous findings demonstrating that main stem height of peanut is often shorter than non-treated peanut when prohexadione calcium is applied (Mitchem *et al.*, 1996; Culpepper *et al.*, 1997; Beam *et al.*, 2002). Response of peanut to cyclanilide has not been reported previously.

The interaction of experiment by treatment was not significant for pod yield in the data set including all 10

Table 2. Influence of cyclanilide and prohexadione calcium on row visibility, main stem height, and pod yield of peanut.[a]

Plant growth regulator	Row visibility[c]			Main stem height					
treatment[b]	Group 1[d]	Group 2[e]	Pooled[f]	Group 1[g]	Exp. 3	Exp. 8	Exp. 10	Pooled[f]	Pod yield[f]
				cm					kg/ha
Non-treated control	3.1 b	2.2 c	2.8 c	42 a	36 a	29 a	32 a	39 a	4370 ab
Cyclanilide	6.8 a	5.0 b	6.2 b	31 b	34 a	24 a	27 b	30 b	4210 b
Prohexadione calcium	7.0 a	7.5 a	7.2 a	32 b	27 b	27 a	22 c	30 b	4480 a

[a]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test at $P \leq 0.05$.
[b]Cyclanilide and prohexadione calcium applied at 0.05 kg/ha and 0.14 kg/ha, respectively.
[c]Visual estimates of row visibility were recorded in early September using a scale of 1 to 10 where 1 = a peanut canopy that is flat with indistinguishable rows and 10 = a peanut canopy with triangular-shaped rows that are clearly visible.
[d]Data are pooled over experiments 1, 3, 5, 6, 7, 8, and 10.
[e]Data are pooled over experiments 2, 4, and 9.
[f]Data are pooled over all experiments.
[g]Data are pooled over experiments 1, 2, 4, 5, 6, 7, and 9.

Table 3. Influence of cyclanilide rate and prohexadione calcium on row visibility, main stem height, and pod yield of peanut.[a]

Plant growth regulator		Row visibility[b]			Main stem height			
treatment	Rate	Exp. 1	Exp. 2	Exp. 3	Exp. 1	Exp. 2	Exp. 3	Pod yield[c]
	kg/ha				cm			kg/ha
Non-treated control	–	2.9 b	1.5 c	3.6 c	47 a	46 a	36 a	4870 a
Cyclanilide	0.025	5.8 a	2.0 bc	4.3 c	43 ab	41 ab	35 a	4840 a
Cyclanilide	0.05	5.1 a	3.2 b	7.0 b	39 b	39 b	34 ab	4950 a
Cyclanilide	0.10	5.5 a	3.2 b	6.9 b	38 b	36 b	30 bc	4940 a
Prohexadione calcium	0.14	6.3 a	6.8 a	8.1 a	38 b	39 b	27 c	5270 a

[a]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test at $P \leq 0.05$.
[b]Visual estimates of row visibility were recorded in early September using a scale of 1 to 10 where 1 = a peanut canopy that is flat with indistinguishable rows and 10 = a peanut canopy with triangular-shaped rows that are clearly visible.
[c]Data are pooled over Experiments 1, 2, and 3.

experiments or in the analysis consisting of the three experiments that included multiple rates of cyclanilide. When pooled over the 10 experiments, pod yield was similar for non-treated peanut and peanut treated with either cyclanilide or prohexadione calcium (Table 2). However, pod yield of peanut treated with prohexadione calcium was 270 kg/ha higher than peanut treated with cyclanilide. Pod yield of peanut was similar regardless of cyclanilide rate (Table 3). Additionally, no difference in pod yield was noted among cyclanilide-treated peanut and prohexadione calcium-treated peanut compared with non-treated peanut in experiments where multiple cyclanilide rates were included.

These data suggest that cyclanilide was as effective as prohexadione calcium in increasing row visibility in many instances, but a positive yield response was not observed. Although prohexadione calcium did not increase pod yield compared to non-treated peanut, yield following application of cyclanilide was lower than pod yield following application of prohexadione calcium. Peanut treated with prohexadione calcium exhibit a deeper green color compared with non-treated peanut (data not presented). Reduction in vine growth following application of cyclanilide was often accompanied by slight yellowing of foliage. The mechanism of reducing vine growth by prohexadione calcium and cyclanilide are different. Prohexadione calcium reduces internode elongation through inhibition of gibberellin synthesis by blocking kaurene oxidase and increasing levels of abscissic acid and cytokinins (Grossman *et al.*, 1994). Cyclanilide inhibits auxin transport, thereby reducing growth (Pederson *et al.*, 1997; Stewart *et al.*, 2000). Although enhanced row visibility was noted when cyclanilide was applied, it may not be as effective as prohexadione calcium in managing peanut vine growth because of possible negative impacts on pod yield.

Acknowledgments

The North Carolina Peanut Growers Assoc. Inc. and Bayer CropScience provided funding for these studies. Appreciation is expressed to personnel at the Peanut Belt

Research Station and the Upper Coastal Plain Experiment Stations for assistance with these experiments. Appreciation is also extended to Carl Murphy and Brenda Penny for technical assistance and to John Sanderson, Bayer CropScience, for consultation and providing the cyclanilide. BASF Corporation provided the prohexadione calcium.

Literature Cited

Anon. 2003a. Apogee® product label. BASF Corp., Research Triangle Park, NC.

Anon. 2003b. Finish® product label. Bayer CropScience. Research Triangle Park, NC.

Beam, J.B., D.L. Jordan, A.C. York, T.G. Iseib, J.E. Bailey, T.E. McKemie, J.F. Spears, and P.D. Johnson. 2002. Influence of prohexadione calcium on pod yield and pod loss of peanut. Agron. J. 94:331-336.

Brown, A.B. 2003. 2003 Outlook and situation, pp. 1-3. *In* 2003 Peanut Information. Pub. AG-331. North Carolina Coop. Ext. Serv., Raleigh. 108 pp.

Byers, R.E., and K.S. Yoder. 1999. Prohexadione-calcium inhibits apple, but not peach, tree growth, but has little effect on apple fruit thinning or quality. HortSci. 34:1205-1209.

Culpepper, A.S., D.L. Jordan, R.B. Batts, and A.C. York. 1997. Peanut response to prohexadione calcium as affected by cultivar and digging date. Peanut Sci. 24:85-89.

Grossman, K., K.S. Koenig, and J. Kwiatowski. 1994. Phytohormonal changes in intact shoots of wheat and oilseed rape treated with the acylcyclohexanedione growth retardant prohexadione calcium. Physiol. Plant. 90:139-143.

Jordan, D.L. 2003. Peanut production practices, pp. 9-25. *In* 2003 Peanut Information. Pub. AG-331. North Carolina Coop. Ext. Serv., Raleigh. 108 pp.

Lee, I.J., K.R. Foster, and P.W. Morgan. 1998. Effect of gibberellin biosynthesis inhibitors on native gibberellin content, growth and floral initiation in *Sorghum bicolor*. J. Plant Growth Regul. 17:185-195.

Mitchem, W.E., A.C. York, and R.B. Batts. 1996. Peanut response to prohexadione calcium, a new plant growth regulator. Peanut Sci. 23:1-8.

Nakayama, I.M., M. Kobayashi, Y. Kamiya, H. Abe, and A. Sakurai. 1992. Effects of a plant growth regulator, prohexadione-calcium (BX 112), on the endogenous levels of gibberellins in rice. Jpn. Soc. Plant Physiol. 33:59-62.

Pederson, M.K., J.D. Burton, H.D. Coble, J.R. Collins, and D. Fritz. 1997. Efficacy of Finish® and its mechanism of action, pp. 93-94. *In* Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council, Memphis, TN.

Spears, J.F. 2002. Peanut seed supply and quality, pp. 3-6. *In* 2002 Peanut Information. Pub. AG-331. North Carolina Coop. Ext. Serv., Raleigh. 92 pp.

Stewart, A.M., K.L. Edmisten, and R. Wells. 2000. Boll openers in cotton: Effectiveness and environmental influences. Field Crops Res. 67:83-90.

Yamaji, H., N. Katsura, T. Nishijima, and M. Koshioka. 1991. Effects of soil-applied uniconazole and prohexadione calcium on the growth and endogenous gibberellin content of *Lycopersicon esculentum* Mill. seedlings. J. Plant Physiol. 138:763-764.