Peanut Response to Prohexadione Calcium as Affected by Cultivar and Digging Date

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ABSTRACT

An experiment at two locations in 1995 and two locations in 1996 evaluated virginia-type peanut (*Arachis hypogaea* L.) response to the growth regulator prohexadione calcium (calcium salt of 3,5-dioxo-4-propionylcyclohexanecarboxylic acid) as affected by cultivars and digging dates. Prohexadione calcium at 140 g ai/ha was applied at row closure and again 3 wk later in 1995 or 140 g/ha at row closure and 70 g/ha 3 and 6 wk later in 1996. The cultivars AgraTech (AT) VC-1, NC 9, NC 10C, NC 12C, NC-V 11, and VA-C 92R were dug on three separate dates approximately 11 d apart. Response to prohexadione calcium was independent of digging dates. Prohexadione calcium altered canopy architecture and increased row visibility at harvest for all cultivars although the response was greatest with NC-V 11 and least with NC 9. Prohexadione calcium hastened pod maturity, increased percentages of extra large kernels, total sound mature kernels, and fancy pods, and increased peanut value/kg irrespective of cultivars and digging dates. Yield response to prohexadione calcium was cultivar dependent. NC 9 was most responsive, with yield increased 7 to 16% at all locations. Yields of AT VC-1, NC 10C, NC 12C, and NC-V 11 were increased 9 to 15% at two locations and unaffected at two locations. VA-C 92R was the least responsive, with yield increased 5% at two locations and decreased 8% at two locations.

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

Virginia-type peanut often produces more vegetative growth than needed for maximum pod yield, especially when climatic conditions favor vegetative growth (Mitchem *et al.*, 1995, 1996; Phipps, 1995). Nutrients and photosynthate are directed toward vegetative growth and maintenance as opposed to reproductive development (Brown *et al.*, 1973; Henning *et al.*, 1982). Excessive vine growth can enhance disease occurrence and severity by maintaining a humid sub-canopy environment (Bauman and Norden, 1971; Gorbet and Rhoads, 1975; Henning *et al.*, 1982). Additionally, excessive vine growth reduces foliar-applied fungicide deposition in the lower regions of the canopy (Henning *et al.*, 1982; Maloy, 1993) and increases damage from tires of equipment used to apply mid- and late season pesticides (Wu and Santelman, 1977).

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 (Mitchem *et al.*, 1995, 1996). 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 (Beasley, 1970). Synthetic growth regulators which increase row visibility at harvest by modifying canopy architecture could reduce the problem.

Daminozide [butanedioic acid mono (2,2-dimethylhydrazide)] was used through 1989 to suppress excessive peanut vine growth. Daminozide is no longer commercially available because of consumer concerns over residues in peanut and peanut products (Reynolds, 1986; Kremzar, 1990). Prohexadione calcium, a new acylcyclohexanedione-type growth regulator, may be a suitable alternative to daminozide (Mitchem *et al.*, 1996). Prohexadione calcium interferes with gibberellin formation, leading to reduction in internode elongation (Nakayama *et al.*, 1990a,b; Miyazawa *et al.*, 1991).

In earlier research, peanut responded similarly to prohexadione calcium and daminozide (Mitchem *et al.*, 1996). Both growth regulators reduced main stem and cotyledonary lateral branch length and caused the plants to be more triangular shaped. Prohexadione calcium consistently improved row visibility at harvest and was at least as effective as daminozide. It also hastened pod maturity and increased peanut yield in some experiments. Inconsistent effects on yield may have resulted from differences in pod maturity at time of digging.

The objectives of our experiment were to determine if commonly grown virginia-type peanut cultivars respond differently to prohexadione calcium and if digging date influences peanut yield response to prohexadione calcium.

Materials and Methods

The experiment was conducted on private farms at Edenton and Windsor, NC in 1995 and on the Peanut Belt Research Station at Lewiston, NC and the Upper Coastal Plain Research Station at Rocky Mount in 1996. Soil at both locations in 1995 was a Conetoe loamy sand (loamy, mixed, thermic Arenic Hapludults) with pH 5.5 and 2.3% organic matter at Edenton and pH 6.3 and 0.7% organic matter at Windsor. Soil at both locations in 1996 was a Norfolk sandy loam (fine-loamy, siliceous, thermic Aquic Paleudults) with pH 5.8 and 1.5% organic matter at Lewiston and pH 5.4 and 2.1% organic matter at Rocky Mount.

Peanut was planted conventionally in 91-cm rows on 5 May 1995 and 15 May 1996. Pest control practices and fertility programs were standard for the area. Plots were irrigated at Windsor and Rocky Mount.

The experimental design was a two-way whole plot and a one-way split plot. Whole-plot factors were digging dates and prohexadione calcium rates. The split-plot factor was six cultivars randomized within digging dates and prohexadione calcium rates. Treatment structure consisted of a factorial arrangement of digging dates, prohexadione calcium rates, and cultivars replicated four times. Digging dates were on approximately 11-d intervals beginning in

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late September. Cultivars included AgraTech (AT) VC-1, NC 9, NC 10C, NC-V 11, NC 12C, and VA-C 92R. These cultivars represent greater than 99% of the production in the Virginia-Carolina region (Jordan and Spears, 1997; Swann, 1997). Individual plots were two rows by 15 m long. Additional plots were included for equipment passage so that treated plots received no wheel traffic after planting.

Prohexadione calcium, formulated as a 75% wettable powder, was applied with a CO_2-pressurized backpack sprayer calibrated to deliver 160 L/ha at 170 kPa. Crop oil concentrate (Agri-Dex, Helena Chemical Co., Memphis, TN) and 30% urea ammonium nitrate solution each at 2.3 L/ha were included. Prohexadione calcium rates were 0 or the combined total of 280 g ai/ha. In 1995, prohexadione calcium at 140 g/ha was applied at row closure (RC) and again 3 wk later. In 1996, prohexadione calcium at 140 g/ha was applied at RC followed by 70 g/ha 3 and 6 wk later. RC, which occurred about 9 wk after planting, was defined as 50% of the vines from adjacent rows touching in the row middles.

Canopy shape at harvest was estimated visually as an indicator 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). To account for inherent differences in canopy shape among cultivars, differential row visibility (DRV) for each cultivar was calculated as the difference in row visibility ratings for prohexadione calcium-treated peanut and nontreated peanut.

Peanut was mechanically dug and inverted and allowed to dry in the field for 5 to 7 d. Pods were harvested mechanically and dried with conventional drying equipment. Yields were adjusted to 7% moisture. A subsample of pods from each plot was shelled and graded according to industry standards to determine percentages of extra large kernels (ELK), total sound mature kernels (TSMK), and fancy pods (FP) (Davidson *et al.*, 1982). Peanut value/kg was calculated based upon the USDA Farm Services Administration (formerly Agricultural Stabilization and Conservation Service) loan schedule for the respective crop year.

Peanut maturity was determined at the first two digging dates as described previously (Mitchem *et al.*, 1996). Within 2 hr after digging, 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 (Young *et al.*, 1982). 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 (Williams and Monroe, 1986). 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 (Young *et al.*, 1982).

Data were subjected to analysis of variance with appropriate partitioning for a two-way whole plot plus one-way split plot. A separate analysis was conducted on DRV data. Digging dates served as additional sources of replication in analyses of row visibility ratings and DRV. Means of significant main effects and interactions were separated using Fisher's Protected LSD Test at P = 0.05.

Results and Discussion

Row Visibility. Foliage of peanut treated with prohexadione calcium became darker green within 5 d after the initial application. Alterations in canopy architecture were evident 10 d after treatment. Prohexadione calcium-treated plants became triangular shaped (see Fig. 1 in Mitchem *et al.*, 1996), and this response persisted until harvest.

The treatment-by-location interaction for row visibility at harvest was statistically significant but biologically unimportant, and means were pooled over locations. A cultivar-by-prohexadione calcium interaction was observed. In the absence of prohexadione calcium, row visibility at harvest was greatest with NC 12C and VA-C 92R, intermediate with NC-V 11 and AT VC-1, and least with NC 9 and NC 10C (Table 1). Prohexadione calcium substantially increased row visibility of all cultivars. However, as indicated by DRV, cultivars responded differently. NC-V 11 was the most responsive cultivar while NC 9 was the least responsive.

Table 1. Effect of prohexadione calcium (PC) on row visibility of six virginia-type peanut cultivars at harvest.[a]

Cultivar	Row visibility[b] - PC	Row visibility[b] + PC	Differential row visibility[c]
AT VC-1	1.8 g	5.9 c	4.0 c
NC 9	1.1 h	4.1 e	2.9 e
NC 10C	1.3 h	5.0 d	3.8 cd
NC 12C	2.6 f	6.0 c	3.5 d
NC-V 11	1.8 g	6.9 b	5.2 a
VA-C 92R	2.8 f	7.4 a	4.5 b

[a]Data pooled over locations and three digging dates. Means within a variable followed by the same letter are not different according to Fisher's Protected LSD Test at P = 0.05.

[b]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).

[c]Differential row visibility is the difference in row visibility ratings for prohexadione calcium-treated peanut and nontreated peanut.

Yield. A treatment-by-location interaction prevented pooling data over all locations. A separate analysis indicated data from Edenton and Lewiston could be pooled as could data from Windsor and Rocky Mount. Average yields were 4520 and 4690 kg/ha at Edenton and Windsor in 1995, respectively, and 3560 and 6100 kg/ha at Lewiston and Rocky Mount in 1996, respectively (data not shown). Differences in yield between the Lewiston and Rocky Mount locations did not appear to be due to weather conditions, cultural practices, or pest incidence. North Carolina's average yields were 2700 and 2900 kg/ha in 1995 and 1996, respectively (Brown, 1996, 1997).

A cultivar-by-prohexadione calcium interaction was noted at Edenton and Lewiston. In the absence of prohexadione calcium, yield was greatest with VA-C 92R, intermediate with AT VC-1, NC 9, NC 10C, and NC-V 11, and least with NC 12C (Table 2). Prohexadione calcium had no effect on yield of AT VC-1, NC 10C, NC

Table 2. Effect of prohexadione calcium (PC) on yield of six virginia-type peanut cultivars.[a]

Cultivar	Edenton & Lewiston[b] - PC	Edenton & Lewiston[b] + PC	Windsor & Rocky Mount[b] - PC	Windsor & Rocky Mount[b] + PC
	----- kg/ha -----		----- kg/ha -----	
AT VC-1	4565 cde	4575 cde	5535 d	6355 a
NC 9	4735 c	5060 a	5110 f	5920 bc
NC 10C	4545 cde	4480 de	5280 e	5750 c
NC 12C	4415 e	4425 e	5505 d	6010 b
NC-V 11	4665 cd	4520 de	5380 e	5965 b
VA-C 92R	4875 b	4475 de	5560 d	5860 bc

[a]Data pooled over three digging dates. Means within locations followed by the same letter are not different according to Fisher's Protected LSD Test at P = 0.05.

[b]Data pooled over locations.

Table 3. Peanut pod mesocarp color, market quality factors, and value as affected by prohexadione calcium (PC).[a]

Trt.	Pod mesocarp color: White or yellow	Pod mesocarp color: Brown or black	Market quality factors[b]: ELK	TSMK	FP	Value
	-----%-----		------ % ------			$/kg
- PC	38 a	41 b	32 b	67 b	81 b	0.72 b
+ PC	29 b	50 a	38 a	69 a	84 a	0.73 a

[a]Data pooled over locations, cultivars, and two digging dates for pod mesocarp color or three digging dates for market quality factors and value. Means within a column followed by the same letter are not different according to Fisher's Protected LSD Test at P = 0.05.

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

12C, or NC-V 11. It increased yield of NC 9 by 7% and decreased yield of VA-C 92R by 8%.

A cultivar-by-prohexadione calcium interaction also was noted at Windsor and Rocky Mount. In the absence of prohexadione calcium, AT VC-1, NC 12C, and VA-C 92R yielded similarly and greater than NC 10C or NC-V 11 (Table 2). NC 9 produced the lowest yield. Prohexadione calcium increased yield of all cultivars although some cultivars were more responsive than others. NC 9 and AT VC-1 were most responsive, with yield increased 16 and 15%, respectively.

Yield of NC 10C, NC 12C, and NC-V 11 was increased 9 to 11% while yield of VA-C 92R was increased only 5%. A negative correlation (r = -0.77) was observed between row visibility of nontreated peanut and yield response at Windsor and Rocky Mount, suggesting a greater yield response with cultivars having greater vine growth.

Main effects of digging dates and digging date by cultivar and digging date by prohexadione calcium interactions were not significant for peanut yield. However, yield tended to be greater as digging was delayed at Lewiston and Edenton. Pooled over cultivars and prohexadione calcium treatments, yields were 4030, 4050, and 4240 kg/ha at the first, second, and third digging dates, respectively, at Lewiston and Edenton (data not shown). At Windsor and Rocky Mount, yields at the first, second, and third digging dates were 5040, 5090, and 5060 kg/ha, respectively. Lack of a digging date by prohexadione calcium interaction for yield suggests inconsistent yield responses to the growth regulator in previous studies with a single digging date (Mitchem *et al.*, 1996) were not due to differential pod maturity at the time of digging.

Pod Maturity. Pooled over locations, main effects of prohexadione calcium, cultivars, and digging dates were highly significant; interactions of these factors were not observed. Prohexadione calcium hastened peanut maturity as indicated by the greater percentage of pods with brown or black mesocarps and the corresponding decrease in the percentage with white or yellow mesocarps (Table 3). The percentage of pods with orange mesocarps was not affected (data not shown). In contrast to previous research (Mitchem *et al.*, 1996) where the effect of prohexadione calcium on pod maturity was inconsistent over locations, earlier maturity in prohexadione calcium-treated peanut was noted at all locations in the current study.

Pod maturity was similar with NC 10C, NC 12C, NC-V 11, and VA-C 92R (Table 4). Each of these cultivars matured earlier than NC 9. AT VC-1 was the latest maturing cultivar. AT VC-1 is typically later maturing than other commonly grown virginia-type cultivars (Swann, 1997). As expected, peanut was more mature on the second digging date than on the first date (Table 5).

Quality and Value. Pooled over locations, significant main effects of cultivars, prohexadione calcium, and digging dates were observed for all market quality factors. No interactions among the three factors were observed. Prohexadione calcium increased the percent-

Table 4. Peanut pod mesocarp color, market quality factors, and value of six virginia-type peanut cultivars.[a]

Cultivar	Pod mesocarp color: White or yellow	Pod mesocarp color: Brown or black	Market quality factors[b]: ELK	TSMK	FP	Value
	-----%-----		------ % -----			$/kg
AT VC-1	39 a	39 c	28 d	68 c	80 c	0.72 d
NC 9	36 b	43 b	36 c	67 d	89 a	0.72 d
NC 10C	33 c	47 a	19 e	16 e	77 d	0.70 e
NC 12C	32 cd	47 a	51 a	70 a	89 a	0.75 a
NC-V 11	33 c	48 a	36 c	68 c	78 d	0.73 c
VA-C 92R	30 d	47 a	42 b	69 b	85 b	0.74 b

[a]Data pooled over locations, prohexadione calcium treatments, and two digging dates for pod mesocarp color or three digging dates for market quality factors and value. Means within a column followed by the same letter are not different according to Fisher's Protected LSD Test at P = 0.05.

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

Table 5. Peanut pod mesocarp color, market quality factors, and value as affected by digging dates.[a]

Digging date	Pod mesocarp color: White or yellow	Pod mesocarp color: Brown or black	Market quality factors[b]: ELK	TSMK	FP	Value
	---- % ----		---- % ----			$/kg
First	37 a	41 b	33 c	67 b	85 a	0.71 c
Second	31 b	50 a	35 b	67 b	85 a	0.72 b
Third	--	--	38 a	70 a	79 b	0.75 a

[a]Data pooled over locations, cultivars, and prohexadione calcium treatments. Means within a column followed by the same letter are not different according to Fisher's Protected LSD Test at P = 0.05.

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

Table 6. Effect of prohexadione calcium (PC) on gross returns of six virginia-type peanut cultivars.[a]

Cultivar	Edenton & Lewiston[b]: - PC	+ PC	Windsor & Rocky Mount[b]: - PC	+ PC
	----- $/ha -----		----- $/ha -----	
AT VC-1	2900 bc	2965 bc	3515 de	4075 a
NC 9	2955 bc	3285 a	3240 f	3845 b
NC 10C	2845 bc	2830 c	3260 f	3635 cd
NC 12C	2955 bc	2955 bc	3690 c	4075 a
NC-V 11	2975 b	2920 bc	3495 e	3910 b
VA-C 92R	3165 a	2930 bc	3650 c	3935 b

[a]Data pooled over three digging dates. Means within locations followed by the same letter are not different according to Fisher's Protected LSD Test at P = 0.05.

[b]Data pooled over locations.

age of ELK, TSMK, and FP 6, 2, and 3 percentage points, respectively (Table 3). Mitchem *et al.* (1996) also observed that prohexadione calcium increased ELK 4 to 7%, but they observed no effect on percentage of TSMK or FP. Prohexadione calcium increased peanut value $0.01/kg as a result of the increased proportion of ELK.

NC 12C and VA-C 92R produced the greatest and second greatest percentages, respectively, of ELK and TSMK (Table 4). AT VC-1, NC 9, and NC-V 11 produced fewer ELK and TSMK than NC 12C or VA-C 92R but more than NC 10C. Swann (1997) also reported that NC 12C and NC 10C produced the greatest and least amount, respectively, of ELK and TSMK among several virginia-type cultivars. NC 12C and NC 9 produced the greatest percentage of FP while NC-V 11 produced the least amount. Peanut value/kg followed trends in proportions of ELK and TSMK, with NC 12C and VA-C 92R have the greatest value and NC 10C having the least value. Differences among cultivars in the proportion of FP had no effect on value as all cultivars produced greater than 40% FP, the minimum percentage for virginia-type marketing classification.

Delaying digging increased the proportions of ELK and TSMK and decreased the proportion of FP (Table 5). This likely reflects the greater maturity of the crop with the later digging dates (Mozingo *et al.*, 1991). Peanut value/kg is dependent on proportions of ELK and TSMK, hence values were greater at the later digging dates.

Gross Returns. Gross return data could not be pooled over all locations. As with yield, it was possible to pool the Windsor and Rocky Mount locations and also the Edenton and Lewiston locations. A cultivar-by-prohexadione calcium interaction was noted in both analyses. At Edenton and Lewiston, prohexadione calcium had no effect on gross returns of AT VC-1, NC 10C, NC 12C, and NC-V 11 (Table 6). Prohexadione calcium increased gross returns of NC 9 by $330/ha and decreased gross returns of VA-C 92R by $235/ha. In contrast, prohexadione calcium increased gross returns of all cultivars at Windsor and Rocky Mount $285 to $605/ha. Similar to results at Edenton and Lewiston, greatest and least gross returns from use of prohexadione calcium were observed with NC 9 and VA-C 92R, respectively.

Results of this study indicate virginia-type peanut response to prohexadione calcium may be cultivar-dependent. Prohexadione calcium hastened maturity and increased the percentage of ELK, TSMK, and FP at all locations irrespective of the cultivar. However, growth suppression and yield response varied by cultivar. Greatest growth suppression was noted with NC-V 11 while NC 9 was least affected. Growth suppression did not appear to be related to inherent growth potential of the cultivars. The greatest and most consistent yield response to prohexadione calcium was noted with NC 9. Yield of VA-C 92R was sometimes reduced by prohexadione calcium. Cultivars with greater vegetative growth generally expressed a greater positive yield response to prohexadione calcium. Digging date had no effect on peanut response to prohexadione calcium.

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