PEANUT SCIENCE

VOLUME 23 JANUARY - JUNE 1996 NUMBER 1

Peanut Response to Prohexadione Calcium, a New Plant Growth Regulator

Wayne E. Mitchem, Alan C. York*, and Roger B. Batts[1]

ABSTRACT

Experiments in 1992, 1993, and 1994 evaluated prohexadione calcium (calcium salt of 3,5-dioxo-4-propionylcyclohexanecarboxylic acid) as a growth regulator for peanut (*Arachis hypogaea* L.). Two experiments in 1992 compared prohexadione calcium applied at 140 to 560 g ae/ha at the early pegging stage (PG) or at the row closure stage (RC). Greater suppression of main stem (MS) and cotyledonary lateral branch (CLB) length and greater row visibility at harvest were noted when prohexadione calcium was applied at RC. Prohexadione calcium applied at RC decreased MS and CLB length at harvest 16 to 27% and 14 to 29%, respectively, and greatly improved row visibility. Prohexadione calcium applied at PG generally reduced yield and the percentage of extra large kernels (ELK), fancy pods (FP), and total sound mature kernels (TSMK) but had no effect on crop maturity. Prohexadione calcium applied at RC generally had no effect on yield or the proportion of TSMK but increased the percentage of ELK, decreased the percentage of FP, and enhanced crop maturity. Two experiments in 1993 compared prohexadione calcium at rates of 47 to 280 g/ha applied at RC or at RC and again 3 wk later (RC3). Prohexadione calcium at 140 and 280 g/ha applied at RC suppressed MS and CLB length at harvest 11 to 18% and improved row visibility. Single and sequential applications were equally effective. Prohexadione calcium had no effect on yield, maturity, or the percentage of ELK, FP, and TSMK in 1993. One experiment in 1994 compared prohexadione calcium at rates of 186 to 280 g/ha applied at RC and RC3 or at RC and RC3 and 6 wk after RC (RC6). Results were similar with all treatments. MS and CLB length at harvest was reduced 29 to 34% and 28 to 32%, respectively, and row visibility was greatly improved. Prohexadione calcium increased yield 8% and increased the percentage of ELK but had no effect on the percentage of FP and TSMK. Daminozide [butanedioic acid mono (2,2-dimethylhydrazide)] at 950 to 1430 g ae/ha was included in all experiments as a comparison. Row visibility and suppression of MS and CLB length at harvest in prohexadione calcium-treated peanut were at least as great as in daminozide-treated peanut. Results indicate prohexadione calcium could be an effective replacement for daminozide.

Key Words: *Arachis hypogaea* L., vine suppression, row visibility, yield, market quality, daminozide.

Plant growth regulators can play an important role in agricultural and horticultural crop production by reducing unwanted shoot elongation (20). Mepiquat chloride (*N,N*-dimethylpiperidinium chloride), for example, is commonly used in cotton (*Gossypium hirsutum* L.) to reduce plant height (29, 30).

Peanut often produces more vegetative growth than is needed for maximum pod yield, especially when climatic conditions favor vegetative growth. Nutrients and photosynthate are directed toward vegetative growth and maintenance as opposed to reproductive development (5, 12). Additionally, excessive vine growth under high moisture conditions has been linked to increased disease incidence as well as harvesting inefficiency (1, 11, 12). Dense canopies inhibit foliar-applied fungicide contact with lower leaves (12). Suppressing vine growth can improve pesticide spray coverage and placement, resulting in improved disease and insect control (12, 14, 27). Suppressed vine growth also leads to less vine damage from tires of equipment used to apply mid- and late-season pesticides (27).

In peanut grown under irrigation or in years with above-normal rainfall, the top of the crop canopy often is nearly level across the rows and row middles (15). Rows are not easily visible, making it difficult to align the mechanical digger over the rows. Failure to properly align the digger over the rows results in excessive pod loss during the digging operation (2). Synthetic growth regulators which increase row visibility at harvest by modifying canopy architecture would reduce the problem.

[1]Grad. Res. Assist., Prof., and Agric. Res. Tech., respectively, Dept. of Crop Science, North Carolina State Univ., Raleigh, NC 27695-7620.
*Corresponding author.

Use of synthetic plant growth regulators became part of an intensive management strategy for peanut production in the 1970s (10). Through 1989, producers used daminozide to suppress excessive peanut vine growth. Daminozide altered peanut canopy architecture and improved row visibility by shortening the internodes (5, 11, 12). Although yield and quality responses to daminozide were variable (4, 5, 6, 10, 11, 17, 27, 28), the growth regulator consistently suppressed vegetative growth (1, 3, 4, 5, 11, 27). Daminozide is no longer commercially available because of consumer concerns over residues in peanut and peanut products (13, 21).

Producers need an alternative to daminozide to suppress excessive vine growth and facilitate harvesting. Prohexadione calcium is a new acylcyclohexanedione-type growth regulator discovered by Kumiai Chemical Industry Co., Ltd. and Ihara Chemical Industry Co., Ltd. (24, 25) and currently being developed for use in peanut in the U.S. by BASF Corp. Prohexadione calcium reduces internode elongation of a wide range of monocotyledonous and dicotyledonous plants (16). It interferes with gibberellin (GA) formation by blocking 2-oxoglutarate-dependent dioxygenases which catalyze the later steps in the biosynthetic sequence (18). Specifically, it inhibits 3β-hydroxylation of biologically inactive GA_{20} into biologically active GA_1 (19).

The objective of our research was to determine the effect of prohexadione calcium on peanut vegetative growth, yield, maturity, and grade as affected by rate and time of application.

Materials and Methods

Experiments were conducted in 1992 and 1993 at the Peanut Belt Research Station in Lewiston, NC and the Upper Coastal Plain Research Station in Rocky Mount, NC. An experiment in 1994 was conducted on a private farm near Williamston, NC. Soils at Lewiston were a Goldsboro sandy loam (fine-loamy, siliceous, thermic, Aquic Paleudult) with pH 6.0 and 1.6% organic matter in 1992 and a Rains sandy loam (fine-loamy, siliceous, thermic, Typic Paleaquult) with pH 6.1 and 2.2% organic matter in 1993. The soil at Rocky Mount was a Norfolk sandy loam (fine-loamy, siliceous, thermic, Typic Kandiudult) with pH 5.4 and 0.7% organic matter in 1992 and pH 5.8 and 1.0% organic matter in 1993. The soil at Williamston was a Conetoe loamy sand (loamy, mixed, thermic Hapludult) with pH 6.0 and 0.8% organic matter.

Peanut cv. NC 9 was planted conventionally in 94-cm rows on 4 May 1992 and 6 May 1993 at Lewiston and 13 May 1992 and 13 May 1993 at Rocky Mount. NC 9 was selected because it tends to produce more vegetative growth than other commonly grown virginia-type cultivars (G. A. Sullivan, pers. commun., 1992). Peanut cv. NC 10C was planted in 94-cm rows on 9 May 1994 at Williamston following fumigation with 36 kg ae/ha of metam sodium [sodium methyldithiocarbamate (anhydrous)] 2 wk earlier. Metam sodium and the cultivar NC 10C were used at Williamston because the experimental area was known to be infested with cylindrocladium black rot [*Cylindrocladium crotalariae* (Loos) Bell & Sobers]. Other pest control practices and fertility programs at all locations were standard for the region.

The experimental design was a randomized complete block with treatments replicated six times. Plots were four rows by 15 m. Additional plots were included for equipment passage so that treated plots and the nontreated check plots received no wheel traffic after planting. The crop at Rocky Mount in 1992 and 1993, at Lewiston in 1992, and at Williamston in 1994 was irrigated to promote vegetative growth. Irrigation was unavailable at Lewiston in 1993.

Treatments in 1992 consisted of prohexadione calcium at 140, 280, and 560 g/ha applied at PG [70 and 61 d after planting (DAP) at Lewiston and Rocky Mount, respectively] or at RC (84 and 75 DAP at Lewiston and Rocky Mount, respectively). PG was defined as most plants having at least one peg (gynophore) in the soil. RC was defined as 50% of the vines from adjacent rows touching in the row middles. Prohexadione calcium also was applied sequentially at 140 and 280 g/ha at PG followed by a second application of the same rate at RC. For comparison, daminozide at 950 g/ha was applied once at PG or at RC.

Treatments were modified in 1993 in response to results obtained in 1992. Prohexadione calcium at 47, 70, 93, 140, and 280 g/ha was applied once at RC (69 and 62 DAP at Lewiston and Rocky Mount, respectively). Sequential treatments included prohexadione calcium at 47, 70, 93, and 140 g/ha applied at RC followed by a second application of the same rate at RC3. Daminozide treatments included 950 g/ha applied at RC and 475 g/ha applied at RC followed by 475 g/ha at RC3.

Treatments in 1994 included prohexadione calcium at 93 g/ha applied at RC (66 DAP) followed by 70 g/ha at RC3 and 70 g/ha at RC6; prohexadione calcium at 93 g/ha at RC followed by 93 g/ha at RC3; prohexadione calcium at 93 g/ha at RC followed by 93 g/ha at RC3 and RC6; prohexadione calcium at 140 g/ha at RC followed by 70 g/ha at RC3; prohexadione calcium at 140 g/ha at RC followed by 70 g/ha at RC3 and RC6; prohexadione calcium at 140 g/ha at RC followed by 140 g/ha at RC3; and daminozide at 950 g/ha at RC followed by 480 g/ha at RC3. A nontreated check was included in all experiments.

Growth regulators were applied with a CO_2-pressurized backpack sprayer delivering 198 L/ha at 276 kPa. A 10 and 85% wettable powder formulation of prohexadione calcium and daminozide, respectively, was used in all experiments. No adjuvants were added.

Peanut MS and CLB length and number of nodes on the MS and CLB at 3-wk intervals after treatment (1992 only) and at harvest were recorded from 10 randomly selected plants per plot. Canopy shape at harvest was estimated visually as an indication of row visibility using a scale of 1 (flat canopy with vines completely overlapping in the row middles) to 10 (triangular-shaped canopy with no vines from adjacent rows touching in the row middles). A quantitative determination of row visibility also was made at harvest by calculating the difference in canopy height in the rows and in the row middles at three sites per plot.

The crop was mechanically dug and inverted in early to mid-October. Within 2 hr after digging in 1992 and 1993, pods from six randomly selected plants per plot were removed by hand. The exocarp of these pods was removed to reveal the color of the mesocarp (31). Exocarp removal was accomplished by propelling glass beads (Soda Lime Glass, DeLong Co., Atlanta, GA) immersed in water at the pods at high pressure until the color of the mesocarp was visible (26). Pods were separated into three categories (black or brown, orange, and yellow or white) based upon the color of the mesocarp. Pods having a black or brown mesocarp were the most mature; pods having a yellow or white mesocarp were the least mature (31).

After drying in the field for 5 to 7 d, peanut was harvested mechanically, dried for 4 to 5 d with conventional drying equipment (31), and weighed. Yields were adjusted to 7% moisture. A subsample of pods from each plot was then shelled and graded according to industry standards to determine the percentage of FP, ELK, and TSMK (8). Peanut value per kg was calculated based upon the USDA Agricultural Stabilization and Conservation Service loan schedule for the respective crop year.

Data were subjected to analysis of variance using the PROC GLM routine of SAS (22). F tests were based upon partial sums of squares. Treatment by location interactions were not significant in 1993, and data were pooled over locations after checking for homogeneity of error variance. Treatment means were separated using the least squares means test at $P = 0.05$ (23).

Results and Discussion

Rainfall and irrigation combined from June through September 1992 exceeded normal precipitation by 42 and 33% at Lewiston and Rocky Mount, respectively (Table 1). The above normal rainfall in 1992 occurred primarily in August. The 1993 season was drier than normal. Rainfall plus irrigation at Lewiston in 1993 was 18% below normal during June through September, with below normal water supply occurring during each of the four months. At Rocky Mount in 1993, water supply was 7% above normal for June through September. Water supply was below normal in June and August but 115% above normal in September due to substantial rainfall following irrigation. Water supply at Williamston in 1994 was 99% of normal for June through September. Water supply was 8 and 18% below normal in June and July, respectively, and 6 and 21% above normal in August and September, respectively. Average temperatures during June through September were 3 C below normal in 1992, 3 C above normal in 1993, and normal in 1994 (data not shown).

General Observations. Visible effects of prohexadione calcium and daminozide on peanut were similar. Within 4 to 5 d after application, peanut leaflets became darker green in color and appeared to be thicker. The darker color remained evident all season although it was less obvious at harvest in plots where treatment was initiated at PG than where treatment was initiated at RC.

Previous researchers (1, 11, 27) reported darker green foliage on daminozide-treated peanut. This was probably because of greater chlorophyll concentration in treated plants (3). Brown *et al.* (5) reported a lower specific leaf area index in daminozide-treated peanut, indicating thicker leaves.

By 7 to 10 d after treatment, a marked change in canopy architecture was evident. As opposed to the nontreated check, where the top of the canopy was nearly level across the rows and row middles, plants in treated plots became triangular-shaped. When prohexadione calcium or daminozide treatment was initiated at RC, this effect persisted until harvest (Fig. 1).

Growth Suppression and Row Visibility, 1992. Time of application of prohexadione calcium affected peanut MS and CLB suppression at harvest at both locations (Tables 2 and 3). Within application rates, greater suppression of both MS and CLB length at harvest was noted when prohexadione calcium was applied at RC compared with application at PG. Similar results were noted with daminozide at Lewiston. At Rocky Mount, MS and CLB suppression was similar with daminozide applied at PG or at RC.

Time of prohexadione calcium application also affected peanut row visibility at harvest. At Lewiston, row visibility with prohexadione calcium at 280 and 560 g/ha applied at RC was greater than with the same rates applied at PG (Table 2). Row visibility was similar when prohexadione calcium at 140 g/ha or daminozide were applied at PG or RC. However, row visibility with these treatments was poor. Within all application rates of prohexadione calcium at Rocky Mount, greater row visibility was noted when the growth regulator was applied at RC compared with applications at PG (Table 3). Similar results were noted with daminozide.

Canopy height at harvest in the row was 2, 3, 5, and 8 cm greater at Lewiston and 9, 9, 12, and 14 cm greater at Rocky Mount than height in the row middle on peanut treated at RC with daminozide or with prohexadione calcium at 140, 280, or 560 g/ha, respectively (data not shown). In contrast, canopy height at harvest in the row was 0, 1, 1, and 1 cm greater at Lewiston and 5, 3, 7, and 8 cm greater at Rocky Mount than height in the row middle on peanut treated at PG with daminozide or with prohexadione calcium at 140, 280, or 560 g/ha, respectively.

Eighty-two and 77 d elapsed between the PG applications and harvest at Lewiston and Rocky Mount, respectively, compared with 68 and 63 d between RC applications and harvest. However, the greater MS and CLB

Table 1. Precipitation during June through September.[a]

Month	Lewiston 1992		Lewiston 1993		Rocky Mount 1992		Rocky Mount 1993		Williamston 1994	
	cm									
June	18.7	(+8.2)	9.2	(-1.3)	15.9	(+6.2)	5.7	(-4.0)	9.7	(-0.8)
July	12.0	(-3.4)	10.1	(-5.3)	7.2	(-5.8)	13.0	(+0.0)	12.7	(-2.7)
Aug.	33.9	(+19.9)	11.7	(-2.3)	29.7	(+16.9)	7.9	(-4.9)	14.9	(+0.9)
Sept.	7.4	(-3.4)	10.4	(-0.4)	8.2	(-2.3)	22.6	(+12.1)	13.7	(+2.9)

[a]Values listed include irrigation. Numbers in parentheses are departure from the 30-yr average precipitation.

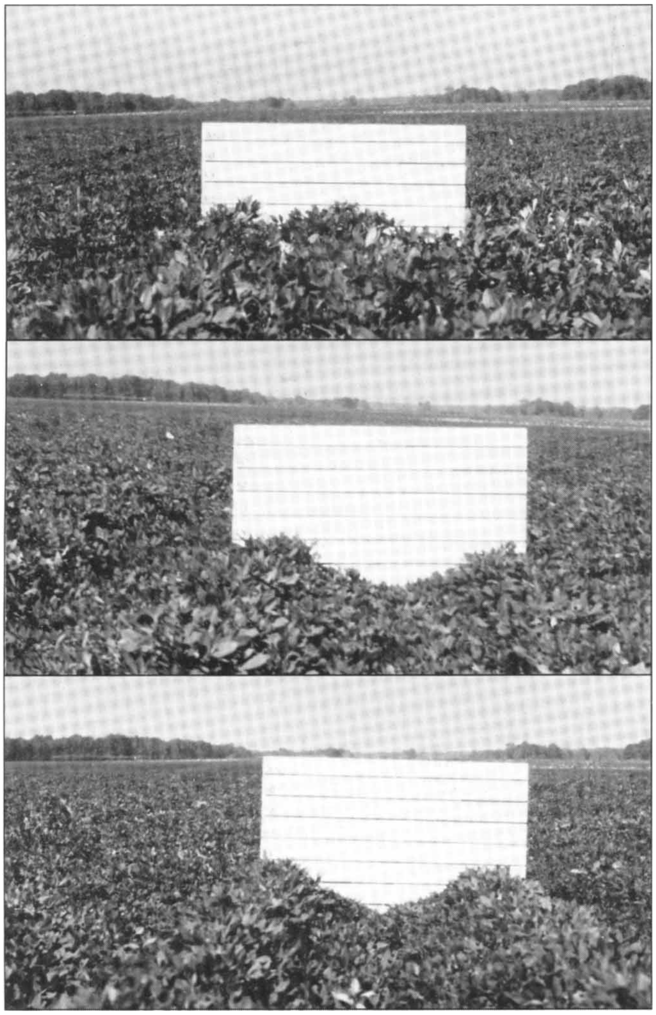

Fig. 1. Peanut canopy profile at harvest in nontreated check (top), daminozide at 950 g/ha at row closure followed by 480 g/ha 3 wk later (center), and prohexadione calcium at 140 g/ha at row closure followed by 140 g/ha 3 wk later (bottom) in 1994.

suppression and greater row visibility at harvest by prohexadione calcium applied at RC compared with application at PG appeared to be due to a differential response of the crop to prohexadione calcium applied at the two growth stages rather than simply the amount of time elapsed between treatment and harvest.

Initial growth suppression was similar when prohexadione calcium was applied at either PG or RC. However, the suppressive effects diminished more rapidly when prohexadione calcium was applied at PG. Averaged over application rates and locations, prohexadione calcium applied at RC suppressed MS length 25, 24, and 22% and CLB length 28, 28, and 24% at 3, 6, and 9.3 (at harvest) wk after treatment (WAT), respectively (data not shown). In contrast, prohexadione calcium applied at PG suppressed MS length 26, 16, and 12% and CLB length 28, 20, and 11% at 3, 6, and 11.4 (at harvest) WAT, respectively. This differential growth response to time of prohexadione calcium application may have been due to a differential ratio of vegetative to reproductive growth following the two application timings. Prohexadione calcium is thought to be metabolized relatively rapidly in peanut (R. Evans, pers. commun., 1994). Hence, when prohexadione calcium was applied at PG, there was more time for vegetative growth to resume after degradation of the growth regulator and prior to onset of the peak photosynthetic demand in developing fruit which would have naturally suppressed further vegetative growth.

At both locations, suppression of MS and CLB length and row visibility at harvest were similar on peanut treated at RC with prohexadione calcium at 140 g/ha and with daminozide (Tables 2 and 3). Daminozide was less effective than prohexadione calcium at 560 g/ha at both locations. MS and CLB suppression and row visibility with prohexadione calcium at 280 g/ha was equal to or greater than with daminozide.

No advantage was noted with split applications of prohexadione calcium at PG and RC compared with prohexadione calcium at the same total rate applied once at RC. MS and CLB suppression and row visibility with split applications were equal to or greater than with the same total rate applied at PG (Tables 2 and 3). However, MS and CLB suppression and row visibility with split applications were equal to or less than with the same total rate applied at RC.

Suppression of MS and CLB length by prohexadione calcium and daminozide was due to a reduction in internode length. Treatments had no effect on the number of nodes on MS or CLB (data not shown).

Yield and Quality, 1992. There was an effect of time of prohexadione calcium application on yield at Lewiston (Table 2). With prohexadione calcium at total rates of 280 or 560 g/ha, greater yield was noted when prohexadione calcium was applied at RC than when applied at PG or at PG and RC. Compared with the nontreated check, prohexadione calcium at all rates applied at PG and prohexadione calcium at 280 g/ha applied at PG and again at RC reduced yield 11 to 19%. Prohexadione calcium at 280 g/ha applied at RC increased yield 13%. Prohexadione calcium at 140 or 560 g/ha applied at RC and prohexadione calcium at 140 g/ha at PG followed by 140 g/ha at RC had no effect on yield.

Yield data were more variable than desired at Rocky Mount. This was at least partially due to excessive rainfall in August (Table 1) causing water damage to the crop in some areas of the field. Compared with the nontreated check, prohexadione calcium at 140 g/ha applied at PG reduced yield 7% (Table 3). Yields with prohexadione calcium at 140, 280, and 560 g/ha applied at PG were similar. Prohexadione calcium at 280 g/ha at RC reduced yield 7% compared with the nontreated check although yields were similar with prohexadione calcium at 140, 280, and 560 g/ha applied at RC. Prohexadione calcium at 280 g/ha at PG followed by 280 g/ha at RC reduced yield 13%. No prohexadione calcium treatment increased yield at Rocky Mount.

Daminozide applied at PG or at RC had no effect on yield at either location (Tables 2 and 3). Yield response to daminozide has been erratic (1, 3, 4, 5, 7, 9). Yield increases occurred more frequently when soil moisture conditions were conducive to abundant vine growth (4, 11, 17). Such were the conditions at our sites in 1992.

Prohexadione calcium applied at PG had no effect on the proportion of ELK at either location (Tables 2 and 3). Prohexadione calcium in split applications of 140 plus

Table 2. Effect of prohexadione calcium and daminozide on peanut main stem (MS), cotyledonary lateral branch (CLB) length, row visibility at harvest, yield, and market quality factors (Lewiston, 1992).[a]

Growth regulator	Rate	Time of application[b]	MS[c]		CLB[c]		Row visibility[d]	Market quality factors[e]			
								Yield	ELK	FP	TSMK
	g/ha		cm					kg/ha	%		
Daminozide	950	PG	57 b	(8)	80 bc	(8)	1.0 c	4400 bcd	27 bcd	73 c	70 abc
Prohexadione calcium	140	PG	57 b	(7)	85 ab	(2)	1.0 c	3830 de	26 cd	79 ab	70 abc
Prohexadione calcium	280	PG	59 ab	(3)	84 ab	(3)	1.0 c	3980 de	25 d	75 bc	68 c
Prohexadione calcium	560	PG	52 c	(14)	76 cd	(13)	1.0 c	3630 e	26 cd	68 d	69 bc
Daminozide	950	RC	51 cd	(17)	73 d	(16)	2.0 c	4880 ab	32 a	75 bc	70 abc
Prohexadione calcium	140	RC	51 cd	(16)	75 cd	(14)	1.5 c	4700 abc	31 ab	77 abc	71 ab
Prohexadione calcium	280	RC	49 de	(20)	67 f	(23)	4.5 b	5150 a	34 a	74 c	72 a
Prohexadione calcium	560	RC	45 f	(27)	62 f	(29)	6.5 a	4730 abc	30 abc	62 e	71 ab
Prohexadione calcium	140 + 140	PG + RC	47 ef	(23)	75 cd	(14)	1.5 c	4250 cd	33 a	77 abc	71 ab
Prohexadione calcium	280 + 280	PG + RC	45 f	(26)	70 de	(19)	1.5 c	3800 de	32 a	68 d	70 abc
Nontreated check			61 a		87 a		1.0 c	4470 bc	27 bcd	81 a	72 a

[a]Means within a column followed by the same letter are not different at P = 0.05 according to the least squares method of means separation.
[b]PG = pegging; RC = row closure.
[c]Numbers in parentheses are percentage reduction compared with the nontreated check.
[d]Row visibility is based on a scale of 1 (flat canopy with vines overlapping in row middles) to 10 (triangular-shaped canopy with no vines from adjacent rows overlapping in row middles).
[e]ELK = extra large kernels; FP = fancy pods; TSMK = total sound mature kernels.

Table 3. Effect of prohexadione calcium and daminozide on peanut main stem (MS), cotyledonary lateral branch (CLB) length, row visibility at harvest, yield, and market quality factors (Rocky Mount, 1992).[a]

Growth regulator	Rate	Time of application[b]	MS[c]		CLB[c]		Row visibility[d]	Market quality factors[e]			
								Yield	ELK	FP	TSMK
	g/ha		cm					kg/ha	%		
Daminozide	950	PG	46 bc	(14)	70 b	(15)	2.0 ef	4900 cd	37 a-d	69 ab	72 a
Prohexadione calcium	140	PG	47 b	(12)	72 b	(12)	1.5 f	4840 d	35 cd	74 a	72 a
Prohexadione calcium	280	PG	44 bcd	(17)	67 bcd	(18)	2.5 def	4960 bcd	34 d	71 ab	72 a
Prohexadione calcium	560	PG	44 bcd	(17)	69 bc	(16)	3.0 de	5020 bcd	36 bcd	73 a	72 a
Daminozide	950	RC	43 b-e	(18)	67 bcd	(18)	4.5 bc	5220 ab	38 abc	64 bc	70 a
Prohexadione calcium	140	RC	42 c-f	(20)	63 def	(23)	4.5 bc	5110 a-d	40 a	67 abc	72 a
Prohexadione calcium	280	RC	40 ef	(24)	62 ef	(24)	5.5 b	4820 de	40 a	59 cd	72 a
Prohexadione calcium	560	RC	39 f	(26)	58 f	(29)	7.0 a	5030 bcd	30 e	51 d	70 a
Prohexadione calcium	140 + 140	PG + RC	41 def	(23)	63 def	(23)	3.5 cd	5360 a	40 a	69 ab	72 a
Prohexadione calcium	280 + 280	PG + RC	39 f	(26)	64 cde	(22)	4.5 bc	4540 e	39 ab	66 abc	71 a
Nontreated check			53 a		87 a		1.5 f	5190 abc	35 cd	73 a	72 a

[a]Means within a column followed by the same letter are not different at P = 0.05 according to the least squares method of means separation.
[b]PG = pegging; RC = row closure.
[c]Numbers in parentheses are percentage reduction compared with the nontreated check.
[d]Row visibility is based on a scale of 1 (flat canopy with vines overlapping in row middles) to 10 (triangular-shaped canopy with no vines from adjacent rows overlapping in row middles).
[e]ELK = extra large kernels; FP = fancy pods; TSMK = total sound mature kernels.

140 and 280 plus 280 g/ha increased the proportion of ELK 4 to 6% at both locations. The proportion of ELK also was increased 7% by prohexadione calcium applied at 280 g/ha at RC at Lewiston and 5% by prohexadione calcium at 140 and 280 g/ha applied at RC at Rocky Mount. The only treatment that reduced the proportion of ELK was prohexadione calcium at 560 g/ha applied at RC at Rocky Mount, where a 5% reduction was noted. Daminozide applied at PG had no effect on the proportion of ELK at either location. The proportion of ELK was unaffected by daminozide applied at RC at Rocky Mount but was increased 5% at Lewiston. Daminozide-induced increases in the proportion of ELK have been reported previously (7, 10, 17).

Prohexadione calcium at 280 and 560 g/ha applied at RC reduced the proportion of FP at both locations 7 to 14% and 19 to 22%, respectively (Tables 2 and 3). Prohexadione calcium at 280 and 560 g/ha applied at PG or 280 g/ha applied at PG followed by 280 g/ha applied at RC reduced the proportion of FP at Lewiston 6, 13, and 13%, respectively. Prohexadione calcium applied at PG or at PG and RC had no effect on the proportion of FP at Rocky Mount. Daminozide applied at PG or at RC reduced the proportion of FP 8 and 6%, respectively, at Lewiston. At Rocky Mount, daminozide applied at RC reduced the proportion of FP 9% but had no effect when applied at PG. Daminozide has commonly reduced the proportion of FP (1, 4, 5, 17, 28). As in our study, Mozingo and Steele (17) also noted simultaneous increases in ELK and decreases in FP.

No treatment affected the proportion of TSMK at Rocky Mount (Table 3). At Lewiston, prohexadione calcium at 280 and 560 g/ha applied at PG reduced the proportion of TSMK 4 and 3%, respectively (Table 2). Other treatments had no effect.

None of the treatments affected the market value of peanut. Pooled over treatments, the market value of peanut was \$0.78 and \$0.79/kg at Lewiston and Rocky Mount, respectively (data not shown).

Pod Maturity, 1992. Prohexadione calcium applied at PG had little to no effect on pod maturity at either location (Table 4). Prohexadione calcium at all rates applied at RC enhanced maturity at both locations as indicated by a lesser proportion of the pods having a yellow or white mesocarp and a corresponding increase in the proportion having an orange, brown, or black mesocarp. Prohexadione calcium applied sequentially at PG and RC also enhanced maturity at Lewiston but not at Rocky Mount. Daminozide applied at PG or RC enhanced maturity at Lewiston but had little to no effect at Rocky Mount. Wynne *et al.* (28) reported no effect of daminozide on maturity.

Growth Suppression and Row Visibility, 1993. Prohexadione calcium at rates of 93 g/ha or greater applied at RC reduced MS length at harvest 11 to 18% (Table 5). MS suppression was similar with prohexadione calcium at rates of 93, 140, and 280 g/ha and with daminozide at 950 g/ha applied at RC. Prohexadione calcium at rates of 70 to 280 g/ha applied at RC reduced CLB length 10 to 18%. CLB suppression was similar with prohexadione calcium at 93, 140, and 280 g/ha but suppression by prohexadione calcium at 280 g/ha was greater than that by 47 or 70 g/ha. CLB suppression by prohexadione calcium at rates of 70 to 280 g/ha applied at RC and daminozide at 950 g/ha applied at RC was similar. Treatments had no effect on the number of nodes on either MS or CLB (data not shown). Hence, reduction in MS and CLB length was due to shortening of the internodes.

Row visibility at harvest increased as the rate of prohexadione calcium applied at RC increased (Table 5). Daminozide and prohexadione calcium at 140 and 280 g/ha applied at RC increased row visibility at harvest. Prohexadione calcium at 93 g/ha or less did not improve row visibility.

There was no advantage from making split applications of prohexadione calcium or daminozide at RC and RC3 compared with applying the same total rate at RC (Table 5). MS and CLB suppression and row visibility with prohexadione calcium at 47 plus 47, 70 plus 70, and 140 plus 140 g/ha applied at RC and RC3 were similar to that with prohexadione calcium applied at 94, 140, and 280 g/ha, respectively, applied only at RC. Also, MS and CLB suppression and row visibility with daminozide applied at 950 g/ha at RC and with daminozide at 475 g/ha at RC followed by 475 g/ha at RC3 were similar.

In previous studies (11, 15), daminozide caused greater suppression of vegetative growth on peanut with more robust vine growth. Peanut at all locations in our experiments had adequate to excessive vegetative growth but a relationship between vine growth and suppression of MS and CLB length by daminozide was not observed. MS and CLB length in the nontreated checks in 1992 were 20 to 39% and 14 to 21% greater than in 1993 (Tables 2, 3, and 5). The percentage suppression of MS and CLB length by daminozide applied at RC, however, was simi-

Table 4. Peanut mesocarp color as affected by prohexadione calcium and daminozide in 1992.[a]

Growth regulator	Rate	Time of application[b]	Lewiston: Black and brown	Lewiston: Orange	Lewiston: Yellow and white	Rocky Mount: Black and brown	Rocky Mount: Orange	Rocky Mount: Yellow and white
	g/ha		%			%		
Daminozide	950	PG	37 ab	17 c	46 bcd	27 a	22 cde	51 ab
Prohexadione calcium	140	PG	30 cde	19 bc	51 ab	23 a	19 e	58 a
Prohexadione calcium	280	PG	30 cde	19 bc	51 ab	21 a	20 e	59 a
Prohexadione calcium	560	PG	34 a-d	15 c	50 abc	25 a	21 de	54 ab
Daminozide	950	RC	39 a	25 ab	41 de	31 a	28 bcd	41 cd
Prohexadione calcium	140	RC	34 a-d	29 a	37 e	32 a	31 b	37 de
Prohexadione calcium	280	RC	32 bcd	30 a	37 e	30 a	29 bc	41 cd
Prohexadione calcium	560	RC	28 de	28 a	44 b-e	32 a	39 a	29 e
Prohexadione calcium	140 + 140	PG + RC	36 abc	21 bc	42 cde	27 a	26 b-e	47 bc
Prohexadione calcium	280 + 280	PG + RC	36 abc	25 ab	39 de	30 a	23 cde	47 bc
Nontreated check			25 e	19 bc	56 a	23 a	21 de	56 ab

[a]Means within a column followed by the same letter are not different at P = 0.05 according to the least squares method of means separation. Black and brown mesocarp = mature pods; orange mesocarp = moderately mature pods; yellow and white mesocarp = immature pods.

[b]PG = pegging; RC = row closure.

Table 5. Effect of prohexadione calcium and daminozide on peanut main stem (MS), cotyledonary lateral branch (CLB) length, row visibility at harvest, yield, and market quality factors (1993).[a]

Growth regulator	Rate	Time of application[b]	MS[c]	CLB[c]	Row visibility[d]	Market quality factors[e] Yield	ELK	FP	TSMK
	g/ha		cm			kg/ha	%		
Daminozide	950	RC	37 cd (17)	61 c-f (15)	4.5 bc	5500 a	49 a	50 d	70 a
Prohexadione calcium	47	RC	41 ab (7)	67 ab (7)	3.0 d	5810 a	50 a	60 ab	70 a
Prohexadione calcium	70	RC	41 ab (7)	65 bc (10)	3.5 cd	5850 a	48 a	54 bcd	69 a
Prohexadione calcium	93	RC	39 bcd (11)	63 b-e (13)	4.0 cd	5940 a	51 a	58 abc	70 a
Prohexadione calcium	140	RC	39 bcd (11)	64 bcd (11)	4.5 bc	5880 a	48 a	58 abc	69 a
Prohexadione calcium	280	RC	36 d (18)	59 def (18)	6.5 ab	5950 a	49 a	52 cd	69 a
Daminozide	475 + 475	RC + RC3	39 bcd (11)	64 bcd (11)	5.5 abc	5980 a	51 a	50 d	70 a
Prohexadione calcium	47 + 47	RC + RC3	40 abc (9)	66 bc (9)	4.5 bc	6020 a	50 a	61 a	70 a
Prohexadione calcium	70 + 70	RC + RC3	39 bcd (11)	63 b-e (13)	4.5 bc	5910 a	49 a	58 abc	70 a
Prohexadione calcium	93 + 93	RC + RC3	36 d (19)	58 ef (19)	6.5 ab	5450 a	49 a	58 abc	70 a
Prohexadione calcium	140 + 140	RC + RC3	36 d (18)	57 f (21)	7.5 a	6160 a	51 a	59 ab	70 a
Nontreated check			44 a	72 a	2.0 d	5670 a	49 a	58 abc	70 a

[a]Data pooled over locations. Means within a column followed by the same letter are not different at P = 0.05 according to the least squares method of means separation.

[b]RC = row closure; RC3 = 3 wk after row closure.

[c]Numbers in parentheses are percentage reduction compared with the nontreated check.

[d]Row visibility is based on a scale of 1 (flat canopy with vines overlapping in row middles) to 10 (triangular-shaped canopy with no vines from adjacent rows overlapping in row middles).

[e]ELK = extra large kernels; FP = fancy pods; TSMK = total sound mature kernels.

lar. Daminozide suppressed MS and CLB length 17 to 18% and 16 to 18%, respectively, in 1992 and 17 and 15%, respectively, in 1993. There was, however, a trend for greater suppression by prohexadione calcium at 280 g/ha applied at RC in 1992 where greater vegetative growth was noted compared with the 1993 crop. Prohexadione calcium at 280 g/ha applied at RC suppressed MS and CLB length 18 and 18%, respectively, in 1993 compared with 20 to 24% and 23 to 24%, respectively, in 1992.

Yield and Quality, 1993. Excellent yields were obtained in 1993. Neither daminozide nor any of the prohexadione calcium treatments affected peanut yield or the proportion of ELK or TSMK (Table 5). None of the prohexadione calcium treatments affected the proportion of FP. However, daminozide at 950 g/ha applied at RC or 475 g/ha applied at RC followed by 475 g/ha at RC3 reduced the proportion of FP by 8%. This effect of daminozide on FP is similar to those reported previously (1, 4, 5, 17, 28).

None of the treatments affected market value of peanut. Pooled over treatments and locations, the market value was $0.77/kg (data not shown).

Pod Maturity, 1993. No treatment affected pod maturity in 1993. Averaged over treatments, 36, 38, and 26% of the pods had black or brown, orange, and yellow or white mesocarps, respectively (data not shown). The crop in 1993 was more mature when dug than was the 1992 crop. Only 26% of the pods had yellow or white mesocarps in 1993 compared with 56% in the nontreated checks in 1992 (Table 4). Although this likely did not alter the response to prohexadione calcium, the relationship between pod maturity at digging and response to prohexadione calcium needs to be examined.

Growth Suppression and Row Visibility, 1994. Daminozide and all prohexadione calcium treatments suppressed MS and CLB length at harvest similarly (Table 6). Averaged over treatments, MS and CLB length was suppressed 32 and 30%, respectively. As in the previous experiments, reductions in MS and CLB length were due to shortened internodes. The growth regulators had no effect on the number of nodes on either MS or CLB (data not shown).

All growth regulator treatments enhanced peanut row visibility at harvest (Table 6). Row visibility with all prohexadione calcium treatments was similar to that with daminozide. Although differences among the prohexadione calcium treatments were minor, there was a trend for greater row visibility with higher rates of prohexadione calcium. Quantitative measurements of row visibility revealed no differences among the various growth regulator treatments. The canopy in the row averaged 18 cm taller than in the row middles in treated plots compared with 7 cm in the nontreated check (data not shown).

Yield and Quality, 1994. No differences in peanut yield were noted among the various growth regulator treatments, but all treated peanut yielded an average of 8% more than nontreated peanut (Table 6). No growth regulator treatment affected the proportion of FP or TSMK (Table 6). Most prohexadione calcium treatments increased the proportion of ELK 4 to 7%. Daminozide had no effect on the proportion of ELK. None of the treatments affected market value of peanut. Pooled over treatments, market value was $0.78/kg (data not shown).

Table 6. Effect of prohexadione calcium and daminozide on peanut main stem (MS), cotyledonary lateral branch (CLB) length, row visibility at harvest, yield, and market quality factors (1994).[a]

Growth regulator	Rate	Time of application[b]	MS[c]	CLB[c]	Row visibility[d]	Market quality factors[e] Yield	ELK	FP	TSMK
	g/ha		------cm-----			kg/ha	-----%------		
Daminozide	950 + 480	RC + RC3	27 b (34)	52 b (28)	5.1 ab	5420 a	32 bc	93 a	71 a
Prohexadione calcium	93 + 70 + 70	RC + RC3 + RC6	28 b (32)	51 b (29)	4.9 b	5470 a	34 ab	93 a	71 a
Prohexadione calcium	93 + 93	RC + RC3	29 b (29)	52 b (28)	5.0 ab	5440 a	35 ab	93 a	72 a
Prohexadione calcium	93 + 93 + 93	RC + RC3 + RC6	29 b (29)	52 b (28)	5.1 ab	5490 a	32 bc	92 a	71 a
Prohexadione calcium	140 + 70	RC + RC3	28 b (32)	50 b (31)	4.9 b	5650 a	32 bc	91 a	71 a
Prohexadione calcium	140 + 70 + 70	RC + RC3 + RC6	27 b (34)	49 b (32)	5.6 a	5580 a	37 a	93 a	71 a
Prohexadione calcium	140 + 140	RC + RC3	27 b (34)	49 b (32)	5.3 ab	5560 a	35 ab	91 a	71 a
Nontreated check			41 a	72 a	1.1 c	5100 b	30 c	93 a	71 a

[a]Means within a column followed by the same letter are not different at P = 0.05 according to the least squares method of means separation.
[b]RC = row closure; RC3 = 3 wk after row closure; RC6 = 6 wk after row closure.
[c]Numbers in parentheses are percentage reduction compared with the nontreated check.
[d]Row visibility is based on a scale of 1 (flat canopy with vines overlapping in row middles) to 10 (triangular-shaped canopy with no vines from adjacent rows overlapping in row middles).
[e]ELK = extra large kernels; FP = fancy pods; TSMK = total sound mature kernels.

Conclusions

Prohexadione calcium caused variable effects on peanut yield, maturity, and grade. If application was initiated at RC, yield and market value were not adversely affected. In some cases, yield increases were noted. Prohexadione calcium applied at RC consistently suppressed MS and CLB length and improved row visibility at harvest. Daminozide also produced variable results. Prior to cancellation of registration, daminozide was used on an estimated 30% of the peanut crop in North Carolina and Virginia (A. B. Rogerson, pers. commun., 1995). Growers used it for vine growth suppression to aid in digging and for other perceived benefits. The results of our experiments suggest prohexadione calcium could be an effective replacement for daminozide.

Acknowledgments

This research was supported in part by a grant from the N. C. Peanut Growers Assoc. and BASF Corp. Dr. Cavell Brownie, N. C. State Univ., assisted with the statistical analyses. Mr. Billy Griffin, N. C. Coop. Ext. Serv., assisted with the mesocarp color determinations.

Literature Cited

1. Bauman, R. W., and A. J. Norden. 1971. Effect of growth regulators on vegetative and reproductive characteristics of six peanut genotypes. J. Amer. Peanut Res. Educ. Assoc. 3:75-80.
2. Beasley, E. O. 1970. Field losses of peanuts in North Carolina. J. Amer. Peanut Res. Educ. Assoc. 2:78-86.
3. Brittain, J. E. 1967. Response of *Arachis hypogaea* L. to succinic acid 1,1-dimethylhydrazide. Ph.D. Diss. Virginia Polytech. Inst. and State Univ., Blacksburg. Diss. Abs. 28:3938B.
4. Brown, R. H., and W. J. Ethredge. 1974. Effects of succinic acid 2,2-dimethylhydrazide on yield and other characteristics of peanut cultivars. Peanut Sci. 1:20-23.
5. Brown, R. H., W. J. Ethredge, and J. W. King. 1973. Influence of succinic acid 2,2-dimethylhydrazine on yield and morphological characteristics of Starr peanuts. Crop Sci. 13:507-510.
6. Buchanan, G. A., E. W. Hauser, W. J. Ethredge, and S. R. Cecil. 1976. Competition of Florida beggarweed and sicklepod with peanuts. II. Effects of cultivation, weeds and SADH. Weed Sci. 24:29-39.
7. Daughtry, C. S., R. H. Brown, and W. J. Ethredge. 1975. Effects of time of application of succinnic acid 2,2-dimethylhydrazide on yields and associated characteristics of peanuts. Peanut Sci. 2:83-86.
8. Davidson, J. I., Jr., T. B. Whitaker, and J. W. Dickens. 1982. Grading, cleaning, storage, shelling, and marketing of peanuts in the United States, pp. 571-623. *In* H. E. Pattee and C. T. Young (eds.) Peanut Science and Technology. Amer. Peanut Res. Educ. Soc., Yoakum, TX.
9. Gardner, F. P. 1988. Growth and partitioning in peanut as influenced by gibberellic acid and daminozide. Agron. J. 80:159-163.
10. Gorbet, D. W., and D. A. Knauft. 1990. Agronomic response of virginia and runner market type peanuts to the growth regulator SADH. Soil Crop Sci. Soc. Florida 49:132-134.
11. Gorbet, D. W., and F. M. Rhoads. 1975. Response of two peanut cultivars to irrigation and Kylar. Agron. J. 67:373-376.
12. Henning, R. J., A. H. Allison, and L. D. Tripp. 1982. Cultural practices, pp. 123-138. *In* H. E. Pattee and C. T. Young (eds.) Peanut Science and Technology. Amer. Peanut Res. Educ. Soc., Yoakum, TX.
13. Kremzar, M. H. 1990. Proactive for peanut butter. Peanut Farmer, July. pp. 12-14.
14. Maloy, O. C. 1993. Fungicide development and use, pp. 163-180. *In* Plant Disease Control: Principles and Practices. John Wiley and Sons, New York.
15. Mitchem, W. E., A. C. York, and R. B. Batts. 1995. Evaluation of chlorimuron as a growth regulator for peanut. Peanut Sci. 22:62-66.
16. Miyazawa, T., K. Yanagisawa, S. Shigematsu, K. Motojima, and M. Matsuzawa. 1991. Prohexadione-calcium, a new plant growth regulator for cereals and ornamental plants, pp. 967-972. *In* Brighton Crop Prot. Conf. - Weeds 1991. The British Crop Prot. Counc., Farnham.
17. Mozingo, R. W., and J. L. Steele. 1985. Growth regulator effects on the market quality of five virginia-type peanut cultivars. Peanut Sci. 12:64-66.
18. Nakayama, I., Y. Kamiya, M. Kobayashi, H. Abe, and A. Sakurai. 1990. Effects of a plant-growth regulator, prohexadione, on the biosynthesis of gibberellins in cell-free systems derived from immatute seeds. Plant Cell Physiol. 31:1183-1190.
19. Nakayama, I., T. Miyazawa, M. Kobayashi, Y. Kamiya, H. Abe, and A. Sakurai. 1990. Effects of new plant growth regulator prohexadione-calcium (BX-112) on shoot elongation caused by exogenously applied gibberellins in rice seedlings. Plant Cell

Physiol. 31:195-200.
20. Rademacher, W. 1991. Inhibitors in gibberellin biosynthesis: applications in agriculture and horticulture, pp. 296-310. *In* N. Takahashi, B. O. Phinney, and J. MacMillan (eds.) Gibberellins. Springer-Verlag, New York.
21. Reynolds, S. 1986. Blackmailed by bad science, the facts about Kylar. Peanut Farmer, June. pp. 6-7.
22. SAS Institute. 1982. SAS User's Guide: Statistics, 1982 Edition. SAS Institute Inc. Cary, NC.
23. Steele, R.G.D., and J. H. Torrie. 1980. Linear regression in matrix notation, pp. 299-300. *In* C. Napier and J. M. Maisel (eds.) Principles and Procedures of Statistics. McGraw-Hill, New York.
24. Takahashi, S., Y. Toyokawa, T. Miyazawa, and K. Motojima. 1987. Plant growth regulatory activity of dioxocyclohexanecarboxylate derivatives (2). Proc. Soc. Chem. Regulation Plants 22:70-71.
25. Toyokawa, Y., T. Miyazawa, K. Motojima, M. Matsuzawa, H. Hokari, and S. Kusano. 1987. Plant growth regulatory activity of dioxocyclohexanecarboxylate derivatives (1). Proc. Soc. Chem. Regulation Plants 22:68-69.
26. Williams, E. J., and G. E. Monroe. 1986. Impact blasters for peanut pod maturity determination. Trans. Amer. Soc. Agric. Eng. 29:263-266, 275.
27. Wu, C. H., and P. W. Santelmann. 1977. Influence of six plant growth regulators on spanish peanuts. Agron. J. 69:521-522.
28. Wynne, J. C., W. R. Baker, Jr., and P. W. Rice. 1974. Effects of spacing and a growth regulator, Kylar, on size and yield of fruit of virginia-type peanut cultivars. Agron. J. 66:192-194.
29. York, A. C. 1983. Cotton cultivar response to mepiquat chloride. Agron. J. 75:663-667.
30. York, A. C. 1983. Response of cotton to mepiquat chloride with varying N rates and plant populations. Agron. J. 75:667-672.
31. Young, J. H., N. K. Person, J. O. Donald, and W. D. Mayfield. 1982. Harvesting, curing and energy utilization, pp. 458-485. *In* H. E. Pattee and C. T. Young (eds.) Peanut Science and Technology. Amer. Peanut Res. Educ. Soc., Yoakum, TX.

Accepted 5 January 1996