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Research Article

Influence of Variety, Digging Date, and Fungicide Regimen on Peanut (*Arachis hypogaea*) Response to Prohexadione Calcium

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Abstract

Prohexadione calcium affects peanut (*Arachis hypogaea* L.) vegetative growth and improves row visibility and efficiency of digging pods and inverting vines. While cultivar response to this plant growth regulator in peanut has been reported in the peer-reviewed literature, information on the impact of digging date and fungicide program for late leaf spot disease [*Nothopassalora personata* (Berk. & M.A. Curtis) U. Braun, C. Nakash., Videira & Crous] in presence of prohexadione calcium is limited. To address this limitation, research was conducted at two locations in 2018 with two levels of prohexadione calcium (0 or 2 applications at 140 g ai/ha), two levels of cultivar (Bailey and Sullivan), three levels of fungicide regimen (no fungicide, two sprays early in the cropping cycle when the pathogen for leaf spot disease was active, and five sprays throughout the time when the pathogen for this disease was active), and two levels of digging pods and inverting vines (optimum pod maturity or 10 days after optimum pod maturity). Prohexadione calcium increased row visibility of both cultivars regardless of other treatment factors, and row visibility of Sullivan was greater than Bailey in absence of prohexadione calcium. Canopy defoliation in presence of late leaf spot disease at optimum pod maturity was affected by prohexadione calcium but not at 10 days after optimum maturity. Greater canopy defoliation at optimum pod maturity and lower peanut yield were observed when prohexadione calcium was applied. These results suggest that a more compact plant following prohexadione calcium may create a microenvironment that supports late leaf spot disease. However, additional research is needed to support or refute these findings.

Introduction

Prohexadione calcium is registered for use in peanut (*Arachis hypogaea* L.) and other crops to prevent excessive vine growth by limiting expression of gibberellic acid and subsequent internode elongation [1]. Prohexadione calcium increases row visibility in peanut fields and minimizes pod loss through greater precision and less vegetative growth during digging and vine inversion [2-11].

Early leaf spot disease [caused by *Passalora arachidicola* (syn. *Cercospora arachidicola* Hori] and late leaf spot disease [*Nothopassalora personata* (Berk. & M.A. Curtis) U. Braun, C. Nakash., Videira & Crous] can reduce peanut yield if the pathogens causing these diseases are not suppressed with fungicides [12-15]. Leaf spot disease can cause canopy defoliation followed by pod shed when weather conditions favor pathogen activity and subsequent disease development when cultivar resistance is inadequate to protect peanut or fungicides are not used or are used in a limited manner. The cultivars Bailey [16] and Sullivan [17] are Viginia market type cultivars that were historically popular in North Carolina and surrounding states. These cultivars exhibit significantly different growth habits and canopy architecture from one another. Practitioners consider Bailey and the more recently released high oleic version of this cultivar Bailey II [18] to have excessive vegetative growth that makes digging pods and inverting vines challenging. Jordan et al. [5] reported that pod yield increased when prohexadione calcium was applied to the cultivars Bailey and Bailey II when 50% of lateral vines from adjacent rows were touching or when applied at this timing and with a repeat application 2 to 3 weeks later. The cultivar Sullivan has a more compact plant stature compared with Bailey or Bailey II. Balota [19] reported a yield increase when prohexadione calcium was applied to Bailey and Sullivan under irrigated and non-irrigated conditions. A positive response to prohexadione calcium is likely a combination of greater precision in tracking rows when row visibility is greater after application of prohexadione calcium and greater pod retention [2,8].

It is postulated that alteration of canopy architecture could impact disease development in the peanut canopy. To date, research has not been conducted to determine if leaf spot disease is affected by changes in canopy architecture when prohexadione calcium is applied. To address this limitation in the peer-reviewed literature, research was conducted to determine defoliation of peanut caused by leaf spot disease when prohexadione calcium was applied to the cultivars Bailey and Sullivan under three different fungicide regimens designed to protect peanut from this disease. To further document the possible impact of prohexadione on disease reaction and peanut yield, digging pods and inverting vines occurred at optimum pod maturity and 10 days after optimum pod maturity when pod shed would likely be higher.

Materials and Methods

The experiment was conducted in North Carolina in 2018 at the Peanut Belt Research Station located near Lewiston-Woodville (36.07 N, 77.11 E) and at the Border Belt Tobacco Research Station located near Whiteville (34.41 N, 78.79 E) on sandy loam soils common in the North Carolina coastal plain. The cultivars Bailey [16] and Sullivan [17] were planted in conventionally prepared, raised seedbeds in rows spaced 91 cm apart at an in-row population of 15 to 17 plants/m. Plot size was four rows wide by 9 m long. Except for prohexadione calcium treatments and fungicide regimens, all other production and pest management practices were the same across the entire experiment [20].

Treatments consisted of two levels of cultivar (Bailey and Sullivan), two levels of prohexadione calcium (none and two sequential applications), three fungicide regimens (no fungicide, two sprays of fungicides, and five sprays of fungicide), and two digging dates (optimum maturity and 10 d after optimum maturity). Prohexadione calcium (Apogee, BASF Corp., Research Triangle Park, NC) at 140 g ai/ha was applied when 50% of lateral branches from adjacent rows were touching followed by a second application at the same rate 14 to 21 days later. Prohexadione calcium was applied with crop oil concentrate (Agri-Dex, Helena Chemical Corp., Memphis, TN) and 28% urea ammonium nitrate at 1.0 L/ha in aqueous solution using a CO2-pressurized backpack sprayer calibrated to deliver 145 L/ha at 240 kPa. Fungicide regimens to protect peanut from leaf spot disease consisted of:

a) no fungicide.
b) chlorothalonil (Bravo Weather Stik, Syngenta, Greensboro, NC) applied at the R-3 stage of peanut growth [21] followed by prothioconazole plus tebuconazole (Provost, Bayer CropScience, Research Triangle Park, NC).
c) the fungicides listed in regimen 2 followed by a second application of prothioconazole plus tebuconazole followed by pyraclostrobin (Headline, BASF Corp., Research Triangle Park, NC) followed by chlorothalonil.

Chlorothalonil, prothioconazole plus tebuconazole, and pyraclostrobin were applied at 1.4 kg ai/ha, 0.027 kg ai/ha, and 1.1 kg ai/ha, respectively. Fungicides were applied bi-weekly using the procedure described for prohexadione calcium. Peanut pods were dug and vines inverted at optimum maturity based on pod mesocarp color [22] and in separate plots 10 d after optimum maturity.

The experimental design was a split-plot with combinations of cultivars, prohexadione calcium, and fungicide regimen randomized within digging dates. Each combination of cultivar, prohexadione calcium rate, fungicide regimen, and digging date was replicated 4 times. Peanut pod yield was determined after threshing and drying pods to 8% moisture. Visibility of rows was estimated using a scale of 1-10 where 1 = a flat canopy with no row definition and 10 = triangular-shaped rows [3,6]. Data for row visibility, canopy defoliation at optimum maturity and 10 d past optimum maturity, and pod yield were subjected to ANOVA using the GLMMIX procedure in SAS (PROC GLMMIX, SAS version 9.4, SAS Institute, Cary, NC) with location and replication within a location serving as random effects and cultivar, prohexadione calcium, fungicide regimen, and digging date serving as fixed effects. Means of significant main effects and interactions were separated using Tukey's HSD test at $p < 0.05$.

Results and Discussion

Main effects of cultivar ($F = 20.0$, $p < 0.0001$) and prohexadione calcium rate ($F = 169.9$, $p < 0.0001$) were significant for row visibility. When pooled over fungicide regimens and locations, row visibility for the cultivar Bailey was 6.6 while a value of 7.4 was observed for the cultivar Sullivan (data not presented in tables). These results are consistent with previous research demonstrating that Sullivan expressed less vegetative growth than Bailey [16,17,19]. When pooled over cultivars and locations, row visibility was 8.2 when prohexadione calcium was applied compared with 5.8 for non-treated peanut (data not presented in tables). Previous research [2,5] has shown that two sequential applications of prohexadione calcium results in greater row visibility near the end of the cropping cycle compared with non-treated peanut. No other interactions among treatment factors were noted for row visibility.

Peanut canopy defoliation at optimum pod maturity was affected by main effects of fungicide regimen ($F = 169.0$, $p < 0.0001$) and prohexadione calcium rate ($F = 13.3$, $p < 0.0001$). No other main effects or interactions were significant for canopy defoliation at this point in the cropping cycle. The highest level of defoliation was noted for the no-fungicide control (76%) (data not shown in tables). As expected, canopy defoliation decreased as the number of fungicide sprays increased. When the fungicide regimen increased from two sprays to five sprays, defoliation decreased from 51% to 31% . Canopy defoliation was 56% when prohexadione calcium was applied compared with 49% when prohexadione calcium was not applied (data not presented in tables). There are no other reports in the peer-reviewed literature reporting the impact of prohexadione calcium on leaf spot disease in peanut. However, southern stem rot (*Athelia rolfsii* Sacc.) incidence was lower when prohexadione calcium was applied compared with non-treated peanut [11]. Prohexadione calcium decreased fire blight disease (*Erwinia amylovora* Burrill) in apple *(Malus domestica)* [23,24].

Canopy defoliation was affected by the interaction of prohexadione calcium rate × digging date ($F = 3.8$, $p = 0.0045$) and fungicide regimen × digging date ($F = 10.1$, $p < 0.0001$). Canopy defoliation was lower (46%) for non-treated peanut compared with defoliation when prohexadione calcium was applied (56%) (Table 1). Canopy defoliation increased from 56% to 76% when digging was delayed by 10 d when prohexadione calcium was applied. In absence of prohexadione calcium, defoliation increased to 74% when digging was delayed.

Table 1: Peanut canopy defoliation at optimum pod maturity based on pod mesocarp or 10 days after optimum pod maturity when prohexadione calcium was applied when peanut was dug at two dates at two locations in 2018.[a]

	Peanut canopy defoliation	
Prohexadione calcium rate[b]	Pods dug at optimum maturity[c]	Pods dug 10 d after optimum pod maturity
g/ha	%	
0	46 c	74 a
140 then 140	56 b	76 a

[a]Means with the same letter are not significantly different based on Tukey's HSD test at $\alpha = 0.05$. Data are pooled over levels of location, cultivar, and fungicide regimen.
[b]Prohexadione calcium applied when 50% of laterals from adjacent rows were touching followed by a repeat application 14 d later.
[c]Optimum pod maturity determined based on the method described by Williams and Drexler [22].

Canopy defoliation at optimum pod maturity and when digging was delayed 10 d past optimum maturity was the lowest when fungicides were applied over the entire cropping cycle (e.g., five fungicide sprays) when the pathogen for leaf spot was active (Table 2). Applying fungicides only twice early in the cropping cycle resulted in greater canopy defoliation than the 5-spray regimen. These results were expected given the pathogen causing leaf spot disease is common in these fields and regions of North Carolina [13,20].

The main effect of prohexadione calcium rate was significant for peanut pod yield ($F = 9.5$, $p = 0.0024$). No other interactions of prohexadione calcium and other treatment factors were significant. Peanut pod yield was lower (3,520 kg/ha) when prohexadione calcium was applied compared with non-treated peanut (3,820 kg/ha) (data not shown in tables). These results are surprising given the considerable information in the peer-reviewed literature showing that peanut yield is often similar to or greater than non-treated peanut when prohexadione calcium is applied [2,5,7,19]. Other research in North Carolina [25,26] has shown yield reductions when prohexadione calcium is applied compared with non-treated peanut, especially under dry conditions when two applications are made.

The interaction of fungicide regimen and digging date was significant for pod yield ($F = 13.0$, $p = <0.0001$). The interaction was likely caused by the magnitude of difference in yield for each digging date when comparing the no-fungicide control with the 5-spray fungicide regimen. When comparing within a digging date, protecting peanut from the pathogen causing leaf spot disease resulted in greater yields (Table 2). For each fungicide regimen, a delay in digging past optimum maturity resulted in a decrease in peanut yield.

The highest peanut yield was observed when peanut was dug at optimum maturity following protection from leaf spot disease during the time when the pathogen was most active (e.g., five fungicide sprays) (Table 2). Canopy defoliation caused by leaf spot disease was 29% for this combination of digging date and fungicide regimen compared with 49 to 88% for other treatment factor combinations (Table 2). Previous research [12,14,20] has shown that reductions in peanut yield for Virginia market type cultivars occur when 40% or more of the canopy is defoliated due to this disease.

Table 2: Peanut canopy defoliation 10 da after optimum pod maturity and pod yield based on fungicide regimen.[a]

	Canopy defoliation		Peanut yield	
Fungicide regimen	Pods dug at optimum pod maturity	Pods dug 10 d after optimum pod maturity	Pods dug at optimum pod maturity	Pods dug 10 d after optimum pod maturity
	————— % —————		————— kg/ha —————	
No fungicides	75 b	88 a	3,500 c	2,030 d
Two fungicide sprays[b]	49 d	75 b	4,210 b	3,520 c
Five fungicide sprays[c]	29 e	63 c	4,560 a	4,210 b

[a]Means for canopy defoliation or pod yield followed by the same letter are not significantly different based on Tukey's HSD test at $\alpha = 0.05$. Data are pooled over levels of year, cultivar, and prohexadione calcium treatment.
[b]Treatment included chlorothalonil at 1.4 kg/ha followed by prothioconazole plus tebuconazole at 0.027 kg/ha 14 days later.
[c]Treatment included the following fungicides in order on a 124-d schedule: chlorothalonil, prothioconazole plus tebuconazole, prothioconazole plus tebuconazole, pyraclostrobin, and chlorothalonil. Chlorothalonil, prothioconazole plus tebuconazole, and pyraclostrobin were applied at 1.4 kg/ha, 0.027 kg/ha, and 1.1 kg/ha, respectively.

Lack of differences in canopy defoliation and peanut yield when comparing Bailey to Sullivan was not unexpected. Bailey and Sullivan often express similar levels of resistance to the pathogen causing leaf spot disease [16,17,20].

Conclusion

Results from these experiments indicate that prohexadione calcium can reduce peanut yield compared with non-treated peanut irrespective of fungicide regimen or digging date under the conditions of these experiments. Additionally, canopy defoliation was greater in some instances when prohexadione calcium was applied. Our results contrast those of numerous other studies that demonstrate a positive yield response to prohexadione calcium. There are no other published results in the peer-reviewed literature documenting the impact of prohexadione calcium on canopy defoliation caused by leaf spot disease. Although not substantiated in our research, a more compact plant resulting from prohexadione calcium may create a microenvironment that is more conducive to pathogen development than plants with greater internode lengths. Penetration of fungicide spray into the peanut canopy could be affected by canopy architecture and the compactness of the canopy. Given our results in the context of other experiments, additional research is needed to define interactions of fungicide regimens and subsequent protection of peanut from leaf spot disease and peanut yield.

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