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ARTICLE

Effect of Prohexadione Calcium Application Timing and Rate on Peanut (*Arachis hypogaea*) Growth and Yield in Mississippi

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ABSTRACT

Excessive vegetative growth in peanut can lead to decreased harvest efficiency. Peanut vegetative growth is often managed with the plant growth regulator prohexadione calcium. Although application of prohexadione calcium is recommended at 50% and 100% canopy closure (CC) as defined by lateral vines touching, research on the optimal application timing and rate has been minimal. The objective of this research was to evaluate the effect of prohexadione calcium application timing and rate based on percent canopy closure. Experiments were conducted at 6 different sites in Mississippi over 2 years. Treatments in 2020 included prohexadione calcium applied at 50% CC + one application at 100% CC (recommended by product label), two applications in one week at 100% CC, and three applications in one week at 100% CC. In 2020, all prohexadione calcium applications were made at 140 g a.i./ha. Treatments in 2021 included application timings at 50% and 100% CC and multiple application rates at each timing including 70 g a.i./ha, 140 g a.i./ha, and 280 g a.i./ha. Peanut response was evaluated based on pod weight after digging, pod count after digging, dry plant weight, pod loss, and peanut yield. Dry plant weight, pod loss, and pod weight were unaffected by prohexadione calcium application. Peanut yield ranged from 6200 kg/ha to 7300 kg/ha across years, locations, and prohexadione calcium treatments. Yields following all prohexadione calcium application timings and rates were similar to those following applications at the recommended timings and rate. With the exception of two applications in one week at 100% CC, yield response following prohexadione application was similar to that of the untreated check. Therefore, prohexadione calcium application timings and rates are likely more flexible than the labelled recommendation with respect to vegetation management; however, yield enhancement following application was inconsistent.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an important food and oil crop in Mississippi (MS) and the United States (U.S.). Approximately 8,900 and 670,000 ha of peanut were harvested in MS and the U.S., respectively, in 2020 (USDA NASS, 2021). Mississippi ranked 7th out of the 13 peanut producing states in total production in 2020 (USDA FAS, 2021). The U.S. is ranked 4th in peanut production worldwide at 2,900,000 metric tons in 2020 (USDA FAS, 2021; USDA NASS, 2021). Total production can be divided into four different market types of peanut. Virginia market types comprise approximately 15% of the U.S. crop while Spanish and Valencia market types account for approximately 5% of the U.S. crop (Boote, 1982; USDA NASS, 2021). Runner market type peanut accounts for approximately 80% of the U.S. market (Boote, 1982; Putnam et al., 1991; USDA NASS, 2021).

During the 130 to 160 days after planting needed for runner types to reach maturity (Boote, 1982; Putnam et al., 1991), peanut is prone to excessive vegetative growth. Peanut produces more vegetative growth than required for maximum pod yield (Mitchem et al., 1996). Excessive vegetative growth can increase the likelihood of disease occurrence and severity due to increased humidity beneath the canopy (Beam et al., 2002; Culpepper et al., 1997; Jordan et al., 2008; Studstill, et al., 2020; Wu and Santelmann, 1977). Excessive vegetative growth can also contribute to damage from equipment traveling through fields during mid- or late-season chemical applications. Reduced digging and harvest efficiency is an additional consequence of excessive vegetative growth often attributed to decreased row visibility (Beam et al., 2002; Culpepper et al., 1997; Jordan et al., 2008; Studstill, et al., 2020; Wu and Santelmann, 1977). Additionally, pods lost from plants during digging can increase with excessive canopy growth contributing to substantial yield loss (Beam et al., 2008). Over the past 40 years, negative effects of excessive vegetative growth have often been managed by plant growth regulators (Beam et al., 2002; Brown and Ethredge, 1974).

Historically, daminozide was applied to peanut to prevent internode elongation (Brown and Ethredge, 1974). Brown and Ethredge (1974) observed increased pods per plant and enhanced row visibility when daminozide was applied. Although daminozide application enhanced row visibility, overall yield and growth response was inconsistent, and product registration was cancelled in 1989 due to health concerns from consumers (Anonymous, 1989; Beam et al., 2002; Culpepper et al., 1997; Mitchem et al., 1996). In early 2000, prohexadione calcium was developed as a suitable alternative to daminozide (Studstill et al., 2020). In comparative studies, peanut growth and yield responded similarly to both prohexadione calcium and daminozide application (Culpepper et al., 1997; Mitchem et al., 1996).

Prohexadione calcium is a plant growth regulator used in apple (*Malus domestica* Borkh.), grain sorghum [*Sorghum bicolor* (L.) Moench], oilseed rape (*Brassica napus* L.), peanut, rice (*Oryza sativa* L.), tomato (*Solanum lycopersicum* L.), and wheat (*Triticum aestivum* L.) to prevent excessive vegetative growth and promote reproductive growth (Grossmann et al., 1994; Mitchem et al.1996; Studstill, et al., 2020). Prohexadione calcium prevents excessive vegetative growth by affecting gibberellin biosynthesis by blocking kaurene oxidase (Nakayama et al., 1990a; Nakayama et al., 1990b; Nakayama et al., 1991). Promotion of reproductive growth is attributed to increased abscisic acid and cytokinin levels (Grossmann et al., 1994; Studstill et al., 2020).

The effects of prohexadione calcium on peanut have been elucidated in several studies. Prohexadione calcium application resulted in increased row visibility, increased overall pod maturity, decreased pod loss, and increased yield (Beam et al., 2002; Jordan et al., 2001; Jordan et al., 2008; Mitchem et al., 1996; Studstill et al.¸ 2020). Studstill et al. (2020) found that, when compared to yields following prohexadione calcium application at 140 g a.i./ha at 50% canopy closure (CC) and at 100% CC (7,600 kg/ha), reduced application rates (70 g a.i./ha) did not decrease yield (7,500 kg/ha). Mitchem et al. (1996) observed increased yield only when specific application timings were utilized. While these studies elucidated the benefits of prohexadione calcium application, few studies were conducted using modern runner market type peanut cultivars which is the most common market type grown in MS. Furthermore, research regarding prohexadione calcium effects on runner market type peanut growth and yield is lacking.

The prohexadione calcium product label recommends application of 140 g a.i./ha at both 50% CC and 100% CC, i.e., when 50% and 100% lateral vines initially touch, respectively. Environmental conditions and management strategy may prevent application of prohexadione calcium at these precise timings. Runner market type peanut growers have little information on the implications of applying prohexadione calcium at timings and rates that deviate from the labelled recommendation. Therefore, the objectives of this research are to determine if applying prohexadione calcium to peanut at timings and rates that differ from the labelled recommendation will affect runner-type peanut growth and yield.

MATERIALS AND METHODS

Research was conducted in 2020 and 2021 at multiple on-farm locations in Mississippi. In 2020, the effect of prohexadione calcium application timing was investigated, while in 2021, both prohexadione calcium application timing and rate were investigated. In each year, three locations were included (Table 1). Treatments and dates for planting, prohexadione calcium application, digging, and harvest in 2020 and 2021 are given in Table 2 and Table 3, respectively. Prohexadione calcium (Apogee® 27.5 WDG, BASF Corp. or Kudos® 27.5 WDG, Fine-Americas) treatments, including the labelled rate of 140 g a.i./ha, were applied with a surfactant blend plus urea ammonium nitrate at 1% v/v (Dyne-A-Pak, Helena Agri-Enterprises). All treatments in 2020 were applied with a tractor-mounted, roller-pump sprayer utilizing ULD 120025 nozzles (Pentair Hypro), whereas all treatments in 2021 were applied with a Mudmaster ™ sprayer (Bowman Manufacturing Co.) equipped with a hydraulic roller-pump utilizing ULD 120025 nozzles.

Peanut at all locations and years were grown under dryland conditions and peanut cultivar Georgia-06G was seeded at 20 seeds/m at a depth of 4 to 6 cm. All sprayers were calibrated to deliver 187 L/ha at 276 kPa. Agronomic practices including fertilization and pest management were determined by each grower at each location per local recommendations. Application timings were determined by utilizing images from Canopeo (Oklahoma State University, Stillwater, OK) which uses true color images that convert all green reflectance to white and all other light reflectance to black and the percent white to black is calculated (Patrignani and Ochsner, 2015).

Table 1. Location, soil series and texture, row spacing, and treatment area for peanut experiments investigating the effect of prohexadione calcium application timing in 2020 and 2021.

Year	Location	Coordinates		Soil Series and Texture	Row Spacing	Treatment Area
		Latitude	Longitude		cm	ha
2020	Cruger	33°18'08.4"N	90°09'58.5"W	Collins silt loam	97	0.32
	Carlisle	32°01'01.4"N	90°46'59.0"W	Calloway silt loam	97	0.21
	Hamilton	33°46'57.0"N	88°27'50.5"W	Prentiss fine sandy loam	92	0.20
2021	Tchula	33°09'04.3"N	90°12'09.8"W	Morganfield silt loam	97	0.13
	Smithville	34°03'35.3"N	88°24'47.9"W	Savannah fine sandy loam	92	0.11
	Port Gibson	31°55'12.8"N	90°56'56.0"W	Loring and Memphis silt loam	97	0.08

Table 2. Planting dates, application dates, digging dates, and harvest dates in Mississippi in 2020.

	Location		
	Carlisle	Cruger	Hamilton
Planting date	04 May	27 April	02 April
Application date[a]			
One week before 50% canopy closure + one week before 100% canopy closure	22 June and 2 July	22 June and 6 July	22 June and 6 July
One week before 50% canopy closure + one week after 100% canopy closure	22 June and 20 July	22 June and 20 July	22 June and 21 July
50% canopy closure + 100% canopy closure[b]	29 June and 9 July	29 June and 13 July	29 June and 13 July
Two applications in one week at 100% canopy closure	9 July and 14 July	13 July and 17 July	13 July and 17 July
Three applications in one week at 100% canopy closure	9 July, 14 July, and 20 July	13 July, 17 July, and 20 July	13 July, 17 July, and 21 July
Digging date	15 September	17 September	06 October
Harvest date	02 October	01 October	19 October

[a] Each application of prohexadione calcium was made at a rate of 140 g a.i./ha

[b] Labelled application timing for prohexadione calcium

Above and below ground peanut biomass samples were collected after digging from a 1-m length of row from each plot and then dried in a forced air dryer at 65ºC for one week. Plant weight, pod weight, and pod count data were collected from these samples. Pod loss data were collected from 1 m^2 within each plot. Peanut plants were machine dug and inverted with Amadas Industries ADI-638 at Cruger, Tchula, Carlisle, and Port Gibson locations and ADI-636 in Hamilton and Smithville locations. After digging, pods were machine harvested with Amadas Industries AR2200 and M2120 at Cruger, Tchula, Carlisle, and Port Gibson locations and Amadas Industries A-9990 at Hamilton and Smithville locations. Peanut pods were weighed using a custom dump cart equipped with load cells (Shortline Manufacturing, Shaw, MS).

Table 3. Planting dates, application dates, digging dates, and harvest dates in Mississippi in 2021.

	Location		
	Port Gibson	Smithville	Tchula
Planting date	03 May	24 May	25 May
Application date[a]			
50% canopy closure + 100% canopy closure[b]	30 June and 10 August	14 July and 24 August	30 June and 10 August
70 g a.i./ha at 50% canopy closure	30 June	14 July	30 June
140 g a.i. at 100% canopy closure	10 August	24 August	10 August
280 g a.i. at 100% canopy closure	10 August	24 August	10 August
Two applications in one week at 100% canopy closure	10 August and 12 August	24 August and 26 August	10 August and 12 August
Digging date	11 October	13 October	11 October
Harvest date	26 October	22 October	14 October

[a] Unless noted otherwise, each application of prohexadione calcium was made at a rate of 140 g a.i./ha

[b] Labelled application timing for prohexadione calcium

Treatments were arranged in a randomized complete block design with three replications. Plant weight, pod loss, pod weight/plant, pod count and yield data were analysed using PROC GLIMMIX in SAS 9.4 and data for all parameters are presented as treatment means pooled over location and year (Blouin, et al., 2011; Buol, et al., 2019). Location, year, and interactions of the two were considered random effects. All data were subjected to analysis of variance and means were separated using Fisher's protected least significant difference (LSD) at α=0.05.

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RESULTS AND DISCUSSION

Prohexadione Application Timing Experiment – 2020

In 2020, prohexadione calcium application timing had no effect on plant weight, pod loss, pod weight/plant, or pod count (Table 4). Plant weight ranged from 54 to 69 g/m of row. Pod loss (pods/m^2) ranged from 5.1 to 6.5 and pod counts (number/plant) ranged from 21 to 26. Pod weight/plant varied from 27 to 34 g. Yield ranged from 6,200 kg/ha to 6,900 kg/ha and responses were observed following prohexadione calcium application. However, varying prohexadione calcium application timing from the labelled recommendation did not affect peanut yield. Applying prohexadione calcium twice in one week at 100% CC was the only application timing to improve peanut yield (6,900 kg/ha) relative to not applying the plant growth regulator (6,200 kg/ha).

Table 4. Effect of prohexadione calcium application timing on peanut growth and yield pooled over environment in Mississippi in 2020.

Prohexadione calcium application timing[a]	Plant weight	Pod loss	Pod weight /plant	Pod count	Yield
	g/m of row	pods/m^2	g	#/m of row	kg/ha
Untreated Check	54 a[b]	5.4 a	27 a	21 a	6200 b
One week before 50% canopy closure + one week before 100% canopy closure	60 a	5.8 a	31 a	23 a	6700 ab
One week before 50% canopy closure + one week after 100% canopy closure	65 a	6.5 a	32 a	25 a	6500 b
50% canopy closure + 100% canopy closure[c]	60 a	5.9 a	32 a	26 a	6700 ab
Two applications in one week at 100% canopy closure	69 a	5.5 a	34 a	26 a	6900 a
Three applications in one week at 100% canopy closure	63 a	5.1 a	32 a	23 a	6200 b

[a] Each application of prohexadione calcium was made at a rate of 140 g a.i./ha

[b] Means within a column followed by the same letter are not significantly different from each other according Fisher's protected LSD test at P ≤ 0.05.

[c] Labelled application timing for prohexadione calcium.

Prohexadione Application Timing and Rate Experiment – 2021

In 2021, prohexadione calcium application affected pod count and peanut yield, but had no effect on plant weight, pod loss, or pod weight/plant (Table 5). Plant weight ranged from 46 to 55 g/m of row. Pod loss (pods/m^2) ranged from 3.9 to 4.7 and pod weight/plant varied from 23 to 29 g. Following the recommended prohexadione calcium application timing, pod count per plant was greater (21 pods/plant) compared to those observed following two applications of prohexadione calcium in one week at 100% CC (16 pods/plant). Yield ranged from 6,800 kg/ha to 7,300 kg/ha and responses were observed following prohexadione calcium application. No prohexadione calcium application timing or rate resulted in different peanut yield than that observed following the recommended application timing and rate of 140 g a.i. applied at 50% CC followed by 140 g a.i. at 100% CC. Similarly, applying prohexadione calcium at any specific time or rate did not affect yield relative to the non-treated control. The only difference in peanut yield was observed following a single 140 g a.i./ha application at 100% CC (7,300 kg/ha) compared to yield following either a single application of 280 g a.i. of prohexadione calcium at 100% CC (7,000 kg/ha) or two applications of 140 g a.i. within one week at 100% CC (6,800 kg/ha).

These results deviate slightly from other literature that has investigated prohexadione calcium application effect on pod loss and peanut yield. However, a large portion of previous research was conducted using Virginia market type peanut. Beam et al. (2002) observed reduced pod loss following prohexadione calcium application whereas in our work, no difference in pod loss was observed due to prohexadione calcium application. It has also been noted in previous research that yield response following prohexadione calcium application is inconsistent (Culpepper et al. 1997; Jordan et al. 1997; Jordan et al. 2008; Mitchem et al. 1996). Beam et al. (2002) observed increased yield following prohexadione calcium application but noted variation in magnitude and significance of response between cultivars. Studstill et al. (2020) observed no differences in yield of runner market type peanut following application of prohexadione calcium. However, they also observed increased yield following application of prohexadione calcium at 105 g ai/ha compared to a non-treated control. These data differ from previous results as we observed no difference in peanut yield following application at labelled rates or timings. Cultivar, variation in vine growth, soil type and texture, environmental conditions, and cultural practices may contribute to variation in yield response and should be investigated further with runner type peanut (Jordan et al. 2000; Studstill et al. 2020).

SUMMARY AND CONCLUSIONS

The objectives of this research were to determine if applying prohexadione calcium to peanut at timings and rates that differ from the labelled recommendation will affect runner market type peanut growth and yield. Peanut growth as defined by plant weight, pod loss, and pod loss/plant was unaffected by prohexadione calcium application. Yields from all treatments, including those from non-treated areas, were similar to those observed following application of the label recommendation of one application at 50% CC + one application at 100% CC at 140 g a.i./ha. Also noteworthy, only one prohexadione application treatment, two applications of 140 g a.i./ha within one week at 100% CC, resulted in increased yield compared to the non-treated control. Numerous previous studies have elucidated the benefit of prohexadione calcium application for management of excessive vegetative growth while also noting variation in yield response to prohexadione calcium application. Therefore, application of prohexadione calcium to manage excessive vegetative growth should be considered in MS peanut production; however, yield response may be inconsistent.

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Table 5. Effect of prohexadione calcium application timing and rate on peanut growth and yield pooled over environment in Mississippi in 2021.

Prohexadione calcium application timing & rate[a]	Plant weight		Pod loss		Pod weight/plant		Pod count		Yield	
	g/m of row		pods/m^2		g		#/m of row		kg/ha	
Untreated Check	54	a[b]	4.6	a	27	a	19	ab	7200	ab
50% canopy closure + 100% canopy closure[c]	55	a	4.7	a	27	a	21	a	7100	ab
70 g a.i./ha at 50% canopy closure	50	a	4.1	a	25	a	18	ab	7100	ab
140 g a.i. at 100% canopy closure	49	a	3.9	a	29	a	17	ab	7300	a
280 g a.i. at 100% canopy closure	57	a	4.0	a	26	a	19	ab	7000	b
Two applications in one week at 100% canopy closure	46	a	4.0	a	23	a	16	b	6800	b

a Unless noted otherwise, each application of prohexadione calcium was made at a rate of 140 g a.i./ha

b Means within a column followed by the same letter are not significantly different from each other according Fisher's protected LSD test at P ≤ 0.05.

c Labelled application timing for prohexadione calcium.

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