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Influence of Row Pattern and Prohexadione Calcium on Peanut (Arachis Hypogaea L.) Maturity and Profitability

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INFLUENCE OF ROW PATTERN AND PROHEXADIONE CALCIUM ON PEANUT MATURITY AND PROFITABILITY

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the Graduate School of
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by
Samantha Nicole Mehl
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ABSTRACT

Many newer peanut cultivars are offering growers yield benefits but have much larger canopies and are taking 10 or more days longer to reach maturity levels that were historically desired for optimal profitability out of a crop. Prohexadione calcium, a growth regulator used in peanut, and twin row planting pattern have been reported to increase the amount of orange, brown or black pods compared to their respective alternatives. Our objectives were to evaluate the maturity development in single versus twin row planted peanuts, and to evaluate how prohexadione calcium application at 0.75× the label rate will affect the maturity development and profitability of both single and twin row planted peanuts. Four cultivars were selected based on frequency of use in South Carolina then paired into an earlier maturing group that reached optimal maturity at 135 to 140 days after planting, and a later maturing group that reached optimal maturity at 150 or more days after planting.

Twin row planted plots were higher in yield and in percentage of both total sound mature kernels and orange, brown or black kernels. Twin row plots and prohexadione calcium treatment were associated with a greater frequency of pods being located closer to the taproot. When plants were manually dug and pod maturity was analyzed in the time leading up to digging, prohexadione calcium was frequently associated with an increase in the percentage of orange, brown or black pods, with this advantage being seen in sampling times ranging from 133 to 158 days after planting. Twin row plots were associated with cooler ground temperatures than single rows, while the effects of prohexadione calcium on ground temperature varied between cultivars.

DEDICATION

This thesis is dedicated to my parents, Mike and Cyndi, for unconditional love and support during this endeavor. I also dedicate this to my sister, Abby, for always being honest, encouraging, and a breath of fresh air when I needed a break from academia. I would also like to dedicate this to my partner, Jacob, who has been my rock and constant cheerleader while I completed my degree. Without the four of them, I could never have completed this.

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CHAPTER ONE

Literature Review

Section 1: Peanut

Cultivated peanut (*Arachis hypogaea* L.) is a geocarpic legume that matures underground. Peanuts are a vital crop because they possess more protein than any other culinary nut, contain more than 30 essential minerals and vitamins, and are a good source of fiber and unsaturated, or good, fat (Linton, 2023; Settaluri, 2012). In addition, regular peanut consumption can effectively prevent the onset of chronic disease like cardiovascular disease, cancer, and diabetes because the chemical composition of peanuts harbors bioactive compounds (i.e. stilbenes, lignans, and isoflavonoids) which reduce oxidative stress and inflammation caused by free radicals in the body (Çiftçi & Suna, 2022). Peanuts are very versatile and are consumed in several ways, some of those being raw, oil extracted, roasted, boiled, paste, or in energy bars and snack candies (Settaluri, 2012).

Peanut is a legume that is capable of biological nitrogen fixation, the transformation of nitrogen gas (N_2) to plant-usable ammonia (NH_3) by infection and subsequent nodulation of the roots by bacteria *Bradyrhizobium*. Peanut's ability to fix N makes it highly desirable in rotation with crops like corn (*Zea mays* L.) or cotton (*Gossypium hirsutum* L.) because it fixes N_2 into approximately 124 kg ha^{-1} soil N when planted the year prior to these crops (Jordan et al., 2009). Not only are peanuts beneficial to a producer's soil fertility, peanuts also require less water and have a smaller carbon footprint than any other nut (National Peanut Board, 2023).

The vegetation of peanut plants is also very high in nutrients needed by livestock. The chemical composition of peanut fodder is very similar to that of the highly desirable full-bloom alfalfa (*Medicago sativa* L.) (Yang, 2005), making it an important feedstuff in sub-Saharan Africa (Adda et al., 2021), semi-arid parts of Asia (Yang, 2005), and parts of the USA (Foster et al., 2011). Manure obtained from animals fed peanut fodder is also highly desirable because of the high level of N in the excrements and benefits soil fertility in a sustainable manner (Adda et al., 2021).

Section 2: Production Area

Peanuts are grown in arid and semiarid areas of Africa, Asia, Australia, and in both North and South America. The top five peanut producing countries in 2022 were China, India, Nigeria, the United States and Sudan, respectively, (FAO, 2024). According to the 2023 USDA Crop Production Summary (2024), 5,890,020,000 lbs of peanuts were harvested from 1,574,000 acres in the USA. According to the National Peanut Board (2023), peanuts have a farm value of more than $1 billion and are the seventh most valuable crop in the United States. Peanuts are grown in 13 southern and southeastern states within the United States, with the top 6 states producing over 90% of the total peanuts produced yearly, (NASS, 2024; National Peanut Board, 2020). South Carolina is the USA’s 6th largest producer of peanuts, producing between 4 to 6% of the country's peanut production yearly, (NASS, 2024).

In 2022, 77,000 acres of peanuts were planted in South Carolina, with 74,000 acres reported as harvested, which produced an average of 4,050 lbs per acre adding up to a state total of 299,700,000 lbs of peanuts, (NASS, 2024). The majority of peanuts produced in SC are grown in the central, south central and eastern parts of the state. The top two producing counties in SC in 2022 were Calhoun and Orangeburg Counties which produced 47,090,000 and 43,320,000 lbs respectively (NASS, 2024). Peanut yield and therefore profitability are influenced by many factors, with some of them being planting date, row planting pattern, irrigation, maturity, and diseases.

Section 3: Diseases

Diseases can be detrimental to peanut production. Thrips are a notable pest in peanut production because Tobacco thrips (*Frankliniella fusca* Hinds) and western flower thrips (*Frankliniella occidentalis* Pergande) both serve as vectors of *Tomato spotted wilt virus* (TSWV: Family: *Bunyaviridae*, Genus: *Tospovirus*) which causes spotted wilt (SW) of peanut (Srinivasan et al., 2017) Feeding from these insects can cause significant yield losses due to stunting of the crop (Brandenburg et al., 2019). Symptoms of SW in peanut range from asymptomatic to plant death, but include yellow ring spots, chlorotic mottling or streaking on leaves, stunting of entire plant and deformed pods, pegs, and kernels (Haynes et al., 2019). Broad spectrum insecticides like phorate, aldicarb, and acephate have commonly been used to control thrips populations (Srinivasan et al., 2017; Brandenburg et al., 2019). In addition to insecticides, SW incidence has been reported to be decreased with increased plant populations as associated with twin row planting pattern and planting in May after peak thrips populations are seen, which commonly occur in the later part of April (McKinney & Tillman, 2017; Brown et al., 2005).

Cylindrocladium black rot (CBR) is another notable peanut disease, caused by soilborne fungus *Cylindrocladium parasiticum* (Dong et al., 2008). Above ground symptoms include chlorosis and wilting of the main axis followed by wilting the remaining foliage, then plant death; below ground the root system is destroyed leaving a blackened, fragmented hypocotyl, and commonly, reddish orange perithecia appear on diseased stems just above the groundline (Johnston & Beutke, 1975). Symptoms can appear in the field as early as July (Dong et al, 2008). Fumigation with metam-sodium has been successfully used to control CBR, but it is expensive and significant management input is necessary after treatment (Dong et al., 2008) therefore most CBR management tactics are more cultural than chemical. Crop rotations of four years or more to non-hosts such as cotton (*Gossypium hirsutum* L.), corn (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench] or small grains are necessary to avoid CBR outbreaks, adding soybean [Glycine max (L.) Moench] into this rotation is not recommended because CBR is known to infect and reproduce on soybean (Shew, 2020a).

Late leaf spot (LLS) can be detrimental to a peanut field, causing severe economic losses. LLS is caused by the fungus *Nothopassalora personata,* which is able to spread through a field rapidly due to how easy it is for the spores to travel (Shew, 2020b) Spores have been reported to travel up to 70 m either via wind or splashing water from an inoculum source (Renfroe et al., 2024). LLS causes dark brown to black lesions or spots on both the upper and lower leaf surface which are sometimes surrounded by a yellow halo, the lesions on the underside of the leaf will have a dark mass of spores that give it a velvety appearance (Shew, 2020b). Severe defoliation and yield losses may occur if LLS is not controlled, making a diligent fungicide program a necessity. A fungicide program typically consists of five to seven applications per season starting at no later than 45 DAP, with multi-site chlorothalonil being one of the most commonly used fungicides for preventative management of LLS infections (Anco, 2022).

Section 4: Planting Date

Planting date is another important factor affecting peanut yield. The window to plant peanuts typically spans from late April to early-June. It has been reported that the highest yields come from stands that are planted in April or early May, and the lowest yields come from those planted in June (Carley et al., 2008; Drake et al., 2014; Branch et al., 2021). Peak thrips (*Frankliniella* spp.) populations are seen in the later part of April (Brown et al., 2005). Not only do thrips serve as a viral vector, they also injure young peanuts in a fashion that limits vegetative growth, delays pod maturation and reduces yield due to direct feeding (Mahoney et al. 2019). Tillman et al. (2007) reported that SW incidence is significantly decreased with later planting dates. Studies have reported that planting the most TSWV resistant cultivar, with irrigation, in mid-May maximized yield (Tillman et al., 2007 & Nuti et al., 2014). It is important to note that planting too late has serious disadvantages as well. Later planting dates are associated with later digging dates, which pushes the drying process into late fall, where days are shorter and cooler, and there is a higher risk of tropical storms. It has also been reported that there is an increased incidence of LLS when planting peanuts in late May into June (Nuti et al., 2014; Branch et al., 2021).

Section 5: Row Pattern

Peanut fields are normally planted in either single row or twin row arrangement on an elevated bed (Wehtje et al., 1994). Traditionally, single row plantings are spaced between 91 to 102 cm apart (Sorenson et al., 2007) and twin row plantings are spaced approximately 18 cm apart with the centers of these rows being 91 to 102 cm apart (Lanier et al., 2004). Peanut planted in twin rows has often been shown to have a yield advantage over single row planting pattern (Nuti et al., 2008; Lanier et al., 2004; Tubbs et al., 2011), likely because of the lower incidence of SW that has been associated with twin row planting (Lanier et al., 2004; Tubbs et al., 2011). Sorenson et al. (2004) reported single rows had a much lower incidence of southern stem rot (SSR), caused by soil-borne fungus *Agroathelia rolfsii* Sacc. (syn. *Athelia rolfsii*, *Sclerotium rolfsii*), than twin rows but more recent studies have not shown the same significant difference in the incidence of SSR on twin rows versus single rows (Tubbs et al., 2011).

Section 6: Irrigation

Water is a limiting factor of yield potential in peanut production. Research has shown that peanuts respond positively to irrigation (Lamb et al., 2020) and multiple studies have reported that irrigation improves yield, grade and economic return of peanuts when compared to non-irrigated peanuts (Lamb et al., 1997; Pegues et al., 2019). Irrigation has been reported to increase soil pH making nutrients such as calcium, which is critical for pod development, more readily available to the plant (Pegues et al., 2019). Irrigating peanuts has been found to have varying effects on disease incidence. Wilson and Stansell (1983) found that irrigation helped prevent the contamination of the crop by *Aspergillus flavus*, a soil borne fungi with the ability to produce aflatoxin which is one of the most potent carcinogens in food (Guo et al., 2009). Other studies have reported that irrigating peanut increases the risk of pathogenic fungi, such as peanut rust, caused by *Puccinia arachidis,* and SSR (Black et al., 2001).

Section 7: Maturity

Peanuts must be dug during the optimal window of maturity for producers to garner the highest profit from their crop. Determining the maturity status of a field can be difficult as peanuts grow in an indeterminate manner, and how quickly a field matures is influenced by various factors including market type, cultivar, and environmental factors, such as amount of precipitation and temperature during each growing season (Jordan et al., 1998). Many studies have reported inverting a crop either too early or too late leads to negative impacts on yield, flavor, market grade and profitability (Sanders et al., 1989; Wright & Porter, 1991; Jordan et al., 1998. Jordan et al., 2016). Immature peanuts have been reported to have fruity off-flavors and less of a roasted peanut taste after curing (Sanders et al., 1989). Additionally, when more immature peanuts enter storage facilities, there is an increased risk of toxic mold (*Aspergillus flavus*) production (Sorenson et al., 2015). Conversely, if a field is dug too late, yield loss is more likely to occur due to mechanical or biological damage on overmature plants with weakened or diseased pegs (Chapin & Thomas, 2005; Sorenson et al., 2015).

Williams and Drexler (1981) described the correlation between specific stages of kernel development with pod mesocarp characteristics, such as color and texture, then further detailed the temporal relationship between the various stages of development. The current industry-accepted method of evaluating the maturity status of a field and determining when to invert a field is referred to as the peanut maturity profile board. The peanut maturity profile board was created from the works of Williams and Drexler and divides each of the large color classes (white, yellow 1, yellow 2, orange, brown and black) into individual columns, in which the successive stages of development within the large classes are represented.

It is recommended that between 150 to 200 pods be collected from five to six plants in random but representative spots in a field, the pods are then exposed to rough abrasion such as high pressure washing or sand blasting to remove the tan exocarp and reveal the colored mesocarp. Each pod is then placed on its corresponding color on the maturity profile board, and the percentages of pods in each maturity class is then used to predict the optimal inversion date of a field. For Virginia market types, the maturity goal is 70% in orange, brown and black categories combined and 30% in the brown and black categories combined (Anco & Thomas, 2023). For slower maturing runner market types, the maturity goal is 60% in orange, brown and black categories combined, and for quicker maturing runner types, the maturity goal is 75-80% in the orange, brown and black categories combined (Anco & Thomas, 2023).

Section 8: Prohexadione Calcium in Peanut Production

Prohexadione calcium (PC) is a plant growth regulator used in peanut, apple (*Malus x domestica* Borkh.), pear (*Pyrus communis* L.), cherry (*Prunus avium* L.*)*, grain sorghum [*Sorghum bicolor* (L.) Moench], oilseed rape (*Brassica napus* L.), rice (*Oryza sativa* L.), tomato (*Solanum lycopersicum* L.), and wheat (*Triticum aestivum* L.) production to reduce the rate of vegetative growth (BASF, 2012 & Studstill et al., 2020). PC is a calcium salt of 3,5-dioxo-4-propionylcyclohexanecarboxylic acid ($C_{10}H_{10}CaO_5$) (NCBI, 2022) and was registered by BASF Corporation in 2000 and Fine Americas, Inc. in 2015 marketed under the trade names Apogee 27.5 WDG and Kudos 27.5 WDG respectively, for the management of excessive vegetative growth in peanut (Monfort, 2021). PC acts as a growth regulator by inhibiting the biosynthesis of gibberellin, which causes a decrease in cell elongation and a reduction in shoot growth (BASF, 2012). The inhibition of gibberellin production shortens the internodes of the stems, reducing the overall size and denseness of the canopy. In order to inhibit gibberellin synthesis, PC blocks kaurene oxidase (Chahal et al., 2012), an enzyme that catalyzes three sequential oxidations that occur in the biosynthesis of gibberellins, (Morrone et al., 2010). Additionally, PC increases levels of abscisic acid and cytokines in certain plant species (Grossman et al., 1994).

Application of a plant growth regulator has been reported to be beneficial in peanut production. Peanut is known for producing more vegetative growth than is necessary for maximum pod yield, which leads to more nutrients and photosynthates being directed to vegetative growth and maintenance instead of reproductive development (Culpepper et al., 1997). PC is commonly used on Virginia market type peanuts due to their larger canopy sizes, while it has comparatively been minimally used in runner market type production (Studstill et al., 2020). Reducing the size and denseness of the canopy allows for more air movement within the canopy (Jordan et al., 2001) and more evenly distributed foliarly-applied fungicide and insecticide spray coverage, leading to reduced diseases and insect pressure (Mitchem et al., 1996). A larger, rank canopy can also lead to decreased harvest efficiency due to the thick canopy overwhelming the inversion machinery and the rows being more difficult for a driver to distinguish upon inversion (Mitchem et al., 1996, Beam et al., 2002).

In the last decade, breeding programs have been reintroducing larger canopied runner-types, producing a need for managing excessive vine growth. Studstill et al. (2020) reported yield improvement and canopy size reduction on runner type peanuts following two applications of PC at the 0.75× label rate. Additionally, Monfort et al. (2021) reported an increase in yield after two applications of PC at the label rate, but also reported a decrease in percentage of total sound mature kernels. This was in contrast to early reports, in which Culpepper et al. (1997) reported a 9% and Mitchem et al. (1996) reported a 19% increase in the percent of orange, brown or black pods near harvest when treated with PC.

Section 9: Closing

Several researchers have evaluated the effects of PC single row planted peanuts over the years in peanut literature (Mitchem et al., 1996; Culpepper et al., 1997; Beam et al., 2002; Jordan et al., 2008; Studstill et al., 2020; Monfort et al., 2021), but little is known about the effects of PC on twin row planted fields, especially when it comes to runner types. Faircloth et al. (2005) found inconsistent results after evaluating the effects of prohexadione calcium on single versus twin row planting arrangements using now out of production Virginia types. Further, reports of maturity development for single rows versus twin rows is lacking even with no growth regulator treatment.

Early reports on prohexadione calcium suggested the growth regulator potentially hastened maturity in Virginia type peanuts. Culpepper et al. (1997) reported a 9%, while Mitchem et al. (1996) reported a 19% increase in the percent of orange, brown or black pods near harvest when treated with prohexadione calcium. Nevertheless, cultivars that were used in these studies are no longer commercially grown (AT VC 1, NC 9, NC 10C, NC-V 11, VA-C 92R). Therefore, research was conducted to evaluate the independent and combined effects of prohexadione calcium and row pattern on the maturity development and profitability of peanut, specifically with respect to newer runner cultivars.

Objectives

The first objective of this project was to evaluate the maturity development of single versus twin row planted peanuts. The second objective of this project was to evaluate both the maturity development and profitability of both single and twin row planted peanuts treated with prohexadione calcium at 0.75 × the label rate.

Literature Cited

Adda, K., Addah, W., Rahman, N. A., & McAllister, T. A. 2021. Inter-row plant spacing effects on grain and fodder yields, growth performance, digestibility and manure quality of sheep. *Peanut Science, 48*(2), 144–152.

Anco, D. J. 2023. Peanut disease management. Peanut money-maker 2023 production guide: 44-55

Anco, D. J. & Thomas, J. S. 2023. Determining Harvest Maturity. Peanut money-maker 2023 production guide: 62-63

BASF. 2012. *Apogee: Plant growth regulator booklet*. Ontario, Canada.

Beam, J. B., Jordan, D. L., York, A. C., Isleib, T. G., Bailey, J. E., McKemie, T. E., Spears, J. F., & Johnson, P. D. 2002. Influence of prohexadione calcium on pod yield and pod loss of peanut. *Agronomy Journal, 94(2),* 331–336.

Black, M. C., Tewolde, H., Fernandez, C. J., & Schubert, A. M. 2001. Seeding rate, irrigation, and cultivar effects on tomato spotted wilt, rust, and southern blight diseases of peanut. *Peanut Science, 28(1)*: 1–4.

Branch, W. D., Brown, N., Mailhot, D. J., Culbreath, A. K. 2021. Relative tomato spotted wilt incidence and field performance among peanut cultivars as influenced by different input production practices in Georgia.. *Peanut Science, 48(2),* 118–122.

Brandenburg, R. L., Jordan, D. L., Royals, B. R., Mahoney, D. J. & Johnson, P. D. 2019. Utilization of imidacloprid to control thrips in peanut in North Carolina. *Peanut Science, 46(1)* 8-13.

Brown, S. L., Culbreath, A. K., Todd, J. W., Gorbet, D. W., Baldwin, J. A., & Beasley, J. P. 2005. Development of a method of risk assessment to facilitate integrated management of spotted wilt of peanut. *Plant Disease, 89(4),* 348–356.

Carley, D. S., Jordan, D. L., & Dharmasri, L. C. 2008. Peanut response to planting date and potential of canopy reflectance as an indicator of pod maturation. *Agronomy Journal, 100(2),* 376–380.

Chahal, G. S., Jordan, D. L., Brandenburg, R. L., Shew, B. B., Burton, J. D., Danehower, D., & York, A. C. 2012. Interactions of agrochemicals applied to peanut; part 3: Effects on insecticides and prohexadione calcium. *Crop Protection, 41,* 150–157.

Chapin, J. W., & Thomas, J. S. 2005. Effect of fungicide treatments, pod maturity, and pod health on peanut peg strength. *Peanut Science,* 3*2(2),* 119–125.

Çiftçi, S., & Suna, G. 2022. Functional components of peanuts (*Arachis hypogaea* L.) and health benefits: A review. *Future Foods*, *5*, 100-140.

Crop Production - 2023 Summary. 2024. In *USDA Economics, Statistics, and Market Information System* (ISSN: 1057-7823). National Agricultural Statistics Service (NASS), United States Department of Agriculture.

Culpepper, A. S., Jordan, D. L., Batts, R. B., & York, A. C. 1997. Peanut response to prohexadione calcium as affected by cultivar and digging date. *Peanut Science, 24(2),* 85–89.

Dong, W. B., Brenneman, T. B., Holbrook, C. C., & Culbreath, A. K. 2008. Evaluation of resistance to *Cylindrocladium parasiticum* of runner-type peanut in the greenhouse and field. *Peanut Science, 35(2),* 139-148.

Drake, W. L., Jordan, D. L., Johnson, P. D., Shew, B. B., Brandenburg, R. L., & Corbett, T. 2014. Peanut response to planting date, tillage, and cultivar in North Carolina. *Agronomy Journal, 106(2),* 486–490.

Faircloth, J. C., Coker, D. L., Swann, C., Mozingo, W., Phipps, D. L., & Jordan D. L. 2005. Response of four virginia-type peanut cultivars to prohexadione calcium as affected by cultivar and planting pattern. Peanut Science, 32 (1): 42-47.

Food and Agriculture Organization of the United Nations (FAO). 2024. FAOSTAT: Production: Countries by Commodity. Online. http://www.fao.org/faostat/en/#rankings/countries_by_commodity

Foster, J. L., Carter, J., Sollenberger, L. E., Blount, A. R., Myer, R. O., Maddox, M. K., Phatak, S. C., & Adesogan, A. 2011. Nutritive value, fermentation characteristics, and in situ disappearance kinetics of ensiled warm-season legumes and bahiagrass. *Journal of Dairy Science, 94(4),* 2042–2050.

Grossman, K., Koenig, K. S., & Kwiatkowski, J. 1994. Phytohormonal changes in intact shoots of wheat and oilseed rape treated with the acylcyclohexanedione growth retardant prohexadione calcium. *Physiologia Plantarum 90* (1): 139–143.

Guo, B., Yu, J., Holbrook, C. C., Cleveland, T. E., Nierman, W. C., & Scully, B. T. 2009. Strategies in prevention of preharvest aflatoxin contamination in peanuts: Aflatoxin biosynthesis, genetics and genomics. *Peanut Science, 36(1)*, 11–20.

Haynes, J. M., Smith, N., Culbreath, A. K., Kirk, K. R., & Anco, D. J. 2019. Effects of insecticides applied with in-furrow with superabsorbent polymer on peanut cultivars infected with tomato spotted wilt virus. *Peanut Science, 46(2),* 127-139.

Johnston, S. A., & Beute, M. K. 1975. Histopathology of Cylindrocladium. *Phytopathology*, *65*, 649-653.

Jordan, D. L., Spears, J. F., & Sullivan, G. A. 1998. Influence of digging date on yield and gross return of Virginia-type peanut cultivars in North Carolina. *Peanut Science*, *25(1)*, 45-50.

Jordan, D. L., Beam, J. B., Johnson, P. D., & Spears, J. F. 2001. Peanut response to prohexadione calcium in three seeding rate–row pattern planting systems. *Agronomy Journal*, *93(1)*, 232–236.

Jordan, D. L., Nuti, R. C., Beam, J. B., Lancaster, S. H., Lanier, J. E., Lassiter, B. R., & Johnson, D. E. 2008. Peanut (Arachis hypogaea L.) cultivar response to prohexadione calcium. Peanut Science, 35(2): 101-107.

Jordan, D. L., Barnes, J. S., Corbett, T., Bogle, C. R., Marshall, T., & Johnson, D. T. 2009. Influence of crop rotation on peanut (*Arachis hypogaea* L.) response to *Bradyrhizobium* in North Carolina. *Peanut Science*, *36(2)*, 174–179.

Jordan, D. L., Shew, B. B., & Johnson, D. J. 2016. Response of peanut cultivar (*Arachis hypogaea* L.) cultivar Gregory to interactions of digging date and disease management. *Advances in Agriculture*, *2016*, 1–9.

Lamb, M. C., Davidson, J., Childre, J. W., & Martin, N. G. 1997. Comparison of peanut yield, quality, and net returns between nonirrigated and irrigated production. *Peanut Science*, *24(2)*, 97–101.

Lamb, M. C., Sorensen, R. B., & Butts, C. L. 2020. Agronomic and economic effects of irrigation and rotation in peanut-based cropping systems. *Peanut Science, 47(3),* 173-179.

Lanier, J. E., Jordan, D. L., Spears, J. F., Wells, R., Johnson, P. D., Barnes, J. S., Hurt, C. A., Brandenburg, R. L., & Bailey, J. E. 2004. Peanut response to planting pattern, row spacing, and irrigation. *Agronomy Journal*, *96*(4), 1066–1072.

Linton, J. 2023. Peanut nutrition 101. National Peanut Board. Retrieved October 25, 2023, from https://nationalpeanutboard.org/news/peanut-nutrition/

Mahoney, D. J., Jordan, D., Brandenburg, R. L., Shew, B. B., Royals, B., Inman, M. D., & Hare, A. T. 2019. Influence of planting date, fungicide seed treatment, and phorate on peanut in North Carolina. *Peanut Science, (46)1,* 14-21.

McKinney, J., & Tillman, B. L. 2017. Spotted wilt in peanut as impacted by genotype resistance, planting date, and plant population. *Crop Science*, *57*(1), 130–136.

Mitchem, W. E., York, A. C., & Batts, R. B. 1996. Peanut response to prohexadione calcium, a new plant growth regulator. *Peanut Science*, 23(1), 1–9.

Monfort, W. S., Tubbs, R. S., Cresswell, B., Jordan, E., Smith, N., & Luo, X. L. 2021. Yield and economic response of peanut (*Arachis hypogaea* L.) cultivars to prohexadione calcium in large-plot trials in Georgia. *Peanut Science, 48(1),* 15-21.

Morrone, D., Chen, X., Coates, R. M., & Peters, R. J. 2010. Characterization of the kaurene oxidase CYP701A3, a multifunctional cytochrome P450 from gibberellin biosynthesis. *The Biochemical Journal, 431(3),* 337–344.

National Center for Biotechnology Information (NCBI). 2023. PubChem Compound Summary for CID 12001831, Prohexadione calcium. Retrieved October 12, 2022 from https://pubchem.ncbi.nlm.nih.gov/compound/Prohexadione-calcium.

National Peanut Board. 2020. Peanut Country, U.S.A. Online. https://www.nationalpeanutboard.org/peanut-info/peanut-country-usa.htm

National Peanut Board. 2023. Peanuts are the crop of now: The future of sustainable farming. https://nationalpeanutboard.org/news/peanuts-are-crop-now/#:~:text=Peanuts%20are%20nature%E2%80%99s%20%E2%80%9Czero%20waste%E2%80%9D%20plant%2C%20meaning%20from,ability%20to%20improve%20soil%20and%20benefit%20other%20crops.

Nuti, R. C., Faircloth, W. H., Lamb, M. C., Sorenson, R. B., Davidson, J. I., & Brenneman, T. B. 2008. Disease management and variable planting patterns in peanut. *Peanut Science, 35*(1), 11-17.

Nuti, R. C., Chen, C., Dang, P. M., & Harvey, J. T. 2014. Peanut cultivar response to tomato spotted wilt over five planting dates. *Peanut Science, 41*(1), 32–41.

Pegues, K., Tubbs, R. S., Harris, G., & Monfort, W. S. 2019. Effect of calcium source and irrigation on soil and plant cation concentrations in peanut (*Arachis hypogaea* L.). *Peanut Science*, *46*(2), 206–212.

Renfroe-Becton, H., Kirk, K. R., & Anco, D. J. 2024. Measuring the distance and effects of weather conditions on the dispersal of Nothopassalora personata. Phytopathology, 114(3); 549-557.

Sanders, T. H., Vercellotti, J. R., Blankenship P. D., Crippen, K. L., & Civille, G. V. 1989. Interaction of maturity and curing temperature on descriptive flavor of peanuts. Journal of Food Science 54 (4): 1066-1069.

Settaluri, V. S., Kandala, C. V. K., Puppala, N., & Sundaram, J. 2012. Peanuts and their nutritional aspects—A review. *Food and Nutrition Sciences*, *3*(12), 1644–1650.

Shew, B. 2020a. *Cylindrocladium black rot of peanut*. NC State Extension. https://content.ces.ncsu.edu/cylindrocladium-black-rot-of-peanut#:~:text=Planting%20a%20resistant%20cultivar%20often%20is%20all%20that,cultivars%20in%20fields%20with%20a%20history%20of%20CBR.

Shew, B. 2020b. *Peanut leaf spots*. NC State Extension. https://content.ces.ncsu.edu/early-leaf-spot-of-peanut-1

Sorenson, R. B., Sconyers, L. E., Lamb, M. C., & Sternitzke, D. A. 2004. Row orientation and seeding rate on yield, grade, and stem rot incidence of peanut with subsurface drip irrigation. *Peanut Science, 31(1),* 54-58.

Sorenson, R. B., Lamb, M. C., & Butts, C. L. 2007. Peanut response to row pattern and seed density when irrigated with subsurface drip irrigation. *Peanut Science*, *34*(1), 27–31.

Sorenson, R. B., Lamb, M. C., & Butts, C. L. 2015. Can peg strength be used as a predictor for pod maturity and peanut yield? *Peanut Science*, *42(2)*, 92–99.

Srinivasan, R., Abney, M. R., Culbreath, A. K., Kemerait, R. C., Tubbs, R. S., Monfort, W. S., & Pappu, H. R. 2017. Three decades of managing tomato spotted wilt virus in peanut in southeastern United States. *Virus Research*, *241*, 203–212.

Studstill, S. P., Monfort, W. S., Tubbs, R. S., Jordan, D. L., Hare, A. T., Anco, D. J., Sarver, J. M., Ferguson, J. C., Faske, T. R., Creswell, B. L., & Tyson, W. G. 2020. Influence of prohexadione calcium rate on growth and yield of peanut (*Arachis hypogaea*). *Peanut Science, 47(3),* 163–172.

Tillman, B. L., Gorbet, D. W., & Andersen, P. 2007. Influence of planting date on yield and spotted wilt of runner market type peanut. *Peanut Science, 34(2),* 79–84.

Tubbs, R. S., Beasley, J. P., Culbreath, A. K., Kemerait, R. C., Smith, N. B.,& Smith A. R. 2011. Row pattern and seeding rate effects on agronomic, disease, and economic factors in large-seeded runner peanut. *Peanut Science*, 38 (2), 93–100.

United States Department of Agriculture, National Agricultural Statistics Service (NASS). 2024. Quick Stats. Online. https://quickstats.nass.usda.gov/

Wehtje, G., Weeks, R., West, M., Wells, L., & Pace, P. 1994. Influence of planter type and seeding rate on yield and disease incidence in peanut. *Peanut Science, 21 (1),* 16–19.

Williams, E.J., & Drexler, J.S. 1981. A Non-Destructive Method for Determining Peanut Pod Maturity. *Peanut Science, 8*(2), 134-141.

Wilson, D. M., & Stansell, J. R. 1983. Effect of irrigation regimes on aflatoxin contamination of peanut pods. *Peanut Science, 10(2)*: 54–56.

Wright, F. S. & Porter, D. M. 1991. Digging date and conservational tillage influence on peanut production. Peanut Science 18 (2): 72-75.

Yang, C. 2005. Proteolysis, fermentation efficiency, and in vitro ruminal digestion of peanut stover ensiled with raw or heated corn. *Journal of Dairy Science*, *88*(8), 2903–2910.

CHAPTER TWO

INFLUENCE OF ROW PATTERN AND PROHEXADIONE CALCIUM ON PEANUT (ARACHIS HYPOGAEA L.) MATURITY AND PROFITABILITY

Introduction

Harvesting peanut when the highest percentage of pods are at optimal maturity is critical for growers to attain the highest profit from their crop. For the past two decades, most growers have been using the hull scrape method in conjunction with methods akin to the maturity profile board, employing the correlation between pod maturity and mesocarp color to project optimal harvest time (Williams and Drexler, 1981; Colvin et al., 2014). Predicting maturity in peanut can be difficult as peanut grows in an indeterminate manner, and how quickly a field matures is highly influenced by the amount of rainfall and the temperature during each growing season (Jordan et al., 1998). Inverting a crop too early or too late leads to negative impacts on yield, market grade and profitability (Mozingo et al., 1991; Wright & Porter, 1991; Jordan et al., 1998. Jordan et al., 2016). Digging a crop early additionally leads to more immature peanuts entering storage facilities which may increase the risk of toxic mold (*Aspergillus flavus)* production (Sorenson et al., 2015). Immature peanuts have also more commonly been reported to develop fruity off-flavors and less roasted peanut flavor after being cured (Sanders et al., 1989; Sanders et al., 1990). Conversely, when a field is dug too late, yield loss can increase due to mechanical or biological damage on overmature plants with weakened or diseased pegs (Chapin & Thomas, 2005; Sorenson et al., 2015).

Many recently released cultivars offer growers yield benefits and improved disease resistance packages when compared to their predecessors (Anco & Heirs, 2022). However, many of these newer cultivars have also taken between 10 to 15 days longer to reach pod maturity levels comparable to those traditionally considered optimal (i.e., >75% mature pods, Boote 1982) to serve as a target for inversion (Anco et al., 2024). This has in recent years resulted in newer cultivars Georgia 16HO, FloRun 331, and TUFRunner 297 being given 150 or more days after planting (DAP) to approach pod maturity levels that older and earlier maturing cultivars Georgia 06G and Georgia 09B generally obtain in 140 or 135 DAP, respectively (Anco et al., 2024).

There are several yield-limiting fungal diseases that can potentially cause significant economic losses in peanut production. In South Carolina, late leaf spot, caused by *Nothopassalora personata* ((Berk & M.A. Curtis) S.A. Kahn &M. Kamal), is the most consistent cause of economic losses among fungal pathogens (Anco, 2023). In order to manage late leaf spot, it is recommended that commercial growers initiate a fungicide application program beginning at 30 DAP and consisting of five to seven applications in 14-day intervals (Anco, 2023). When a growing season is extended into October and November to allow a maturing crop to reach optimal maturity, cooler temperatures and shorter days become more favorable for late leaf spot (Alderman & Nutter, 1994) and other late-season diseases (Davidson et al., 1991), causing many producers to apply one more fungicide spray to extend protective coverage. If this late season fungicide spray could be avoided, it could increase revenue by ~$15 per hectare, not including equipment or labor. Another added risk of late season harvest is the increased risk of slower drying conditions and frost damage after inversion (Jordan et al., 2019), both of which can lead to the crop being graded as segregation II. Segregation II peanuts have no visible *Aspergillus flavus* mold but over 3.49 % damaged kernels, including physical, concealed (i.e. mold or decaying kernels) or freeze damage (American Peanut Shellers Association, 2020). If yield potential could be maintained while maturity was simultaneously hastened, this would save time and revenue for growers.

Peanuts are commonly planted in either single row (91 to 102 cm apart) or twin row arrangement (18 cm between two rows of peanuts, on 91 to 102 cm centers), often on an elevated bed (Wehtje et al., 1984; Lanier et al., 2004; Sorenson et al., 2007). Planting in twin rows versus single rows increases the plant population from 19 seeds per meter in single rows to 23 seeds per meter spread between two rows, which effectively decreases the intra-row competition while also increasing plant populations (Sorenson et al., 2004). Previous research has consistently shown that there is a significant yield advantage when peanuts are planted in a twin row arrangement (Wehtje et al., 1984; Lanier et al., 2004; Tillman et al., 2006; Nuti et al., 2008; Tubbs et al., 2011). The amount of thrips injury and tomato spotted wilt (TSW) infection that typically follows thrips infestations has repeatedly been reported to be reduced in twins compared to single rows (Baldwin et al., 2001; Culbreath et al., 2008; Tubbs et al., 2011). Several studies have also reported higher market grades (total sound mature kernels; TSMK) when peanut is planted in twin rows (Sorenson et al., 2004; Lanier et al., 2004; Sorenson et al., 2007).

Twin row configuration reduces the time normally required for peanut to lap the row. This earlier shading of the ground aids in reducing soil geocarposphere temperatures. Davidson et al., (1991) reported a reduction in premium priced kernels when severe drought and high geocarposphere temperatures lead to a delay in fruit initiation; additionally, high geocarposphere temperatures were typically associated with a smaller canopy, reduced yield, and poorer quality. A delay in fruit initiation can lead to an increased limb crop (addition of small pods away from the taproot) instead of a taproot crop (addition of large pods near the taproot) (Davidson et al., 1991). Being set first, a taproot crop will mature earlier than a limb crop. Encouraging more of a tap root focused crop and less of a limb crop potentially may hasten maturity and produce a more uniform maturity, due to optimal maturity applying more to one crop rather than the balance between two crops (i.e. taproot versus limb crop) that have begun to be set at different points in the season. However, the distribution of pods produced in association with a taproot versus limb crop and the maturity development of produced pods have not been quantitatively reported for twin versus single row planting configurations.

Peanuts have been reported to produce more vegetative growth than necessary to reach maximum pod yield, where nutrients and photosynthate are directed to vegetative growth instead of developing pods (Mitchem et al., 1996). Excessive vine growth leads to decreased disease resistance (Phipps, 1995), and a dense canopy will inhibit pesticides from contacting lower leaves (Mitchem et al., 1996). A larger canopy has been reported to decrease inversion and harvest efficiency (Beam et al., 2002). Classic runner type peanuts, such as the widely used cultivar Georgia 06G (Branch, 2007), grow a smaller and more compact canopy. Virginia market types like Bailey II characteristically exhibit a larger and more robust canopy which intertwines among adjacent rows and can make digging without GPS assistance more difficult due to reduced visual distinction of rows (Beam et al., 2002). Plant growth regulators have been studied and employed for decades to manage excessive vine growth in peanut, with most studies focusing on Virginia-types due to their larger canopies.

Prohexadione calcium (a calcium salt of 3,5-dioxo-4 propionylcyclohexanecarboxylic acid) is a plant growth regulator used in the production of peanut, apple (*Malus x domestica* Borkh.), pear (*Pyrus communis* L.), cherry (*Prunus avium* L.*)*, grain sorghum [*Sorghum bicolor* (L.) Moench], oilseed rape (*Brassica napus* L.), rice (*Oryza sativa* L.), tomato (*Solanum lycopersicum* L.), and wheat (*Triticum aestivum* L.) to decelerate the rate of vegetative growth (Yamaji et al., 1991, BASF, 2012; Nakayama et al., 1992; Grossman et al., 1994; Mitchem et al. 1996; Lee et al., 1998; Byers and Yoder, 1999). Prohexadione calcium inhibits the biosynthesis of plant hormone gibberellin, which causes a reduction in shoot growth and decreased cell elongation (Grossman et al., 1994; BASF, 2012). Prohexadione calcium inhibits gibberellin biosynthesis by blocking kaurene oxidase and increases the level of abscisic acid and cytokines in certain species (Grossman et al., 1994).

In the last decade, breeding programs have released runner type peanut cultivars with larger canopies, producing a need for managing excessive vine growth. More recent studies have reported yield improvement and canopy size reduction on runner type cultivars following the application of prohexadione calcium at a 0.75× rate (Studstill et al., 2020 & Monfort et al., 2021). Early studies of prohexadione calcium demonstrated a significant increase in the earliness of Virginia type cultivars. Culpepper et al. (1997)

reported a 9% increase, while Mitchem et al. (1996) reported a 19% increase in the percent of orange, brown or black pods near harvest when treated with prohexadione calcium. Nevertheless, cultivars that were used in those studies (AT VC 1, NC 9, NC 10C, NC-V 11, and VA-C 92R) are no longer commercially grown.

Information regarding the effect of prohexadione calcium on the maturity of newer cultivars is lacking. Additionally, most research that has involved prohexadione calcium has either evaluated single row planted or Virginia market type peanuts. Therefore, research was conducted to evaluate the combined and independent effects of prohexadione calcium and row pattern on the maturity development and profitability of peanut in South Carolina, specifically with respect to newer runner cultivars.

MATERIALS AND METHODS

Field experiments were conducted during the 2021 and 2022 growing seasons in different fields at Clemson University's Edisto Research and Education Center (EREC; 33.3648N, -81.3298E) in Blackville, SC on a Barnwell loamy sand (fine-loamy, kaolinitic, thermic Typic Kanhapludults) and at Pee Dee Research and Education Center (PDREC; 34.2898N, -79.7388E) in Florence, SC on a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults). Plot dimensions consisted of four rows wide (3.9 m) by 30.5 m in length, which were separated into two yield rows and two traffic rows. Yield rows were used for data collection while traffic rows were used to drive over to apply prohexadione calcium and maintenance agrochemicals. A split plot experimental design was utilized, with the interaction of row pattern and growth regulator application as the main plot and cultivar as the sub plot. Treatments were replicated five (EREC: 2021 and 2022; PDREC: 2021) or four times (PDREC: 2022). Single rows were spaced 96-cm apart and planted at a rate of 19 seeds per m, while twin rows were spaced 18-cm apart on 96-cm centers and planted at a rate of 23 seeds per m.

Three runner-type cultivars and one Virginia type cultivar were selected based on frequency of use by SC farmers and desired optimal maturity requirements. Cultivars were then paired into separate experiments based on maturity - earlier maturing cultivars (E, i.e., ~138 to 140 DAP) and later maturing cultivars (L, i.e., ~145 to 150 DAP). In 2021, planted cultivars were Bailey II (E), Georgia 06G (E), FloRun 331 (L) and Georgia 16HO (L). The later maturing experiment was planted at EREC on 10 May and earlier maturing experiment was planted 11 May. All cultivars were planted at PDREC on 1 June. In 2022, cultivars included Emery (E), Georgia 06G (E), FloRun 331 (L) and Georgia 16HO (L); EREC was planted on 5 May, and at PDREC twin rows were planted on 18 May and single rows were planted the following day, 19 May.

In 2021, SW incidence was evaluated at 69 (E) and 70 (L) DAP (19 July) at EREC and at 65 DAP (5 August) at PDREC. In 2022, SW incidence was evaluated at 74 DAP (18 July) at EREC and at 61 (single rows) and 62 (twin rows) DAP (19 July) at PDREC. SW incidence was rated using methodology previously detailed in Haynes et al. (2019). Late leaf spot (LLS) was measured as percentage incidence prior to inversion following its development in the field where applicable. If any defoliation from LLS was seen, it was recorded as a percentage as well.

Canopy temperature at ground level was measured in 15 minute intervals using RC-5 USB temperature loggers. Loggers were installed at approximately 35 to 40 DAP, once the crop was large enough to begin shading the ground. Loggers were placed into a plastic bag to protect them from the elements, then installed approximately 25 cm off center from planted row. Daytime temperatures were approximately defined as those occurring from 6:00 am to 7:00 pm. When 50% of the lateral vines from adjacent rows began touching (i.e., 50% row lap), prohexadione calcium was applied at 0.75× the label rate, with a second application applied 14 days later, using a tractor mounted boom sprayer with two DG 8002 nozzles/row delivering 140 L/ha at 345 kPa. Per the prohexadione calcium label, crop oil concentrate and ammonium sulfate were applied with the growth regulator at respective rates of 2.33 L/ha and 1.17 L/ha.

Following prohexadione calcium application, row visibility was visually assessed using a 1 to 10 scale, with 1 being a flat canopy and 10 being a triangular canopy (Mitchem et al., 1996). Main stem height from four plants per plot were measured in addition to row visibility. In 2021, main stem heights and row visibility was assessed at 139 (E) and 140 (L) DAP (27 September) at EREC and 139 DAP (18 October) at PDREC. In 2022, row visibility was assessed at 134 DAP (16 September) at EREC and 128 (twin rows) and 127 (single rows) DAP (23 September) at PDREC. Plots were dug based on pod mesocarp color (William & Drexler, 1981) at a time reasonable for each experiment. Peanut production management practices followed Clemson University Extension recommendations (Anco, 2021).

In 2021, plots were inverted on 20 October (PDREC), 28 September (EREC E group), and 5 October (EREC L group); then combined on 18 November (PDREC), 11 October (EREC E group) and 18 October (EREC L group). In 2022, plots were inverted on 6 October (PDREC), 23 September (EREC E group), and 3 October (EREC L group); then combined on 19 October (PDREC), 28 September (EREC E group) and 17 October (EREC L group). Pod yield (kg/ha) data was collected from two rows per plot with a Hobbs 2-row combine using load cells mounted to the weight basket of the combine. A 500-g subsample of peanuts was collected from plots located at EREC and graded according to USDA standards. Grade and pod yield data was then used to calculate economic values, calculated as treatment net loan value × treatment yield – treatment costs. Net loan values were calculated using the following formulae (Haynes et al., 2019; USDA FSA 2019):

Runner net loan value =

$$(\%TSMK \times Loan\ Rate\ per\ \%TSMK) + (\%OK \times Loan\ Rate\ per\ \%OK) - deductions$$

Virginia net loan value =

$$(\%TSMK \times Loan\ Rate\ per\ \%TSMK) + (\%OK \times Loan\ Rate\ per\ \%OK) + (\%ELK \times Loan\ Rate\ per\ \%ELK) - deductions$$

where TSMK is total sound mature kernels, OK is other kernels, and ELK is extra-large kernels. Loan rates for 2021 were \$5.308 (% TSMK for runner market types), \$5.414 (%

TSMK for Virginia market types), $1.544 (% OK), and $0.386 (% ELK) (USDA FSA 2021). Loan rates for 2022 were $5.281 (%TSMK for runner market types), $5.387 (% TSMK for Virginia market types), $1.544 (% OK), and $0.386 (% ELK) (USDA FSA 2021). Deductions were $0.88 for each percent of sound splits over 4%. Listed loan rates and deductions correspond to pod yield in units of 1,000 kg/ha. Treatment costs were obtained from the 2022 South Carolina Agronomic Crop Production Budget. Local treatment costs for prohexadione calcium was $40.31 per hectare for both twin and single row planting pattern. Inoculant cost per hectare was $46.68 and $93.37 for single and twin row pattern respectively. Phorate cost per hectare was $41.57 and $53.06 for single and twin rows, respectively.

Image Analysis

To measure maturity development, pods from six plants per plot were collected from traffic rows, and the pod exocarp was removed by placing the sample in a rotating bucket then pressure washing the sample for 6-8 minutes to expose the pod mesocarp color. The sample was then transferred to a large tray and busted pods, rocks, pegs, and other foreign material were manually removed. An image was then taken of each sample, to categorize pods by mesocarp color (i.e., % white, yellow, orange, brown and black pods) using Batch Load Image Processor v1.1 (BLIP; Anco et al., 2024; Kirk, 2020; Renfroe-Becton et al., 2022).

Limb crop versus taproot crop distribution was determined at inversion by photographing ten inverted peanut plants per plot at Blackville. Photographs were then processed using Peanut Limb Crop Analyzer (Kirk, unpublished), which analyzed the distribution of the pods from the center of the taproot, from which radii corresponding to 73-75% pod pixel mass per photograph were measured. To examine pod pixel distribution densities across a range of pixel masses, pod pixel radius ratios per image were calculated as the proportion of pod pixel radii at 10%-intervals from 10 to 90% of the corresponding total pod pixel radius (upper limit of ~98.5%) / total pod pixel radius.

On-Farm Trials

During both 2021 and 2022, on farm experiments were conducted. In 2021 there was one field trial located in Orangeburg County and in 2022 there were three field trials located in Bamberg County. In 2021, cultivar TUFRunner 297 was planted in twin row arrangement and a randomized complete block design was utilized. In 2022, cultivar Georgia 16HO was planted in twin row arrangement at all three fields. Treatments consisted of prohexadione calcium at a 0.75× label rate, and a non-treated control in all experiments. Yield and maturity information from 2021 was obtained from the buying point. In 2022, samples of three to five plants per field per treatment were manually dug in biweekly intervals to track maturity development in the weeks leading up to digging. Maturity samples were then processed as previously described for EREC and PDREC experiments.

Data Analysis

Treatment effects for TSW, row visibility, main stem heights, maturity, pod density, yield, grade and economic value were analyzed using generalized linear mixed modeling (GLIMMIX procedure) with SAS 9.4 (SAS Institute, Cary, NC). Replication was considered a random effect. The random effect of the main plot error term was examined but removed from the model due to lack of model improvement. Analyses conducted across experiments additionally included random effects for experiment (i.e., location-year) and replication within experiment. Fixed effects included cultivar, row pattern, prohexadione calcium application, and interactions thereof. Response variable data were modeled using a beta (pod maturity), Gaussian (TSMK), or negative binomial (row visibility, plant height, SW incidence, pod distribution, yield, and economic value) distribution, with distributional appropriateness assessed through residual plots and information criterion (i.e., Akaike's Information Criterion). To account for day-to-day variation during continued sampling of each logger while deployed in field plots, the model for average daytime canopy ground temperature incorporated day of measurement into the residual error term (i.e., residual error term = date × pattern × prohexadione calcium application × cultivar × replicate), in addition to a random effect term for experiment and a gamma distribution. In addition to the fixed effects listed for earlier-mentioned models, models for temperature included a term for the approximate point of 50% rows lapped to allow for examination of effects and interactions before and after this stage of growth. Pod pixel ratio data were analyzed using glmmTMB (Brooks et al., 2017) in R 4.3.3 (R Core Team 2023) according to a beta distribution where fixed effects included cultivar, prohexadione calcium application, pattern, proportion of total pod pixels and interactions thereof. Random effects for pod pixel ratio models included the interaction of replicate within experiment and a term for proportion of total pod pixels within each photograph per experiment as specified according to an unstructured or reduced rank covariance structure, respectively. Estimated treatment means were separated at α = 0.10.

RESULTS

Early maturing experiment. Spotted wilt incidence was significantly greater among single rows compared to twins at Blackville in both 2021 and 2022 (P = 0.0051 and P = 0.038 respectively). Conversely, no significant differences between row patterns or cultivars were seen at Florence in either year. Spotted wilt incidence of all treatments was less than 5%, with pooled results across years reported in Table 1. Row visibility was significantly greater following the application of prohexadione calcium at 0.75× (P = 0.0005), indicating prohexadione calcium made the canopy more triangular. Though single row planting pattern often had a numerical advantage in row visibility over twin rows, this was only significant in Blackville in 2021 (P = 0.0085). Main stem heights of both single and twin row planted plots treated with prohexadione calcium were significantly shorter than those of untreated plots (P < 0.0001). Main stem heights of twin rows were taller than those of single rows (P < 0.0001).

Table 1. Influence of row pattern on the percentage of spotted wilt incidence from experiments conducted in 2021 and 2022.

	Blackville[a]		**Florence**	
	Single	**Twin**	**Single**	**Twin**
Early group	2.9 a	1.6 b	2.1	2.3
Later group	2.9 a	1.8 b	3.4	3.1

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected-LSD at α = 0.10.

In 2021 maturity samples were dug at 121, 133 and 140 DAP. Twin row planting pattern exhibited a significantly greater percentage of orange, brown, or black (OBB) pods when compared to corresponding single row plots (57% vs 52%, respectively, $P = 0.0393$). In 2022, samples were dug at 125, 132 and 144 DAP. In 2022, no treatment effects were found to significantly influence the percentage of OBB pods. When results were pooled across years, twin row plots again had a significantly greater percentage of OBB pods than single row plots (67% vs. 63%, respectively, $P = 0.0038$). Maturity values significantly varied at the row pattern × growth regulator × cultivar × sample DAP level ($P = 0.0481$), with interactions likewise being significant within the Georgia 06G ($P < 0.0001$) and Virginia cultivar data ($P = 0.0015$) (Table 2). Among Georgia 06G samples, twin rows treated with prohexadione calcium exhibited pod maturity at 133 DAP (71%) not different from those in the upper statistical grouping for maturity from samples collected at 140 DAP (67 to 74%). With respect to Virginia cultivar samples at 133 DAP, only those from single rows without prohexadione calcium treatment (59%) did not exhibit pod maturity comparable to those in the upper statistical grouping among samples from 133 and 140 DAP (69 to 73%).

Table 2. Influence of row pattern and prohexadione calcium application on % orange, brown or black (OBB) pod maturity's from earlier maturing cultivars from pooled experiments conducted in 2021 and 2022**.**

Cultivar	**Sample DAP**	**Row pattern**	**PC application**[b]	**OBB %**[c]
Georgia 06G	122	Single	-	46 d
			+	49 d
		Twin	-	61 c
			+	53 d
	133	Single	-	66 bc
			+	64 bc
		Twin	-	65 bc
			+	71 ab
	140	Single	-	64 bc
			+	67 abc
		Twin	-	74 a
			+	69 ab
Virginia cultivar[a]	122	Single	-	60 d
			+	61cd
		Twin	-	62 bcd
			+	60 d
	133	Single	-	59 d
			+	69 ab
		Twin	-	73 a
			+	71 a
	140	Single	-	72 a
			+	72 a
		Twin	-	69 abc
			+	74 a

[a] Virginia cultivar = Bailey II (2021) or Emery (2022).

[b] PC = prohexadione calcium, "+" indicates treatments with PC application, "-" indicates treatments without PC application.

[c] Means within a column followed by the same letter are not significantly different according to Fisher's protected-LSD at α = 0.10. Mean separations were performed within each cultivar.

When canopy temperature was analyzed, plots treated with prohexadione calcium overall had a significantly lower average daytime temperature than untreated plots (30.0 vs 30.3°C, respectively, $P = 0.0007$). Single row plots had a greater mean daytime temperature than twins by ~0.6°C ($P < 0.0001$). Across the pooled cultivar data, single rows with or without prohexadione calcium had warmer canopies than corresponding twin row untreated plots (~30.5 vs 30.1°C, respectively; row pattern × growth regulator $P = 0.0004$), with twin rows with prohexadione calcium treatment in turn exhibiting cooler temperatures (~29.4°C). Within the Georgia 06G data ($P < 0.0001$), single rows with prohexadione calcium (30.9°C) were warmer than untreated single rows (30.4°C), both of which were not different from nontreated twin rows (~30.6°C), all of which being warmer than treated twin rows (29.5°C). Virginia cultivar average daytime temperatures ($P < 0.0001$) exhibited a slightly different response, as twin rows with or without prohexadione calcium treatment (~29.6°C) had the coolest temperatures followed by single rows with prohexadione calcium treatment (30.0°C) which were in turn cooler than untreated single rows (30.4°C).

Prohexadione calcium did not significantly affect yield at either location during either year. Twin row planted plots yielded significantly greater than single row plots when data was combined across years and locations at $P = 0.0319$. In 2021 at Florence, the experimental field was heavily defoliated by LLS, in which single row planted plots had a significantly greater pod yield than twin rows at $P = 0.0186$ (3,799 vs 3,352 kg/ha).

Individual year results and combined results across year and locations can be found in Table 3.

Table 3. Influence of row pattern and prohexadione calcium application on pod yield (kg/ha) from earlier maturing cultivars from experiments conducted in 2021 and 2022**.**

Cultivar	**Row pattern**	**PC application[b]**	**Blackville 2021[c]**	**Blackville 2022**	**Florence 2021**	**Florence 2022**	**Combined**
Georgia 06G	Single	-	3481 b	5252	4452	3835	4254
		+	3416 b	4889	4083	3929	4073
	Twin	-	4148 a	6271	3621	4274	4459
		+	4165 a	5630	3940	4464	4502
Virginia cultivar[a]	Single	-	3518 b	5074	3534	3772	3925
		+	3917 ab	4656	3229	4711	4075
	Twin	-	4506 a	5087	2734	4295	4070
		+	4366 a	5293	3189	4461	4255
Pooled	Single	Pooled	3192 b	4963 b	3795 a	4044 b	4080 b
	Twin		4294 a	5553 a	3339 b	4371 a	4318 a
Pooled	Pooled	-	3889	5400	3533	4037 b	4171
		+	3949	5103	3588	4381 a	4222

[a] Virginia cultivar = Bailey II (2021) or Emery (2022).

[b] PC = prohexadione calcium, "+" indicates treatments with PC application, "-" indicates treatments without PC application.

[c] Means within a column followed by the same letter are not significantly different according to Fisher's protected-LSD at α = 0.10. Where not pooled, mean separations were performed within each cultivar.

Across pooled pod distribution results, plots treated with prohexadione calcium had pods distributed significantly closer to the taproot when compared to untreated plots

(371 vs. 381 pixel radius, respectively, P = 0.0343). Regardless of cultivar, twin row planted plots with no prohexadione calcium application had a pod set that was distributed significantly closer to the taproot than prohexadione calcium treated twin rows, single rows either with or without prohexadione calcium application had pod sets furthest from the taproot (Figure 1).

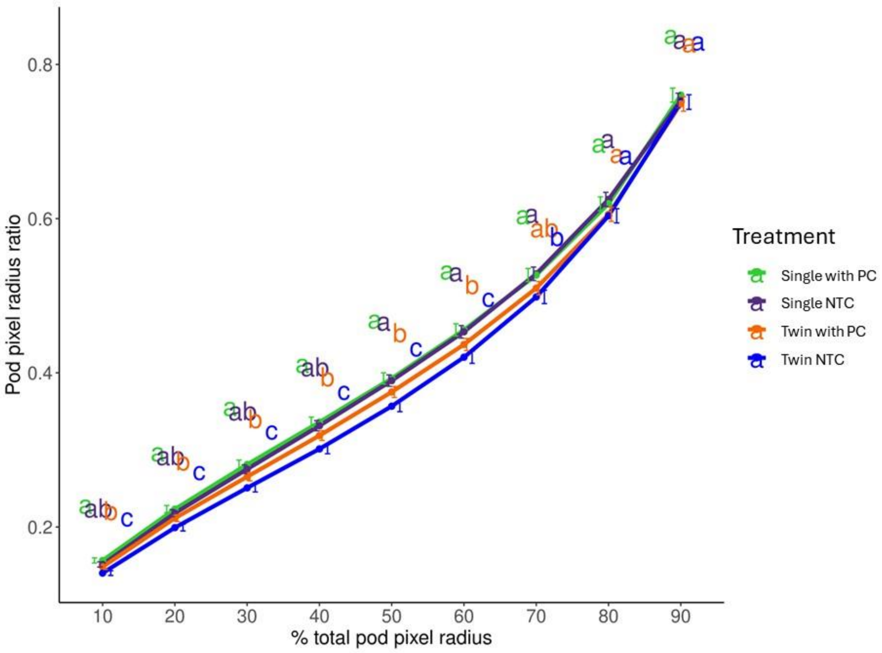

Figure 1. Influence of row planting pattern and prohexadione calcium (PC) on the ratio of radii corresponding to % pod pixels : radii of total pixels among pooled cultivars.

Twin row planting arrangement had a significantly greater percentage of total sound mature kernels (TSMK) than single row planted plots (69% vs 67%, respectively, P = 0.0040). Row pattern was the only variable or interaction to have a significant influence on TSMK. At Blackville in 2021, cultivar Emery planted in single rows with prohexadione calcium application had a significantly greater economic return than corresponding single rows with no prohexadione calcium application ($936 vs $832 per hectare, respectively, at P = 0.0921). Similarly, cultivar Georgia 06G planted in single rows without prohexadione calcium was valued significantly higher than corresponding plots treated with prohexadione calcium ($929 vs $832 per hectare, respectively). Additionally in 2021, twin row planted plots had a significantly greater economic value than single row plots ($1,080 vs. $875 per hectare, respectively, at P < 0.0001), though this observation did not continue in 2022 when no treatment effects significantly affected economic return. Across the combined data, twin row planted plots exhibited significantly greater economic value than single rows ($1,321 vs. $1,124 per hectare, respectively, at P < 0.0001). Remaining treatment effects did not significantly affect economic return.

Later maturing experiment. Spotted wilt incidence was significantly greater in single rows when compared to twins at Blackville in 2021 and at Florence in 2022 (P = 0.0011 and 0.0040, respectively). There were no significant differences between row patterns at Florence in 2021 or at Blackville in 2022. In 2021 at Florence, cultivar

Georgia 16HO had significantly greater SW incidence than FloRun 331 (5.7 vs. 3.5, respectively, $P = 0.0025$). Conversely, in 2022 at Blackville cultivar FloRun 331 had a significantly higher incidence than Ga 16HO (3.4 vs. 2.0, respectively, at $P = 0.0437$).

Row visibility was significantly greater following application of prohexadione calcium at $P = 0.0010$. Cultivar FloRun 331 had a less visibly distinguishable canopy than Georgia 16HO (3.75 vs. 4.69; $P = 0.0010$). Additionally, FloRun 331 had a significantly taller average main stem height than Georgia 16HO ($P < 0.0001$), potentially accounting for reduced row visibility. Main stem height was found to be significantly shorter in both single and twin row plots following treatment with prohexadione calcium ($P < 0.0001$). Twin rows exhibited greater main stem lengths compared to single rows ($P < 0.0001$).

When maturity development was evaluated at Blackville in 2021, plots were sampled at 121, 133, and 140 DAP. The greatest percentages of OBB pods were found among samples pulled at 140 DAP (59%, $P < 0.0001$). Single row plots had a significantly higher percentage of OBB pods than corresponding twin row plots at 133 DAP (46 vs 37%, respectively, $P = 0.0125$), but when maturity was evaluated again at 140 DAP, there was no significant differences between single and twin row plots (58 vs. 59% OBB, respectively). In 2022, maturity was sampled at 133, 144 and 158 DAP. In 2022, twin row plots overall had a significantly greater percentage of OBB pods compared to single rows at 133 DAP (83 vs. 75%, respectively, $P < 0.0001$). The highest percentage of OBB pods were detected at the 144 DAP sampling time (86 vs. 79% at 133

DAP and 81% at 158 DAP, P = 0.0020). Plots treated with prohexadione calcium had a significantly greater percentage of OBB pods in 2022 compared to untreated plots, regardless of row pattern or DAP (83 vs. 79%, respectively, P = 0.0090).

Table 4. Influence of row pattern and prohexadione calcium application on % orange, brown and black (OBB) pod maturity from later maturing cultivars from pooled experiments conducted in 2021 and 2022.

Cultivar	**Row pattern**	**PC application**[a]	**OBB %**[b]
Pooled	Single	-	60 b
		+	58 b
	Twin	-	61 b
		+	66 a
Pooled	Single	Pooled	59 b
	Twin		64 a
Pooled	Pooled	-	61
		+	62

[a] PC = prohexadione calcium, “+” indicates treatments with PC application, “-“ indicates treatments without PC application.

[b] Means within a column followed by the same letter are not significantly different according to Fisher’s protected-LSD at $\alpha = 0.10$.

When maturity results were pooled across years, twin row plots were more mature than single row plots (64 vs 59%, respectively, P = 0.0209, Table 4). Twin row plots with prohexadione calcium treatment exhibited a significantly greater percentage of OBB pods than untreated twins, or single rows with or without prohexadione calcium (Table 4). Across sampling dates, plots exhibited the greatest levels of maturity between 141 to 147 DAP. The interaction of growth regulator × sample date was significant (P = 0.0075), whereby prohexadione calcium treated plots at 133 or 158 DAP exhibited pod maturities greater than corresponding untreated plots at the same timing (65 vs. 58% and 69 vs 63%, respectively) (Table 5). Treatment interactions did not significantly vary by cultivar (P > 0.133).

Table 5. Influence of digging date and prohexadione calcium application on % orange, brown and black (OBB) pods from later maturing cultivars from pooled experiments conducted in 2021 and 2022**.**

Cultivar	**Sample DAP** [a]	**PC application**[b]	**OBB %**[c]
Pooled	121	-	47 c
		+	36 f
	133	-	58 d
		+	65 c
	141_147	-	73 ab
		+	75 a
	158	-	63 cd
		+	69 bc
Pooled	121	Pooled	41 b
	133		62 ab
	141_147		74 a
	158		66 ab

[a] Samples collected at 141 (2021) and 147 (2022) days after planting (DAP) were grouped for the pooled data.

[b] PC = prohexadione calcium, “+” indicates treatments with PC application, “-“ indicates treatments without PC application.

[c] Means within a column followed by the same letter are not significantly different according to Fisher’s protected-LSD at α = 0.10.

Average daytime temperature was significantly greater in single row plots than corresponding twin row plots (30.3 vs. 29.7℃, respectively, $P < 0.0001$). Plots treated with prohexadione calcium also exhibited a greater temperature than corresponding untreated plots (30.1 vs. 29.9℃, respectively, $P = 0.0492$). When prohexadione calcium application was considered with regard to approximate dates of 50% of row having lapped ($P = 0.0187$), differences were not evident prior to rows lapping (~33°C) but were recorded following rows lapping, where smaller canopies associated with prohexadione calcium treatment were warmer compared to those without treatment (27.5 vs 27.1°C, respectively). The interaction of row pattern and cultivar was also significant ($P = 0.0722$), with either cultivar planted in twin rows having cooler temperatures (~29.7°C) compared to single rows of FloRun 331 (30.1°C) followed by Georgia 16HO (30.6°C).

At Blackville in 2021, plots treated with prohexadione calcium had pods closer to the taproot compared to untreated plots (345 vs. 374 pixel radius, respectively, $P = 0.0004$). Conversely, at Blackville in 2022, treatment effects did not significantly affect pod distribution. When results were pooled across years, plots treated with prohexadione calcium had pods that were distributed closer (~6% smaller radius) to the taproot when compared to untreated plots (354 vs. 377 pixel radius, respectively, $P = 0.0006$). Across pooled pod density results (Figure 2), twins with or singles without prohexadione calcium had the most taproot-focused crop, followed by singles with prohexadione calcium, while twins without prohexadione calcium application had the most limbroot-set crop ($P < 0.0001$). Additionally, the pooled results showed when cultivar Georgia 16HO received prohexadione calcium treatment, the resulting pod set was more taproot-focused, while FloRun 331 showed the inverse reaction (Figure 3).

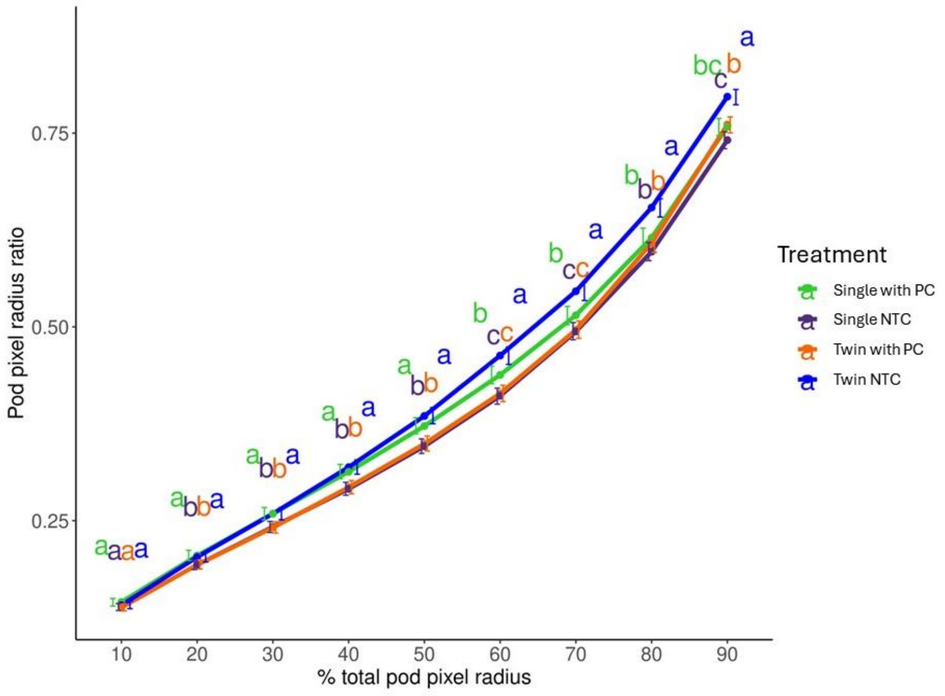

Figure 2. Influence of row planting pattern and prohexadione calcium (PC) on the ratio of radii corresponding to % pod pixels : radii of total pixels among pooled cultivars.

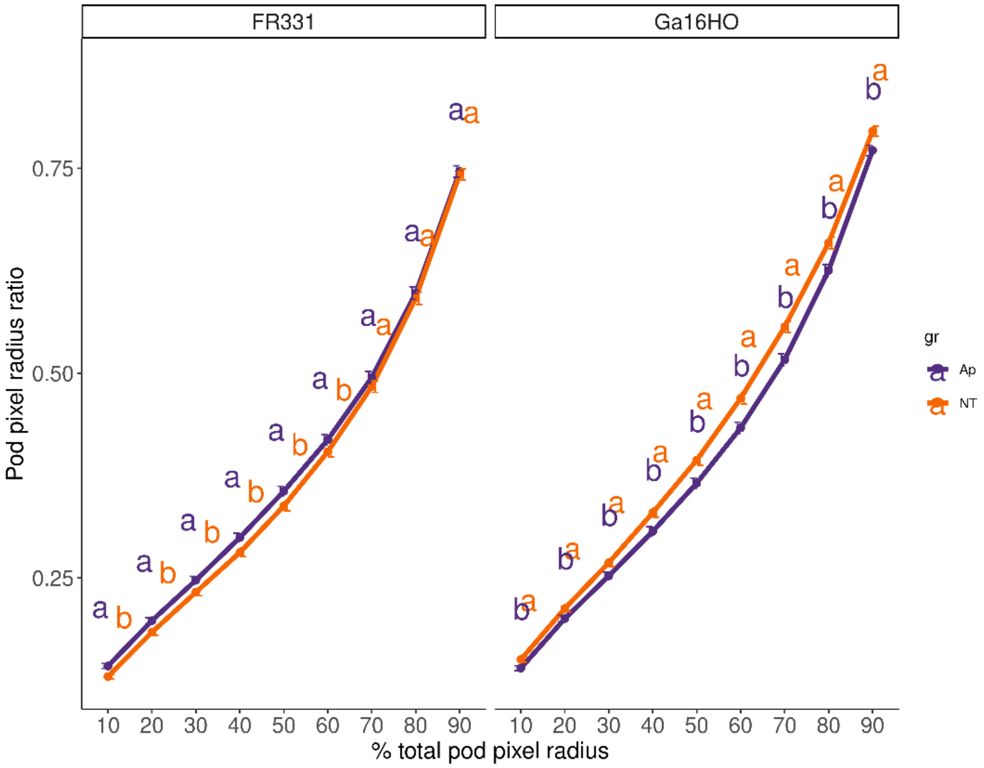

Figure 3. Influence of prohexadione calcium application (labeled “Ap”) on the ratio of radii corresponding to % pod pixels : radii of total pixels in individual cultivars.

Pod yield was significantly greater in twin row versus single row planted plots at P = 0.0018. Plots treated with prohexadione calcium overall yielded significantly less than untreated plots (4,427 vs. 4,594 kg/ha, respectively, P = 0.0865). The interaction of cultivar, row pattern and prohexadione calcium application was significant at P = 0.0774. FloRun 331 planted in twin rows without prohexadione calcium yielded significantly greater than single rows with or without prohexadione calcium application, whereas Georgia 16HO planted in twin rows with or without prohexadione calcium application or single rows without prohexadione calcium yielded greater than corresponding single rows treated with prohexadione calcium (Table 6). Individual year results and results combined across years and locations can be found in Table 6.

Table 6. Influence row pattern and prohexadione calcium application on pod yield (kg/ha) from later maturing cultivars from experiments conducted in 2021 and 2022.

Cultivar	**Row pattern**	**PC application[a]**	**Blackville 2021[b]**	**Blackville 2022**	**Florence 2021**	**Florence 2022**	**Combined**
FloRun 331	Single	-	5858	6000	3341 b	3210	4422 b
		+	5889	5983	3424 ab	2952	4385 b
	Twin	-	6249	5833	4077 a	3619	4838 a
		+	6009	5771	3860 ab	3393	4636 ab
Georgia 16HO	Single	-	5275	6222	3998 a	3164	4553 a
		+	5213	6102	2887 b	2952	4087 b
	Twin	-	5748	6090	3442 ab	3623	4576 a
		+	5106	6534	3929 a	3426	4625 a
Pooled	Single	Pooled	4951	5421	3033 b	3453 b	4358 b
	Twin		5141	5397	3407 a	3956 a	4667 a
Pooled	Pooled	-	5150	5384	3301	3827 a	4594 a
		+	4943	5434	3130	3570 b	4427 b

[a] PC = prohexadione calcium

[b] Means within a column followed by the same letter are not significantly different according to Fisher’s protected-LSD at α = 0.10. Where not pooled, mean separations were performed within each cultivar.

At Blackville in 2022, plots without prohexadione calcium treatment had a significantly greater percentage of TSMK compared to those receiving prohexadione calcium (70 vs 68% respectively, P = 0.0942). Conversely, both at Blackville in 2021 and across the pooled data, there were no significant differences in TSMK observed among treatments. Nevertheless, twin row plots tended to have a slightly higher TSMK than single rows, as was observed in the early maturing group. At Blackville in 2021, plots without prohexadione calcium had significantly greater economic value than treated plots ($1,410 vs $1,306 per hectare, respectively, at P = 0.0909). Contrarily, in 2022 prohexadione calcium application was not significant regarding economic return at P = 0.2287. In 2022, single row planting pattern had a significantly greater economic return when compared to twin rows ($1,649 vs $1,565 per hectare, respectively, at P = 0.0675). When economic return values were combined across years, treatment effects did not significantly influence value.

Large plot on-farm experiments. At Orangeburg County in 2021, plots without prohexadione calcium had a significantly greater percentage of OBB pods than corresponding plots with growth regulator treatment (75 vs. 67%, respectively, P = 0.0209). Conversely, plots with prohexadione calcium yielded significantly greater than untreated plots (5,099 vs. 4,333 kg/ha, respectively, P = 0.0168). In 2022 at on farm trials in Bamberg County, no significant differences in percentage of OBB pods were observed between plots treated and not treated with prohexadione calcium (P = 0.8773).

DISCUSSION

The goal of this work was to evaluate the combined and independent effects of row planting pattern and prohexadione calcium application on the growth, maturity development and profitability of newer peanut cultivars that are being planted frequently in South Carolina. Corroborating earlier reports (Tillman et al., 2006; Culbreath et al.,

2008) twin row planted stands typically exhibited less spotted wilt incidence than single row planted stands.

Results from these experiments showed canopy architecture of both runner type and Virginia type peanut treated with prohexadione calcium to have consistently exhibited a more triangular shape than untreated peanut regardless of cultivar, year, or row planting pattern. This corroborated earlier studies that reported the change in canopy architecture following prohexadione calcium application at 50% row closure (Mitchem et al., 1996; Culpepper et al., 1997; Beam et al., 2002; Jordan et al., 2004; Faircloth et al., 2005; Jordan et al., 2008; Jordan et al., 2009; Studstill et al; 2020). Results of this experiment also supported previous reports that two applications of prohexadione calcium at 0.75× the label rate was efficient at significantly reducing main stem growth and increasing row visibility (Studstill et al., 2020). Based on these results, prohexadione calcium had varying effects on canopy temperature. Among Virginia cultivar single rows and Georgia 06G twin rows, prohexadione calcium treatment reduced ground temperature. In those cases, this was not associated with a parallel significant effect on yield across the pooled data, though the Virginia cultivar yields exhibited a trend of being higher for treatments with cooler ground temperature with this having been more prominent at Blackville in 2021. With respect to collective FloRun 331 and Georgia 16HO row patterns and Georgia 06G single rows, prohexadione calcium was conversely linked to increased ground temperatures. Although it is yet to be determined as to the cause of the differing results among examined cultivars, which may or may not be related to unmeasured canopy architecture or density effects, within the FloRun 331 and Georgia

16HO data, the increased yields seen among some treatments in the absence of prohexadione calcium application may be a result of their correspondingly cooler ground temperatures. Overall, plots planted in twin rows exhibited cooler daytime ground temperatures compared to single rows. While measuring pollen viability was not part of the scope of this study, the cooler temperatures may have potentially created a less stressful environment for fertilization and subsequent pod development.

Twin row planting was associated with a significantly greater amount of yield, % OBB and % TSMK. Twin row planting was significantly greater in economic return when compared to single rows in the earlier maturing group. In the later maturing group, however, no significant difference in economic return was seen between twin and single row plots. The later maturing runner cultivars used, FloRun 331 and Georgia 16HO, have much larger and more bushy canopies than Georgia 06G, the runner cultivar used in the earlier maturing group. Thus, it is interesting that yield improvements were not observed for these cultivars when planted in twin rows in the presence of prohexadione calcium application.

In the small plot experiments (i.e., plot length = 30.5 m), prohexadione calcium application was not associated with a significant difference in yield in the earlier maturing group, but generally resulted in a significant yield reduction in the later maturing experiment with pooled results showing a loss of 170 kg/ha following application. Conversely, in 2021 at large on-farm experiment, prohexadione calcium application increased yield by 770 kg/ha. Studstill et al. (2020) reported a similar relationship in which prohexadione calcium treated small plots (~5.5 to 11 m in length) did not show significant yield differences, but large treated plots (~155 to 455 m in len) yielded significantly greater than untreated plots. Multiple studies have found the influence of prohexadione calcium on yield to be inconsistent and cultivar dependent (Beam et al., 2002; Faircloth et al., 2005; Jordan et al., 2008; Jordan et al., 2009) but reports have varied or not been explicit on the mechanism as to why this happens. Beam et al. (2002) reported up to 4% decrease in pod loss upon inversion in single row plots treated with prohexadione calcium when compared to untreated single rows, which they surmised was due to the gynophores being more strongly attached to the pod and axillary branch of the peanut. When single rows of Georgia 16HO were treated with prohexadione calcium, yield was significantly reduced, indicating that if prohexadione calcium does make gynophore attachment stronger, that is plausibly a cultivar-dependent effect

Based on this research, both twin row planting pattern and prohexadione calcium independently influenced peanut to set pods significantly closer to the taproot, with results varying by cultivar. Ortiz et al. (2013) reported that for every two centimeters a tractor operator deviates off the row center, yield losses of up to 186 kg/ha can be expected. If the rows are easier to distinguish, and pods are located more centrally to the taproot, the yield increases associated with prohexadione calcium may simply or in part be due to greater digging efficiency. While the pod distribution data is novel and contributes informative measurements, it is important to acknowledge the context of its determining radii at which a predetermined proportion (73 to 75%) of total pod pixels were contained. Thus, greater pod pixel radii would be expected in the presence of a greater total number of pods. This context helps to reconcile the results among twin row treated plots exhibiting greater yield and maturity compared to plots in single rows as reflecting a larger pod set area for twins as opposed to a greater proportion of limb root pods. Likewise, the difference in pixel radius for twins compared to singles (~1% for Georgia 06G and ~7% for FloRun 331 or Georgia 16HO) was less than the difference in intra-row seed spacing based on planter settings (i.e., single rows at 19 seed/m compared to 11.5 seed/m per individual twin corresponding to ~65% greater seed density among single rows). This also would be expected, as areas of pod set naturally extend beyond the point of sowing and subsequent taproot. Considering pod pixels as a ratio of radii at varying proportions of pod pixels to radii of total pod pixels likewise helped to compare relative concentrations of pods across the pod distribution profile of images and serves as an additional tool to characterize pod distribution effects and relationships in future studies.

Prohexadione calcium had variable effects to the percentage of TSMK, similar to previous reports (Mitchem et al., 1996; Culpepper et al., 1997; Beam et al., 2002; Monfort et al., 2021). Conversely, when maturity samples were manually taken and analyzed, prohexadione calcium did cause a significant gain in the percentage of OBB pods, which was also observed by Culpepper et al. (1997). The examined Virginia type cultivars characteristically exhibit optimal maturity between 133 and 140 DAP (Anco et al. 2021). Thus, while examined treatments did not result in comparable levels of maturity at the earliest 122 DAP assessment as those in the 133 and 140 DAP samples, those among the 133 DAP samples exhibiting maturity levels not different than those of the 140 DAP group (69 to 73% compared to 69 to 74%) consisted of either twin row planting, prohexadione calcium application, or both. Treatment of Georgia 06G twin rows with prohexadione calcium similarly exhibited pod maturity at 133 DAP not different from the most mature treatments at 140 DAP a week later (71% compared to 67 to 74%, respectively). In addition to twin planting overall, pod maturity of FloRun 331 or Georgia 16HO treated with prohexadione calcium was associated with greater pod maturity at 133, 141 to 147, and 158 DAP than at the same timings when prohexadione calcium was not applied. Though the combining of 141 and 147 DAP sample timings from 2021 and 2022, respectively, facilitated comparison of interpretable groupings, it is possible the difference may have reduced the ability to detect a shorter yet viable length of time where treatments could have contributed maturity levels not different from later-assessed values (e.g., 7 days compared to the subsequent approximation of 11 days). Nevertheless, while corresponding benefits of prohexadione calcium application did not consistently translate over to improved yield for these two runner cultivars from the available (small plot) data, more importantly across cultivars, twin row planting with prohexadione calcium treatment did not result in decreased yields. While the potentially quicker maturity seen among select treatments, where present, approached ~7 days, this would not automatically result in a ready reduction of a fungicide application toward the end of the growing season. Even so, any time potentially saved is potentially able to contribute to the possibility of reducing the need for such a fungicide application, as late-season application decisions depend on a variety of factors not limited to environmental conditions, cultivar susceptibility to diseases, canopy health, present and impending weather conditions, and logistical constraints. Favorably contributing to the reduced-risk nature of such treatments with a potential for improved maturity is their innate compatibility with producer and practitioner capabilities to examine fields for pod maturity in evaluating digging decisions (Anco et al. 2024).

Literature Cited

American Peanut Shellers Association. 2020. Farmers Stock Trading Rules.

Alderman, S. C. and Nutter Jr, F. W. 1994. Effect of temperature and relative humidity on development of *Cercosporidium personatum* on peanut in Georgia. *Plant Disease, 78*: 690–694.

Anco, D. J. 2021. Peanut money-maker 2021 production guide

Anco, D. J. and Heirs, J. B. 2022. Pod yield production among peanut (*Arachis hypogaea* L.) cultivars in South Carolina. *Peanut Science 49* (1): 49-53.

Anco, D. J. 2023. Peanut disease management. Peanut money-maker 2023 production guide: 44-55.

Anco, D. J., Kirk, K. R., and Heirs, J. B. 2024. Revised thresholds for runner peanut harvest maturity pertaining to recent cultivars in South Carolina. *Peanut Science, 51* (1): 8-17.

Baldwin, J. A., Todd, J. W., Weeks, J. R., Gorbet, D. W., Culbreath, A. K., Luke-Morgan, A. S., Fletcher, S. M., and Brown, S. L. 2001. A regional study to evaluate tillage, row patterns, in-furrow insecticide, and planting date on the yield, grade and tomato spotted wilt virus incidence of the Georgia Green peanut cultivar. *Procedures of the Annual. Southern Conservation Tillage Conference in Sustainable Agriculture, 24*: 26-34.

BASF. 2012. *Apogee: Plant growth regulator booklet*. Ontario, Canada.

Beam, J. B., Jordan, D. L., York, A. C., Isleib, T. G., Bailey, J. E., McKemie, T. E., Spears, J. F., and Johnson, P. D. 2002. Influence of prohexadione calcium on pod yield and pod loss of peanut. *Agronomy Journal*, *94*(2): 331–336.

Boote, K. J. 1982. Growth stages of peanut (Arachis hypogaea L.). *Peanut Science*, *9* (1): 35-40

Branch, W. D. 2007. Registration of 'Georgia-06G' Peanut. *Journal of Plant Registrations*, *1*(2): 120–120.

Brooks, M. E., Kristensen, K., van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, Nielsen, A., Skaug, H. J., Mächler, M. and Bolker., B. M. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. the R Journal, 9(2), 378.

Byers, R. E., and Yoder. K. S. 1999. Prohexadione calcium inhibits apple, but not peach, tree growth, but has little influence on apple fruit thinning or quality. *Horticultural Science*, *34*: 1205– 1209.

Chapin, J. W., and Thomas, J. S. 2005. Effect of fungicide treatments, pod maturity, and pod health on peanut peg strength. *Peanut Science*, 3*2(2)*: 119–125.

Colvin, B. C., Rowland, D. L., Ferrell, J. A., and Faircloth, W. H. 2014. Development of a digital analysis system to evaluate peanut maturity. *Peanut Science*, *41* (1): 8–16.

Culbreath, A. K., Tillman, B. L., Gorbet, D. W., Holbrook, C. C., and Nischwitz, C. 2008. Response of new field resistant peanut cultivars to twin row pattern or in-furrow applications of phorate insecticide for management of spotted wilt. *Plant Disease, 92*: 1307-1312.

Culpepper, A. S., Jordan, D. L., Batts, R. B., and York, A. C. 1997. Peanut response to prohexadione calcium as affected by cultivar and digging date. *Peanut Science, 24(2):* 85–89.

Davidson, J. I., Blankenship, P. D., Henning, R. J., Guerke, W. R., Smith, R. D., and Cole, R. J. 1991. Geocarposphere temperature as it relates to Florunner peanut production. *Peanut Science 18* (2): 79-85.

Faircloth, J. C., Coker, D. L., Swann, C., Mozingo, W., Phipps, P. M., and Jordan, D. L. 2005. Response of four Virginia-type peanut cultivars to prohexadione calcium as affected by cultivar and planting pattern. *Peanut Science 32* (1): 42-47.

Grossman, K., Koenig, K. S., and Kwiatkowski, J. 1994. Phytohormonal changes in intact shoots of wheat and oilseed rape treated with the acylcyclohexanedione growth retardant prohexadione calcium. *Physiologia Plantarum 90* (1): 139–143.

Haynes, J. M., Smith, N., Culbreath, A. K., Kirk, K. R., and Anco, D. J. 2019. Effects of insecticides applied with in-furrow with superabsorbent polymer on peanut cultivars infected with tomato spotted wilt virus. *Peanut Science, 46(2):* 127-139.

Jordan, D. L., Spears, J. F., & Sullivan, G. A. 1998. Influence of digging date on yield and gross return of Virginia-type peanut cultivars in North Carolina. *Peanut Science, 25(1):* 45-50.

Jordan, D. L., Beam, J. B., Lanier, S. H., and Johnson, P. D. 2004. Peanut (*Arachis hypogaea* L.) response to cyclanilide and prohexadione calcium. *Peanut Science, 31* (1): 33-36.

Jordan, D. L., Nuti, R. C., Beam, J. B., Lancaster, S. H., Lanier, J. E., Lassiter, B. R., and Johnson, D. E. 2008. Peanut (Arachis hypogaea L.) cultivar response to prohexadione calcium. *Peanut Science, 35* (2): 101-107.

Jordan, D. L., Nuti, R. C., Beam, J. B., Lancaster, S. H., Lanier, J. E., and Johnson, P. D. 2009. Influence of application variables on peanut (*Arachis hypogaea* L.) response to prohexadione calcium. *Peanut Science 36* (1): 96-103.

Jordan, D. L., Shew, B. B., and Johnson, D. J. 2016. Response of peanut cultivar (*Arachis hypogaea* L.) cultivar Gregory to interactions of digging date and disease management. *Advances in Agriculture, 2016:* 1–9.

Jordan, D. L., Hare, A. T., Roberson, G. T., Ward, J., Shew, B. B., Brandenburg, R. L., Anco, D., Thomas, J., Balota, M., Mehl, H., and Taylor, S. 2019. Survey of practices by growers in the Virginia-Carolina region regarding digging and harvesting peanut. *Crop Forage Turfgrass Management 5*: 1-4.

Kirk, K. R. Batch Load Image Processor; v.1.1.; Clemson University: Clemson, SC, USA, 2022.

Lanier, J. E., Jordan, D. L., Spears, J. F., Wells, R., Johnson, P. D., Barnes, J. S., Hurt, C. A., Brandenburg, R. L., and Bailey, J. E. 2004. Peanut response to planting pattern, row spacing, and irrigation. *Agronomy Journal*, *96*(4): 1066–1072.

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

Mitchem, W. E., York, A. C., and Batts, R. B. 1996. Peanut Response to Prohexadione Calcium, a New Plant Growth Regulator. *Peanut Science*, *23*(1): 1-9. https://doi.org/10.3146/i0095-3679-23-1-1

Monfort, W. S., Tubbs, R. S., Cresswell, B., Jordan, E., Smith, N., and Luo, X. L. 2021. Yield and economic response of peanut (*Arachis hypogaea* L.) cultivars to prohexadione calcium in large-plot trials in Georgia. *Peanut Science, 48(1):* 15-21.

Mozingo, R. W., Coffelt, T. A., and Wright, F. S. 1991. The influence of planting and digging dates on yield, value, and grade of four Virginia-type peanut cultivars. *Peanut Science, 18 (1):* 55–62. https://doi.org/10.3146/i0095-3679-18-1-15

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

Nuti, R. C., Faircloth, W. H., Lamb, M. C., Sorenson, R. B., Davidson, J. I., and Brenneman, T. B. 2008. Disease management and variable planting patterns in peanut. *Peanut Science*, *35* (1): 11-17. https://doi.org/10.3146/PS06-051.1

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Renfroe-Becton, H., Kirk, K.R., and Anco, D.J. 2022. Using image analysis and regression modeling to develop a diagnostic tool for peanut foliar symptoms. *Agronomy*, 12: 2712. Doi: 10.3390/agronomy12112712

Sanders, T. H., Vercellotti, J. R., Blankenship P. D., Crippen, K. L., and Civille, G. V. 1989. Interaction of maturity and curing temperature on descriptive flavor of peanuts. *Journal of Food Science, 54 (4):* 1066-1069.

Sanders, T. H., Blankenship, P. D., Vercellotti, J. R. and Crippen, K. L. 1990. Interaction of curing temperature and inherent maturity distributions on descriptive flavor of commercial grade sizes of Florunner peanuts. *Peanut Science, 17* (2): 85-89.

SAS Institute Inc. 2023. "The GLIMMIX Procedure" in *SAS ® 9.4 User's Guide*. Cary, NC: SAS Institute Inc.

Sorenson, R. B., Sconyers, L. E., Lamb, M. C., and Sternitzke, D. A. 2004. Row orientation and seeding rate on yield, grade, and stem rot incidence of peanut with subsurface drip irrigation. *Peanut Science, 31(1):* 54-58.

Sorenson, R. B., Lamb, M. C., and Butts, C. L. 2007. Peanut response to row pattern and seed density when irrigated with subsurface drip irrigation. *Peanut Science, 34 (1):* 27–31.

Sorenson, R. B., Lamb, M. C., and Butts, C. L. 2015. Can peg strength be used as a predictor for pod maturity and peanut yield? *Peanut Science, 42 (2):* 92–99. https://doi.org/10.3146/0095-3679-42.2.92

Studstill, S. P., Monfort, W. S., Tubbs, R. S., Jordan, D. L., Hare, A. T., Anco, D. J., Sarver, J. M., Ferguson, J. C., Faske, T. R., Creswell, B. L., and Tyson, W. G. 2020. Influence of prohexadione calcium rate on growth and yield of peanut (*Arachis hypogaea*). *Peanut Science, 47(3):* 163–172.

Tillman, B. L., Gorbet, D. W., Culbreath, A. K., and Todd, J. W. 2006. Response of peanut cultivars to seeding density and row patterns. *Crop Management Research, 5* (1). https://doi-org.libproxy.clemson.edu/10.1094/CM-2006-0711-01-RS

Treadway, Z. R. 2020. *Determining the effect of prohexadione calcium growth regulator on growth and yield of peanut (Arachis hypogaea L.) in Mississippi.* M. S. Thesis, Department of Plant and Soil Sciences, Mississippi State University, Starkville, MS.

Tubbs, R. S., Beasley, J. P., Culbreath, A. K., Kemerait, R. C., Smith, N. B., and Smith, A. R. 2011. Row Pattern and Seeding Rate Effects on Agronomic, Disease, and Economic Factors in Large-Seeded Runner Peanut. *Peanut Science*, *38*(2): 93–100. https://doi.org/10.3146/PS10-19.1

USDA FSA. 2019. Peanut Buyers and Handlers Program Guidelines for 2019 and Subsequent Crop Years. 1–15.

Wehtje, G., Walker, R. H., Patterson, M. G., and McGuire, J. A. 1984. Influence of twin rows on yield and weed control in peanuts. *Peanut Science, 11 (2):* 88-91. https://doi.org/10.3146/i0095-3679-11-2-10

Williams, E.J. and Drexler, J.S. 1981. A Non-Destructive Method for Determining Peanut Pod Maturity. *Peanut Science, 8* (2): 134-141.

Wright, F. S. and Porter, D. M. 1991. Digging date and conservational tillage influence on peanut production. *Peanut Science, 18 (2):* 72-75. https://doi.org/10.3146/i0095-3679-18-2-3\

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