# Yield and Economic Response of Peanut (*Arachis hypogaea* L.) Cultivars to Prohexadione Calcium in Large-Plot Trials in Georgia

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## ABSTRACT

Prohexadione calcium, a plant growth regulator, has been used on virginia market type peanut cultivars for many years to manage excessive vine growth and improve digging efficiency. Prohexadione calcium has not been widely used on runner market type cultivars due to their slower growth habit and sporadic yield response at the labeled rate until recent research showed lower use rates of prohexadione calcium provided similar vine control and enhanced yield response. Large plot experiments were conducted in Colquitt county at the Darrell Williams Research Farm on the Sun Belt Ag Expo to quantify yield and market grade quality and economics of using prohexadione calcium at 105 g a.i./ha on six runner type cultivars. Prohexadione calcium was applied twice during the growing season. The first application was made when 50% or greater of lateral vines from adjacent rows were touching. A second application of each treatment was applied 14d after the first application. The runner type cultivars were Georgia-06G, Georgia-12Y, Georgia-13M, Georgia-14N, TUFRunner™-297, and TUFRunner™-511. Similar large-plot experiments were conducted on farms in Baker and Early counties evaluating yield and economic response of prohexadione calcium on Georgia-06G. A non-treated control was used in all experiments. Prohexadione calcium increased pod yield in all experiments ranging from 450 to 650 kg/ha compared to the non-treated control with response similar across cultivars. Prohexadione calcium reduced the dollar value per metric ton (DVMT) as a result of lowering total sound mature kernel (%TSMK) percentages up to 3 points. The higher yields obtained for the prohexadione calcium-treated peanut provided higher gross dollar value return/ha (GDR) in all experiments and higher gross dollar value return/ha above treatment cost (GDRAT) in the on-farm trials. Therefore, prohexadione calcium at 105 g/ha applied twice on runner market type peanut is warranted to improve yield and financial return when excessive vine growth is a concern.

Key Words: *Arachis hypogaea* L, growth regulator, virginia market type peanut, runner market type peanut

Utilization of plant growth regulators in peanut (*Arachis hypogaea* L.) to manage vegetative growth in the United States is not a new approach. Growth regulators have been evaluated and utilized for more than 40 years (Beasley et al., 2004; Jordan et al., 2008, 2000; Mitchem et al., 1996; Smith, 1989; Wu and Santelmann, 1977). There have been several growth regulators registered over this time period with some like daminozole which was removed from the marketplace due to safety concerns in food products (Smith, 1989). The most recent growth regulator released for managing vegetative growth in peanut is prohexadione calcium, registered by BASF Corporation in 2000 (Giles-Parker, 2000) and Fine Americas, Inc. in 2015 (Smith, 2015) marketed under the trade names Apogee 27.5 WDG and Kudos 27.5 WDG, respectively.

Since its development, there has been numerous research experiments on virginia market type peanut that have shown the effectiveness of prohexadione calcium in managing vegetative growth in peanut (Culpepper et al., 1997; Faircloth et al., 2005; Jordan et al., 2000). These studies also reported that prohexadione calcium increased pod yield a majority of the time (Beam et al., 2002). During the time period when prohexadione calcium was registered commercially on peanut, it was not marketed for use on runner market type cultivars due to their more moderate vine growth habit along with the introduction of GPS guidance on tractors (Roberson and Jordan, 2014). However, in the last 10 years, breeding programs have reintroduced runner market type cultivars with increased vegetative growth. This resurgence of fast growing runner market type cultivars has increased the need for managing the excessive vine growth. Previous small-plot research on runner market type

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peanut showed similar results in reducing vegetative growth using prohexadione calcium at the labeled rate of rate of 140 g/ha and at the reduced rates of 105 g/ha and 70 g/ha; however, there were not yield improvements associated with the vegetative reduction (Studstill et al., 2020; Treadway, 2020). However, large plot on-farm trial locations in Mississippi and in Georgia showed significant reductions in vine growth and yield improvements with reduced rates of prohexadione calcium (Studstill et al, 2020; Treadway, 2020). Based on these reports, prohexadione calcium at reduced rates has potential for managing vegetative growth and providing the needed yield enhancements to make it economical on runner market type peanut (Studstill et al, 2020; Treadway, 2020). With this in mind, large-plot research trials were conducted to further examine and quantify the yield and quality response and economics of using prohexadione calcium applied twice at a rate of 105 g/ha on runner market type cultivars in Georgia.

## Materials and Methods

Experiments were conducted in Colquitt county at the Darrell Williams Research Farm on the Sun Belt Ag Expo (Latitude 31° 8′16.83″N, Longitude 83°42′28.83″W) to examine the yield, market grade, and economic response to prohexadione calcium at a rate of 105 g/ha applied twice during the growing season across multiple peanut cultivars. Experiments were also conducted on-farm in Baker and Early counties to evaluate the yield, grade, and economic response of utilizing prohexadione calcium on Georgia-06G (Branch, 2007). Experiments at the Darrell Williams Research Farm on the Sun Belt Ag Expo were conducted on a Leefield Loamy Sand (Loamy, siliceous, subactive, thermic Arenic Plinthaquic Paleudults). Experiments in Baker county and Early county were conducted on a Norfolk Loamy Sand (Fine-loamy, kaolinitic, thermic Typic Kandiudults) and Tifton Loamy Sand (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults), respectively.

**Peanut Cultivar by Prohexadione Calcium Experiment**

Two experiments were conducted in irrigated fields to evaluate yield, quality, and economic response of six runner type cultivars to prohexadione calcium applications in 2016 and 2017. A split-plot experimental design was used with three to four replications. Prohexadione calcium treatments were the main plot effect and runner market type cultivars were the subplot variable. Prohexadione calcium treatments consisted of 1.) non-treated check, and 2.) prohexadione calcium at a rate of 105 g/ha (applied twice). Runner market type cultivars included Georgia-06G, Georgia-12Y (Branch, 2013), Georgia-13M (Branch, 2014), Georgia-14N (Branch and Brenneman, 2015), TUFRunner-297 (Tillman, 2017), and TUFRunner-511 (Tillman and Gorbet, 2017). Georgia-06G, Georgia-13M, TUFRunner-297, and TUFRunner-511 are considered to have medium maturity while Georgia-12Y and Georgia-14N have a medium to late maturity (Monfort et al., 2019). Plot dimensions were 1.8 m wide (2 rows) and 97.5 to 122 m long depending on each year and location's field layout. Peanut seed were planted in a single row planting pattern with 91 cm row spacing. Seed was planted at 19.8 seed/m of row to achieve a final in-row plant population of at least 13.1 plants/m of row. Peanut production management decisions were made based on University of Georgia Cooperative Extension Service recommendations (Monfort et al., 2019).

**On-Farm Prohexadione Calcium Experiment**

There were a total of five large on-farm irrigated trials conducted in Early and Baker Counties in 2017 and 2018. Peanut planting date varied by location and ranged from late April to mid-May. Cultivar Georgia-06G was planted in all experiments. Seed was planted at rates (19.8 to 23.1 seed per m row) to achieve a final in-row plant population of 13.1 to 16.4 plants per m of row. Plot dimensions were 5.5 m wide and 305 m to 549 m long. Treatments consisted of 1) prohexadione calcium at 105 g/ha and 2) non-treated control in all experiments. All experiments were conducted in a randomized complete block design. Replications varied by location with a minimum of four. Peanut production management decisions were made based on University of Georgia Cooperative Extension Service recommendations (Monfort et al., 2019).

**Treatment Application**

Crop oil concentrate, (Agri-Dex, 83% paraffin based petroleum oil and 17 % surfactant, Helena Chemical Co., 5100 Poplar Ave., Memphis, TN) was applied at 2.3 L/ha and 28% urea ammonium nitrate or 21% ammonium sulfate was applied at 1.2 L/ha with prohexadione calcium applications as per label instructions. Prohexadione calcium was applied in 233 L/ha water using a tractor mounted sprayer equipped with 8002 regular flat fan nozzles (Teejet nozzles, Spraying Systems Co., Wheaton, IL) in both of the Colquitt County experiments and 140 L/ha of water using commercial large-scale crop sprayers for the large plot on-farm experiments in Early and Baker Counties. All treatments were applied independently of any other pesticide

**Table 1. Analysis of variance for yield, quality, and economic value response of utilizing prohexadione calcium applied twice at 105 g a.i./ha in two large-plot experiments on runner-type peanut cultivars in Colquitt County, Georgia in 2016 and 2017.**

| | Yield (kg/ha) | | %TSMK[a] | | %Other Kernels[b] | | $ Value/ Metric Ton[c] | | Gross $ Value/ha[d] | | Gross $/ha return above treatment cost[e] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | F | P value | F | P value | F | P value | F | P value | F | P value | F | P value |
| Cultivar | 32.8 | <0.0001 | 38.5 | <0.0001 | 25.0 | <0.0001 | 40.7 | <0.0001 | 33.1 | <0.0001 | 33.1 | <0.0001 |
| Prohexadione Calcium | 8.7 | 0.0250 | 11.3 | 0.0012 | 9.4 | 0.0219 | 10.5 | 0.0177 | 6.48 | 0.0438 | 1.6 | 0.2548 |
| Cultivar x Prohexadione Calcium | 0.2 | 0.9652 | 3.3 | .0091 | 2.1 | .0751 | 3.3 | 0.0106 | 0.78 | 0.5714 | 0.8 | 0.5714 |

[a]%TSMK = total sound mature kernels (sound mature kernels + sound splits).

[b]%Other Kernels = percentage of kernels that fall through the sound mature kernel screen.

[c]$value per metric ton was calculated based on loan value of $4.808 times TSMK + $1.40 for each 1% change in other kernels.

[d]Gross $ value per hectare was calculated based on the yield (kg/ha) times the dollar value per metric ton.

[e]Dollar return per hectare above treatment cost was calculated based on the gross dollar value per hectare – cost of prohexadione calcium application.

or nutrient applications. Commercial large-scale crop sprayers (type and size) varied by location. Prohexadione calcium was applied twice during the growing season. The first application was made when 50% or greater of lateral vines from adjacent rows were touching. The second application was applied 14d after the first application.

**Peanut Production Strategies and Harvest**

Peanut plants were dug and inverted based on maturity profile method for each cultivar (pod mesocarp color) (Williams and Drexler, 1981). Maturity of all cultivars ranged from 140 to 150 Day after planting except for Georgia-12Y and Georgia-14N which ranged from 150 to 155 Days after planting. Plants were dried for 5 to 7 d depending on weather to an estimated 12-15% moisture. Once adequate drying occurred in the field, peanut pods were harvested using a commercial peanut combine. Final pod weight was adjusted to 7% moisture. A subsample was taken from each plot per site year and assessed for quality (market grade) by the Georgia Federal State Inspection Service according to USDA-AMS grade standards (USDA-AMS, 1997). Grade data for the Colquitt County locations included percentages of total sound mature kernels (%TSMK) and other kernels (%OK). Grade data only included %TSMK for the Early and Baker County locations. The base loan value for peanut in the United States was $355/farmer stock ton at a base %TSMK grade of 73.65 in 2019. Base grade levels are set each year by USDA. Dollar value per metric ton was calculated based on loan value of $4.808 times %TSMK for the Early and Baker county locations and base loan value of $4.808 times %TSMK + $1.40 for each 1% change in other kernels for the Colquitt county location. Gross dollar value per hectare (GDR) was calculated based on the yield (kg/ha) times the dollar value per metric ton (DVMT). Dollar return per hectare above treatment cost (GDRAT) was calculated based on the gross dollar value per hectare – cost of prohexadione calcium application. The cost of prohexadione calcium at 105 g/ha applied twice was estimated at $92.85/ha at the time the experiments were conducted.

**Data Analysis**

Analysis of variance was conducted using the PROC MIXED function within SAS version 9.4 (SAS Institute, Cary, NC). Field (site year) was treated as a random effect in our experiment statistical analysis. Appropriate means were separated with Fisher's protected least significant difference (LSD) test at $P = 0.05$.

## Results

**Cultivar response to Prohexadione calcium.**

There were no cultivar by treatment interactions for pod yield, %OK, GDR, or GDRAT (Table 1). Therefore, the data for treatment were combined across cultivars and data for cultivar were combined across treatments. Cultivar was significant ($p<0.05$) for yield, %TSMK, %OK, GDR, DVMT, and GDRAT (Table 1). Growth regulator treatment was significant ($p<0.05$) for yield, %TSMK, %OK, DVMT, and GDR (Table 1). Cultivar by treatment interactions for %TSMK and DVMT were significant ($p<0.05$).

Yield, quality, and economic value differences were observed among the cultivars evaluated. Cultivars TUFRunner 297, TUFRunner 511, Georgia-06G, and Georgia-12Y yielded greater than Georgia-14N (Table 2). Yield was improved ($p<0.05$) when prohexadione calcium was applied compared to the non-treated control (Table 2).

**Table 2. Yield, quality, and economic value response of utilizing prohexadione calcium applied twice at 105 g a.i./ha in two large-plot experiments on runner-type peanut cultivars at the Daryl Williams Research Farm in Colquitt County, Georgia in 2016 and 2017.**

| Cultivars | Yield (kg/ha) | | %Other Kernels[a] | | Gross $ Value/ha[b] | | Gross $/ha return above treatment cost[c] | |
|---|---|---|---|---|---|---|---|---|
| Georgia-06G | 6,850 | ab[d] | 2.6 | bc | $2,820 | a | $2,780 | a |
| Georgia-12Y | 6,690 | ab | 5.0 | a | $2,550 | b | $2,510 | b |
| Georgia-13M | 6,500 | b | 3.3 | b | $2,590 | b | $2,550 | b |
| Georgia-14N | 5,670 | c | 4.6 | a | $2,300 | c | $2,270 | c |
| TUFRunner 297 | 7,050 | a | 2.2 | c | $2,900 | a | $2,860 | a |
| TUFRunner 511 | 6,920 | a | 2.6 | bc | $2,790 | a | $2,750 | a |
| Treatments | | | | | | | | |
| Non-treated Check | 6390 | b[e] | 3.1 | b | $2,580 | b | $2,580 | a |
| Prohexadione Calcium | 6830 | a | 3.7 | a | $2,730 | a | $2,660 | a |

[a]% Other Kernels = percentage of kernels that fall through the sound mature kernel screen.

[b]Gross dollar value per hectare was calculated based on the yield (kg/ha) times the dollar value per metric ton.

[c]Dollar return per hectare above treatment cost was calculated based on the gross dollar value per hectare – cost of prohexadione calcium application.

[d]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.05$ for cultivars data pooled over levels of other treatment factors.

[e]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.05$ for prohexadione calcium treatments over levels of other treatment factors.

Similar cultivar and treatment responses were also observed for %OK percentages where Georgia-12Y and Georgia-14N had the highest percentage of %OK compared to the other cultivars when assessed across treatments. Prohexadione calcium increased the percentage of %OK compared to the non-treated control (Table 2). Other kernels represent the percentage of immature kernels in a grade sample which would reduce the %TSMK percentage.

Since there was a significant cultivar x growth regulator interaction for %TSMK, growth regulator treatment and cultivar responses were analyzed separately. In evaluating the cultivar differences within treatments, Georgia-12Y and Georgia -13M had significantly lower %TSMK compared to all other cultivars for the untreated check while Georgia-12Y, Georgia-13M, Georgia-14N had significantly lower %TSMK compared to Georgia-06G and TUFRunner 297 for the prohexadione calcium treatment (Table 3). Examining the treatment effects on cultivars, applications of prohexadione calcium significantly reduced %TSMK three percentage points for Georgia-12Y and two percentage points for Georgia-14N compared to the untreated check. Similar to %TSMK, DVMT was affected by the interaction between cultivar and Prohexadione calcium applications. Similar to %TSMK, Georgia-12Y and Georgia-13M had lower DVMT compared to Georgia-06G and Georgia-14N within the untreated check and Georgia-06G and TUFRunner 297 within the prohexadione calcium treatment (Table 3). Dollar value per metric ton was also reduced for Georgia-

**Table 3. Cultivar Response (Percent TSMK and Value per metric ton) of utilizing prohexadione calcium applied twice at 105 g a.i./ha in two large-plot experiments on runner-type peanut cultivars at the Daryl Williams Research Farm in Colquitt County, Georgia in 2016 and 2017.**

| | %TSMK[a] | | | | $ Value/Metric Ton[b] | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivars | Non-treated Check | | Prohexadione Calcium | | Non-treated Check | | Prohexadione Calcium | |
| Georgia-06G | 77 | a[c] | 76 | a | $410 | a | $409 | ab |
| Georgia-12Y | 72 | c | 69 | c | $390 | c | $375 | d |
| Georgia-13M | 74 | b | 74 | b | $400 | b | $398 | c |
| Georgia-14N | 76 | a | 74 | b | $410 | a | $400 | bc |
| TUFRunner 297 | 76 | ab | 77 | a | $408 | ab | $410 | a |
| TUFRunner 511 | 75 | ab | 75 | ab | $403 | ab | $403 | abc |

[a]%TSMK = % total sound mature kernels (sound mature kernels + sound splits).

[b]$value per metric ton was calculated based on loan value of $4.808 times TSMK + $1.40 for each 1% change in other kernels.

[c]Means within each column followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.05$ for cultivar differences within prohexadione calcium.

**Table 4. Analysis of variance for yield, quality, and economic value response of utilizing prohexadione calcium applied twice at 105 g a.i./ha in five on-farm large-plot experiments on runner-type peanut cultivars in Early and Baker counties in Georgia in 2017 and 2018.**

| | Yield (kg/ha) | | %TSMK[a] | | $ Value/ Metric Ton[c] | | Gross $ Value/ha[d] | | Gross $/ha return above treatment cost[e] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | F | P value | F | P value | F | P value | F | P value | F | P value |
| Prohexadione Calcium | 50.8 | <0.0001 | 48.2 | <0.0001 | 48.2 | <0.0001 | 44.7 | <0.0001 | 21.1 | <0.0001 |

[a]%TSMK = % total of sound mature kernels (sound mature kernels + sound splits).

[b]%Other Kernels = percentage of kernels that fall through the sound mature kernel screen.

[c]$ value per metric ton was calculated based on loan value of $4.808 times TSMK + $1.40 for each 1% change in other kernels.

[d]Gross dollar value per hectare was calculated based on the yield (kg/ha) times the dollar value per metric ton.

[e]Dollar return per hectare above treatment cost was calculated based on the gross dollar value per hectare – cost of prohexadione calcium application.

12Y by $15.00 and Georgia-14N by $10.00 treated with prohexadione calcium compared to the non-treated control (data not shown). This reduction in yield (Georgia-14N), market grade, and DVMT are common characteristics expressed by Georgia-12Y and Georgia-14N (person communication, Monfort, 2020).

To determine the economic impact of utilizing a prohexadione calcium on peanut, GDR and GDRAT were analyzed for both the cultivar and prohexadione calcium treatments. Georgia-06G, TUFRunner 297, and TUFRunner 511 had greater GDR and GDRAT costs compared to Georgia-12Y, Georgia-13M, and Georgia-14N with Georgia 14N having the lowest overall economic return (Table 2). The evaluation of economic impact for GDR and GDRAT showed that prohexadione calcium increased the GDR by $150/ha across all cultivars; however, GDRAT was not improved (Table 2).

**On-Farm Prohexadione Calcium Experiment**

Growth regulator treatment was significant ($p<0.05$) for yield, %TSMK, DVMT, GDR, and GDRAT (Table 4). Grower application of prohexadione calcium increased yields across all locations (Table 5). Similar to the trials with cultivars, %TSMK and DVMT were reduced when prohexadione calcium was applied compared with the non-treated peanut (Table 5). Gross dollar return for prohexadione calcium across the five on-farm locations was higher when prohexadione calcium was applied compared to the non-treated peanut ($p<0.05$) (Table 5). In contrast to the cultivar by prohexadione calcium trial, GDRAT increased in the on-farm trials over that of the non-treated control (Table 5).

## Discussion and Summary

The goal of this research was to evaluate the yield response and the economic returns for utilizing prohexadione calcium at the reduced rate (105 g/ha) on runner market type peanut cultivars in large plot trials. Like with previous research (Beasley, 2004; Jordan et al., 2000), vine growth was reduced utilizing the growth regulator compared to the non-treated plots (data not shown). The results of the large–plot experiments further supported similar experiments in which significant yield responses were observed as a result of applying the prohexadione calcium (Studstill et

**Table 5. Analysis of variance for yield, quality, and economic value response of utilizing prohexadione calcium applied twice at 105 g a.i./ha in five on-farm large-plot experiments on runner-type peanut cultivars in Baker and Early counties in Georgia in 2017 and 2018.**

| Treatments | Yield (kg/ha) | | %TSMK[a] | | $ Value/ metric Ton[b] | | Gross $ Value/ha[c] | | Gross $/ha return above treatment costs[d] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Non-treated Check | 7490 | b[e] | 78.0 | a | $414 | a | $3,100 | b | $3,100 | b |
| Prohexadione Calcium | 8130 | a | 77.9 | b | $412 | b | $3,350 | a | $3,270 | a |

[a]%TSMK = total sound mature kernels (sound mature kernels + sound splits).

[b]Dollar value per metric ton was calculated based on loan value of $4.808 times TSMK.

[c]Gross dollar value per hectare was calculated based on the yield (kg/ha) times the dollar value per metric ton.

[d]Dollar return per hectare above treatment cost was calculated based on the gross dollar value per hectare – cost of prohexadione calcium application.

[e]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.05$ for prohexadione calcium treatments.

al, 2020; Treadway, 2020). Prohexadione calcium treatment increased yield by 440 kg/ha in the cultivar trials and 650 kg/ha in the on-farm trials compared to the non-treated control (Tables 2 and 5). However, it is important to note that prohexadione calcium negatively impacted both market grade (TSMK and OK) and DVMT for two of the six runner market type cultivars evaluated, and TSMK in all of the large on-farm trials. This negative impact on market grade did not support previous research where prohexadione calcium increased %TSMK and dollar value/kg in virginia market type peanut (Mitchem et al., 1996; Culpepper et al., 1997). It is also plausible that because prohexadione calcium reduces vegetative growth by inhibiting gibberellin biosynthesis, vegetative growth is reduced and the development of new pods become the primary sink for photoassimilates. More energy being translocated to reproductive tissues over time results in may have increased potential for higher percentages of OK (immature pods) in selected cultivars, thus leading to reduced DVMT. This difference observed in market grade could be due the longer maturity range for the runner market type peanut compared to the virginia market type peanut. With this in mind, cultivar growth habit (excessive vs. slow-compact vegetative growth habit) and productivity (yield potential) need to be understood before prohexadione calcium is used. Although grade and economic value were negatively impacted in select cultivars, the increase in pod yield from applying prohexadione calcium provided higher GDR across both trials and larger GDRAT in all of the large on-farm experiments. Overall, this research project further confirmed that two applications of prohexadione calcium at 105 g/ha does provide an economic return on investment for managing excessive vine growth in irrigated runner-type peanuts in Goeriga. This research also showed cultivar productivity (yield and quality) needs to be an important factor in deciding to utilize growth regulator as the costs of the product might supersede the economic return for managing the vine growth. Based on this research project and Studstill et al. (2020), prohexadione calcium will be recommended at a rate no higher than 105 g/ha and to be limited for use only on highly productive cultivars produced in fields with a history of producing excessive vine growth.

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