INTEGRATED DISEASE MANAGEMENT IN PEANUT WITH EMPHASIS ON ORGANIC PRODUCTION

by

BRIAN SCOTT JORDAN

(Under the Direction of Albert K. Culbreath)

ABSTRACT

Peanut, *Arachis hypogaea*, has many obstacles in both organic and conventional production systems for disease to weed management. The objective of this study was to evaluate planting date, vigor, and tillage methods in an integrated pest management system. Field trials were conducted at the Gibbs, Ponder, Lang, and Rigdon Farm in 2015 and 2016. No foliar fungicides were applied in any field. Foliar epidemics were more severe at the later planting dates. The tine tillage method was comparable to the hand-weeded checks. Several advanced breeding lines were evaluated for several diseases. A comparison of tools for measuring NDVI was conducted in 2015. Both instruments had similar results when compared to visual ratings using the Florida scale (Chiteka et al. 1988). Georgia-12Y produced greater yields than Georgia-06G in all trials and has the potential to be used with these tools in both production systems for minimizing risks to disease, especially in organic systems.

INDEX WORDS: *Arachis hypogaea*, NDVI, Organic systems, Planting date, integrated pest management, *Sclerotium rolfsii*, *Cercospora arachidicola*, *Cercosporidium personatum*, and resistance.

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DEDICATION

To my family, especially my wife, without their patience and understanding this project would not have been possible.

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INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Early leaf spot and late leaf spot caused by *Cercospora arachidicola* S. Hori, and *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, respectively, are among the most destructive diseases of peanut (*Arachis hypogaea* L.) worldwide. In the southeastern U.S., they cause direct losses in yield and losses through costs of control associated with multiple fungicide applications. Recent estimates for combined direct losses in yield and cost of control attributable to these diseases have been as high as $39.7 million for Georgia alone (Langston, 2009). If not managed, either disease or the combination of the two can cause complete defoliation. High levels of defoliation often result in loss of integrity of the gynophores by which pods are attached to the plant and loss of mature pods when peanut plants are inverted (Knauft et al., 1988, Teare et al., 1984).

Control of leaf spot diseases in the U.S. is very dependent on fungicides (Culbreath et al., 2009). Although fungicides are available for use in conventional production that are very effective, they are expensive and represent potential risks to the environment, the applicator and consumers (Branch and Culbreath, 2008). Synthetic pesticides cannot be used in organic peanut production, and effective fungicides that can be used are much more limited (Cantonwine et al., 2008). Cultivars that have high yield potential and resistance or tolerance to leaf spot diseases would be of benefit to both conventional and organic production systems.

Value of peanut(*Arachis hypogaea)* production in Georgia was estimated at $507.4 million according to the Georgia Farm Gate Report. (Martinez-Espinoza, 2015) The combination of early and late leaf spot is one of the most important problems in peanut causing significant yield reductions. Losses due to leaf spot were estimated at $28.5 million from direct losses and cost of control with fungicides. In the US, the current movement is to reduce pesticide use. In order to accomplish this, alternative methods need to be explored and implemented. Among these methods, tillage, planting dates and seed treatments have implications for affecting one or more peanut diseases, and further characterization of effects of these factors on new cultivars and breeding lines is needed.

An organic system is one way to explore these methods, since synthetic pesticides are not allowed. Currently in the United States, organic production of peanut has remained primarily in Texas and New Mexico. Interest has been growing in Georgia. As of 2013, only 20 acres were dedicated to organic production of peanut. There is a large untapped potential for organic production. Although there is a risk involved in organic production, the potential for increased revenue is present. Sunland Peanut Company in New Mexico, the largest organic processor in the U.S., needs 20% growth per year to meet demand. With yields of 5000 lbs per acre, organic growers could expect to receive $2500 per acre compared to $1000 per acre for conventional peanuts. (Cantonwine E. G., 2006) It has been shown that organic growers can expect 59% more profit compared to conventional. (Sudheer, 2013)

To accomplish this type of production, the entire system needs to be addressed. An integrated management system will have to be implemented. First, cultivars are needed that have resistance and/or tolerance to the leaf spot pathogens, as well as good yield potential. Georgia-12Y has shown good tolerance to leaf spot, as well as a high level of field resistance to tomato spotted wilt virus (Culbreath et al, 2016) and stem rot (*Sclerotium rolfsii).* (W.D. Branch, 2015) Proper cultivar selection is the best way to start a solid organic system. Next, good stands and early season vigor are needed, not only to maximize yield potential but to establish good ground cover to outcompete weeds. In order to have a good stand, causes of damping off need to be determined as well as germination tests to determine optimum temperatures. Weed control is especially challenging in organic production. Mechanical cultivation is the most viable option for control of unwanted weeds. Weed control is an important part of disease management due to the possibility of reservoirs for pathogens. Once cultivars have been chosen, planting date needs to be established. Currently, in Georgia, most growers plant later (mid-May) to avoid TSWV transmission from thrips. However, Georgia-12Y has good resistance/tolerance to TSWV. Planting can potentially be implemented much earlier without increasing the risk of TSWV damage. Cultivars are needed that either provide sufficient suppression of leaf spot epidemics to prevent defoliation or continue to hold onto the pods after defoliation.

Literature Review

Peanut (*Arachis hypogaea* L.*)* is one of the most economically important crops to Georgia. Between 2009 and 2014, reported annual farm gate values for peanut in Georgia ranged from approximately $402 million to over $890 million, with an average of over $570 million per year (2014 Georgia Farm Gate Value Report, 2015).

In 2013, foliar diseases of peanut accounted for losses of $28.5 million in Georgia alone, with cost of control accounting for most of the losses (Martinez-Espinos, 2015). The most important foliar diseases are early leaf spot, *Cercospora arachidicola* S. Hori and late leaf spot, *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton;. If not managed, either of these diseases can cause severe defoliation and yield loss of 50 percent or greater. Significant losses to these pathogens occur every year from both direct losses to the diseases and cost of fungicides applied for their control due to the extreme defoliation.

Organic farming of peanut has the potential to grow substantially in Georgia. Organic farmers are looking to the universities for help in dealing with these diseases in a sustainable manner.

In a low or restricted input system, rotation is crucial for disease management. Crop rotation out of peanut for 2-3 years is needed to prevent or reduce damage by several pathogens. This type of rotation can provide up to a 2-3 week delay in a leaf spot epidemic. (Shokes and Culbreath, 1997) Many of the disease management programs in place are based on some rotation. Programs designed under rotational fields would not be appropriate in fields with continuous peanut plantings and a history of disease. (Woodward et al, 2008) Control of both foliar and soilborne diseases are both helped by crop rotations. Rotations with appropriate crops usually increase yield and quality even when a pathogen has not been identified. Brenneman showed cumulative effects of multiple-year rotations in management of the foliar leaf spots in peanut. The same study showed soilborne and foliar diseases can intensify under a poor rotation schedule in just 4 years. In this case, stem rot increased 10-fold. (Brenneman et al, 1995)

When epidemics of leaf spot occur, defoliation can be very severe. Once the leaves drop, integrity of the pegs may be greatly compromised, resulting in loss of pods during the inverting and harvest process. Information in the literature about peg strength is very limited (Bauman and Norden 1971; Troeger et al, 1976; Thomas et al, 1983; Chapin and Thomas, 2005; Sorensen et al, 2015; Colvin, 2015). There is no information published on peg strength for Georgia-12Y and the breeding lines being proposed. The most recent studies examined peg strength in Tifguard and Georgia-06G (Colvin, 2015) and those cultivars and Georgia-09B (Sorensen et al, 2015). Chapin and Thomas (2005) reported no differential effect of several fungicides on peg strength of healthy pegs in NC-V11.   Determining peg strength has the potential to help determine inverting and digging dates (Sorensen et al, 2015) as well as what the risks of losses are when leaf spot epidemics develop. Peg strength may be a mechanism of tolerance to leaf spot. The standard factor for maturity determination currently used in harvest date estimation is color of the pod mesocarp (Williams and Drexler, 1981). When both pod color and peg strength are used in combination, an appropriate inverting and harvest date might be more effectively identified. Anecdotally, growers in Georgia have complained about Georgia-12Y “not releasing pods” under typical fungicide regimes. If peg strength is stronger in Georgia-12Y than in Georgia-06 and other cultivars, that could be an advantage in production systems in which fungicides are not used or their use is limited. Therefore, it would be very useful to know if peg strength might be a component of tolerance to leaf spot diseases. Peg strength can be measured to evaluate this mechanism and compare to yield.

Tillage methods have moved toward conservation tillage in some areas. It was suspected that conservation tillage will increase disease incidence. However, Porter et al (1991) showed the opposite. Incidence and severity of the leaf spots was higher in conventional plots compared to conservation plots. (Porter et al, 1991) Subsequently in 2000, Monfort reported leaf spot epidemics were less in strip tillage compared to conventional tillage plots. Although disease is generally less in strip tillage plots, yields tend to be lower. (Monfort et al, 2004,2007) Cantonwine investigated effect of strip tillage. Cantonwine results agree with Monfort. In her 3-year study, strip tillage reduced the amount of initial infection. This resulted in 5.7-11.7 days of delay to the leaf spot epidemic. It is hypothesized that the fewer initial infections in the strip tillage regime was due to fewer and less viable conidia and less splash dispersal of initial inoculum from crop debris. It was also shown that in detached trap leaves early infection was significantly lower in the leaves placed in the strip tillage plots.(Cantonwine et al, 2006 and 2007)**.**

Planting date has been shown to be critical for tomato spotted wilt of peanut. It has been shown that middle to late May planting dates typically have a much lower risk of TSWV than earlier planting dates. Higher levels of resistance are required to take advantage of earlier planting dates. (Culbreath et al, 2010) Peanut Rx has different risk values for cultivars. This is related to resistance. The lower the numerical value, the more resistant the cultivar is to TSWV. (Kemerait et al, 2016) Planting date also has different numerical values for planting dates. Little literature is available on planting date effects on leaf spot (Sanden et al, 1981; Shokes et al. 1982) in the southeastern U.S. It is intuitive to think more inoculum is available later in the growing season. Later planting dates typically are recommended in PeanutRx due to tomato spotted wilt. Now, however, cultivars are available that have high levels of field resistance to TSWV. (Culbreath et al. 2016) (Kemerait et al, 2016) Earlier planting dates may allow avoidance of leafspot inoculum. It was reported in 1981 that fewer lesions and less defoliation were associated with the earlier planting dates. The later planting dates decreased yield. (Sanden et al, 1981) In 1982, a similar study found that a late planting date had a six-fold increase in the number of lesions of late leaf spot. (Shokes et al, 1982)

Integrated disease management programs are critical for organic farmers. Some farmers have relied on copper fungicides for leaf spot control. This leads to the concern of copper buildup in the soil since copper is the most used fungicide in organic production (Ma, 1984). The combination of avoidance by planting early with moderate levels of resistance or tolerance in peanut cultivars might provide acceptable levels of control. By planting weekly for approximately 6 weeks in the spring we should be able to determine the appropriate time to plant the six lines that have excellent yield potential to minimize risk of yield loss to leaf spot. Planting date has been looked at in the context of TSWV, and planting between May 10 and June 1 has been recommended to avoid transmission by thrips. (R. C. Nuti, 2014) (Culbreath et al 2010) When TSWV is a major concern on susceptible to moderately resistant cultivars, planting in this time is often essential. However, with higher levels of field resistance to TSWV, the risk is greatly reduced and may allow flexibility in a planting date that would help reduce risk of losses to leaf spot. In preliminary studies, earlier planting dates resulted in higher yields, while leaf spot defoliation was significantly higher and yield decreased in the later planting dates. In the preliminary test, only two cultivars were used. While looking at planting date, it should be noted that this study is based on a rotation of alternating years of peanut and cotton. Rotation is imperative in an alternative disease management program. (J. E. Woodward, 2014)

Germination and stand establishment are even more critical in organic peanut production than conventional, since seed treatment options are limited. Good seed quality is of the utmost importance. Peanut seed can often be infected or infested with fungi that can impede germination rates. Some of the more common fungi are *Aspergillus* spp., *Fusarium* spp., *Rhizopus* stolonifera, and *Penicillium* spp. 46 fungal diseases have been associated with seed infestations. (Al-Amod, 2015) In order to evaluate germination rates and pathogens associated with seeds, a germination table with temperature gradients (Grey et al, 2011) is available that can be used to establish a range of temperatures for seed germination. In a separate test, seed pathogens will be applied to the seed to evaluate the responses under different temperatures. The hope is to find the proper ground temperature for planting seed without pathogen pressure.

As with germination, damping-off is a major concern to a viable stand in both organic and conventional settings. Many of the soil-borne fungi can contribute to damping-off in peanut.

Post-emergence damping-off is often not confirmed, but mostly attributed to *Aspergillus niger*. Many soil pathogens can cause post-season damping-off, such as *Aspergillus flavus, Pythium spp., Rhizoctonia spp., and Cylindrocladium spp.* In order to build an appropriate management strategy, the specific pathogen needs to be determined and quantified.

Weed management is also a key component to organic production. Weeds not only reduce yield, but can be a reservoir for pathogens. Since herbicide use is limited in organic production, mechanical cultivation methods need to be refined to provide maximum weed control with minimal cost and damage to the peanut crop. Hand-weeding is generally not an option due to time involved as well as the cost for labor. Aggressive “dirting” (i.e. moving soil onto the stems and around the crowns of peanuts) may provide additional control of weeds in the row, but has been reported to exacerbate damage by stem rot (*Sclerotium rolfsii*). (Boyle and Hammons, 1956; Garren, 1961; Melouk et al, 1995)   With Georgia-12Y and some of the new breeding lines, resistance to S.rolfsii may be sufficient to allow the hilling of the peanut plants. Hilling is being investigated to provide a means of helping to suppress weed development while the peanut plants are getting established. In other studies, a tine-weeder was used for six weeks and provided greater yield than other methods for control.(Johnson,2014) Several machines for mechanical control of weeds can still be found. The rolling-cultivator, the tine-weeder, and the sweeps are all worth investigating, as well as combinations of all three. (Wann et al. 2011) Managing in-row weeds is of extreme importance in an organic system. It is important to start cultivation early and consistently until plants are well established. (W.C. Johnson, Implements and Cultivation Frequency to Improve In-Row Weed Control in Organic Peanut Production, 2012)The main problem with weed control in organic systems has been the in-row weeds, while between beds can be controlled mechanically. This method of hilling during tillage has not been recommended due to the problem of stem rot incidence. Now that we have resistant cultivars, the peanut production model may be able to be rewritten. The bulletin used by most growers was written in the 1973. (Bulletin 340, UGA Extension)

Sclerotium rolfsii, the cause of stem rot, is one of the most important soil pathogens in peanut production in the southeastern U.S. Plants infected can lose all yield potential. Rotation is used as a way to suppress stem rot (*Sclerotium rolfsii)*. (Garren, 1959) The combination of rotation and resistant cultivars represent the best way to minimize this disease in organic production as well as reduce dependency on fungicides in conventional production. Rotation with cotton, corn, or grass crops has been a standard method of suppressing stem rot in peanut production. In the past, with the wide host range of *S. rolfsii*, it was suspected that rotation would not be effective for stem rot control. However, subsequent studies indicated otherwise. Stem rot loci were low in peanut following two years of grass crops, followed by two years of corn or cotton, with the highest incidence in peanut monocultures. The data from this study showed that the use of corn, cotton, or grass crops in a rotation regime resulted in improved yield and quality. (Johnson et al, 1998) Timper (2009) evaluated 4 different rotation schemes for peanut. The schemes used were 3 years of peanut, 2 years of bahiagrass followed by peanut, 2 years of corn followed by peanut, and 2 years of cotton followed by peanut. The lowest incidence of stem rot was the 2 years of bahiagrass followed by peanut. It should be noted that the 2 years of cotton followed by peanut was not significantly different than the scheme with bahiagrass. The highest yield was found in the 2 years of bahiagrass followed by peanut. This scheme was significantly different than all of the other rotational schemes. (Timper et al, 2001) This was investigated by Brenneman et al (1995) as well. He found the effect of rotation on yield was cumulative with additional years in bahiagrass. The study showed that soilborne disease can intensify with poor rotations in 4 years. Stem rot increased more than 10-fold in the continuous peanut program. (Brenneman et al, 1995)

Row pattern and plant population can have significant effects on TSWV and stem rot. Culbreath showed that twin row planting in peanut can reduce TSWV incidence. (Culbreath et al, 1999) Although this helps with TSWV, the effect of stem rot in the twin row planting was not known. Sconyers et al investigated the effect if twin row patterns on stem rot of peanut. The results of this study showed that severity and incidence of stem rot increased with plants planted close together, and that use of twin row patterns or sparser plant spacing in single rows decreased the ability of the fungus to spread from one plant to another. (Sconyers et al, 2005) Higher density plantings have the potential to be a greater problem in fields planted with susceptible cultivars, especially when fungicides are not an option for stem rot. Higher seeding rates and single row patterns promoted greater incidence of stem rot. It was found that stem rot can be reduced with lower seeding rates in twin rows without compromising TSWV management. (Sconyers et al, 2007)

New peanut cultivars typically have not required as much additional management for spotted wilt as Georgia Green did, and typically have not responded as much as Georgia Green to other inputs such as use of twin row patterns. Therefore, investment in twin-row equipment is not as easily justified. However, if growers have twin-row planters, twin rows help against TSWV and stem rot, but typically have neutral effects on leaf spot diseases (Kemerait et al, 2016) Generally, resistance to S. rolfsii in available cultivars has been limited, with moderate levels of resistance in cultivars Southern Runner, AP-3, Georganic, and Georgia-07W. None of these cultivars have been produced on a large percentage of the peanut acreage in the southeastern United States. Higher levels of resistance have been reported for Virginia cultivar

Bailey (Isleib et al, 2011) and more recently, in the runner-type cultivars Georgia-12Y (Branch, 2013) and Georgia-14N (Branch and Brenneman, 2015). Cultivars with resistance need to be selected. Georgia-12Y has shown good resistance to this pathogen. Resistance in this cultivar might allow the "hilling" method of cultivation. Such practice has been strongly discouraged for many years, but the effects of this practice have not been determined on resistant genotypes. In this study, all the cultivars chosen were exposed to the same conditions as Georgia-12Y to determine resistance or tolerance.

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CHAPTER 2

LEAF SPOT SEVERITY AND YIELD OF NEW PEANUT BREEDING LINES AND CULTIVARS GROWN WITHOUT FUNGICIDES

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ABSTRACT

Peanut (*Arachis hypogaea*) cultivars with resistance or tolerance to *Cercospora arachidicola* and/or *Cercospordium personatum*, the causes of early and late leaf spot, respectively, are needed for organic production in the southeastern U.S. To determine the potential of new breeding lines for use in such production systems, field experiments were conducted in Tifton, GA in 2014 and 2015 in which 9 breeding lines and two cultivars, Georgia-06G, and Georgia-12Y were grown without foliar fungicide applications. In one set of trials cultivar Georgia-12Y and most of the breeding lines evaluated had early season vigor ratings, early-season canopy width measurements, final plant populations and pod yield that were greater than those of standard cultivar Georgia-06G. In those trials, final severity of late leaf spot was lower and canopy reflectance measured as the normalized difference vegetation index (NDVI), was higher for all the breeding lines than those from Georgia-06G. In another set of trials, two of those same breeding lines had final late leaf spot severity ratings similar to those of Georgia-12Y in 2014, whereas in 2015, six of those breeding lines had final leaf spot ratings that were lower than those of Georgia-12Y. Yields were similar for Georgia-12Y and all the breeding lines in the Gibbs Farm trials. Across years and breeding lines at the Lang Farm, the relationship between visual estimates of defoliation and NDVI was described by a two sector piecewise regression with NDVI decreasing more rapidly with increasing defoliation above approximately 89%. The utility of NDVI for spot comparisons among breeding lines appears to be limited to situations where there are differences in defoliation. Georgia-12Y and multiple breeding lines evaluated show potential for use in situations such as organic production where acceptable fungicides available for seed treatment and leaf spot control are limited.

Keywords: *Cercosporidium personatum*, late leaf spot, yield losses, vigor, normalized difference vegetation index (NDVI)

Introduction: Early leaf spot and late leaf spot caused by *Cercospora arachidicola* S. Hori, and *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, respectively, are among the most destructive diseases of peanut (*Arachis hypogaea* L.) worldwide. In the southeastern U.S., they cause direct losses to peanuts through yield reduction and increased management associated with multiple fungicide applications. Recent estimates for combined direct losses in yield and cost of control attributable to these diseases have been as high as $39.7 million for Georgia alone (Langston, 2009). If not managed, either disease or the combination of the two can cause complete defoliation. High levels of defoliation often result in loss of integrity of the gynophores by which pods are attached to the plant and loss of mature pods when peanut plants are inverted (Knauft et al., 1988, Teare et al., 1984).

Control of leaf spot diseases in the U.S. is very dependent on fungicides (Culbreath et al., 2009). Although effective fungicides are available for use in conventional production, they represent potential risks to the environment, the applicator, and consumers (Branch and Culbreath, 2008). They are also expensive, with estimated cost of $216/ha per year, representing approximately 13.7% of the variable costs for irrigated peanut production in Georgia (Rabinowitz and Smith, 2017). Synthetic pesticides cannot be used in organic peanut production, and fungicides that can be used are limited (Cantonwine et al., 2008). Cultivars that have high yield potential and resistance or tolerance to leaf spot diseases would be of benefit to both conventional and organic production systems, but will be necessary for large-scale production in organic systems.

Stand establishment is important for management of tomato spotted wilt, caused by Tomato spotted wilt virus in conventional as well as organic production (Culbreath and Srinivasan, 2011, Kemerait et al., 2016). Cultivars that germinate and emerge quickly with either resistance to prominent damping off pathogens or that are vigorous enough to escape damage by the pathogens would be desirable for both conventional and organic production. Such characteristics would be especially beneficial in organic production systems since few organically acceptable seed treatments are available that provide consistent stand establishment (Cantonwine et al., 2011). In organic production, stand establishment and rapid coverage of the ground by young peanut plants would also help with weed management. Observations in earlier experiments and in production fields indicated that the runner-type peanut cultivar, Georgia-12Y (Branch, 2013) may have potential to improve stand establishment efficiency and reduce time until row middles are covered compared to the predominant cultivar Georgia-06G (Branch, 2007). Several advanced breeding lines have shown similar potential in preliminary trials. Additional characterization of these variables is needed to determine which breeding lines have best potential for use in systems where effective fungicides for foliar disease management or seed treatments are limited.

Visual estimates of percent defoliation or use of the Florida 1-10 severity scale (Chiteka et al., 1988) are effective means of assessing severity of early or late leaf spot in peanut. However, both are subjective, and estimates can vary among evaluators. Measurements of canopy reflectance in the 800 nm wavelength range have been used to assess leaf spot severity (Aquino et al., 1992, Nutter and Littrell, 1996). More recently, Navia Gine (2012) found that a normalized difference vegetation index (NDVI) correlated more closely with percent defoliation by leaf spot in Georgia-06G than reflectance in the near-infrared range. However, the utility of reflectance measurements for evaluating multiple genotypes for response to leaf spot diseases has not been evaluated.

The primary objective of this study was to determine the effect of nine advanced breeding lines and Georgia-12Y on severity of leaf spot epidemics and on yield when grown without application of fungicides for control of leaf spot diseases. Objectives also included determining the effect of new cultivars and breeding lines on stand establishment and early season ground coverage. A secondary objective of this study was to determine how NDVI measurements relate to visual leaf spot severity assessments and whether they might be useful for evaluating genotypes for leaf spot resistance in the field.

MATERIALS AND METHODS

Experimental design, layout, and source of plant materials. Field experiments were conducted in 2014 and 2015 at The University of Georgia, Coastal Plain Experimental Station (UGA-CPES). In each year, one trial was conducted at the Gibbs Farm and one trial at the Lang Farm. The soil type in all fields was a Tifton sandy loam (fine sandy, siliceous thermic Plinthic Paleudult). All the fields from both years had a history of moderate-to-heavy infestations of *C. arachidicola* or *C. personatum* in previous years when peanut was grown. Cotton (*Gossyspium hirsutum*) was grown in the previous season in each of the fields used in this study. Peanuts were planted 14 April in 2014 and 10 April 2015 at the Gibbs Farm, and 30 May 2014 and 20 May 2015 at the Lang Farm. Seeding density was 14.8 seed/m of row in all trials.

A randomized complete block design was used in all trials. Five and three replications were used in 2014 and 2015, respectively at the Gibbs Farm. Five and four replications were used in 2014 and 2015, respectively at the Lang Farm. Plots were 6 m long by 1.8 m wide with two rows for each plot. All trials included 9 advanced breeding lines that had been selected for field resistance to TSWV and *C. personatum* and yield potential when grown without foliar fungicides, and the cultivar Georgia-12Y (Table 1). Georgia-12Y is a high-yielding cultivar with the highest level of field resistance to TSWV available (Culbreath et al., 2016). From preliminary trials, Georgia-12Y has shown indications of maintaining yield even with high levels of defoliation from leaf spot. Georgia-06G has a moderate-high level of field resistance to TSWV (Branch, 2007, Culbreath et al., 2016), but is susceptible to *C. arachidicola*, and *C. personatum*. All of the advanced breeding lines were developed from the cross of Georgia-05E (Branch, 2006) x Georgia Browne (Branch, 1994). Trials at the Lang Farm also included Georgia-06G, the predominant cultivar grown in the southeastern U.S.

Plot establishment and environmental conditions. Soil temperature and rainfall records were obtained from the University of Georgia Automated Environmental Monitoring Network (http://www.georgiaweather.net/) for the station nearest the fields used. Rainfall and irrigation were measured at the Lang Farm with an on-site rain gauge. The average soil temperature indicated at the monitoring station at 10.2 cm depth for three days preceding planting date was 19.9 C in 2014 and 23.9 C in 2015 at the Gibbs Farm, and 27.9 C in 2014 and 22.8 C in 2015 at the Lang Farm. All plots were irrigated as needed. Rainfall amounts during the duration of the experiments at the Gibbs Farm were 15.3 cm in April, 21.4 cm in May, 7.3 cm in June, 7.6 cm in July, 3.8 cm in August and 3.9 cm in September 2014 and 14.3 cm in April, 5.8 cm in May, 8.7 cm in June, 32.5 cm in July, 20.6 cm in August and 0.05 cm in September 2015. Combined rainfall and irrigation amounts during the duration of the experiments at the Lang Farm were 2.4 cm in May, 10.1 cm in June, 12.5 cm in July, 15.2 cm in August, 16.4 cm in September, and 6.0

cm in October in 2014, and 2.3 cm in May, 13.0 cm in June, 32.3 cm in July, 18.4 cm in August, 5.5 cm in September, and 5.1 cm in October in 2015,

Seed treatments and assessment of vigor and plant population. At the Lang Farm, cultivars Georgia-06G and Georgia-12Y were planted with and without seed treatment. In both years, seed treatment consisted of azoxystrobin 0.128 g/kg of seed, fludioxanil 0.008 g/kg of seed, and mefenoxam 0.0016 g/kg of seed applied as Dynasty PD (2.5 g/kg of seed) (Syngenta Crop Protection, Greensboro, NC). No seed treatment was used on any of the other breeding lines, and no seed treatment was used in the trials at the Gibbs Farm. At the Lang Farm in 2014, plant vigor was assessed 32 DAP using an ordinal 0-5 scale where 0 = no plants emerged; 1 = very sparse stand with 0-25% of the row covered; 2 = sparse-moderate stand with 25 – 50% of the row covered; 3 = moderate stand with 50-75% of the row covered; 4 = few interruptions in row coverage with >75% of the row covered and plants growing well; and 5 = no interruptions in the row and plants uniformly growing well.

Canopy width was measured at six arbitrarily chosen points in each plot 32 days after planting (DAP) in 2014 and 56 DAP in 2015 the Lang Farm and 56 DAP in 2015 at the Gibbs Farm locations. Canopy width measurements did not include areas in which there were no plants. Since canopy width measurements at the Lang Farm were made later in 2015 than in 2014, this variable was analyzed independently for each year. At both locations in 2015, immediately after plants were inverted, number of plants were counted for each plot, and converted to plants/m of row, reported as the final population.

Leaf spot assessment. Leaf spot severity was assessed visually using the ordinal Florida 1-10 leaf spot severity scale where 1= no disease, 0% defoliation, and 10=100% defoliation, plants dead, killed by leaf spot (Chiteka et al., 1988). In 2014, leaf spot assessments were made 135

DAP at Gibbs Farm and 142 DAP at Lang Farm. In 2015, leaf spot ratings were made 105, 112, 119, 126, 133, 140, and 147 DAP at the Gibbs Farm and 63, 70, 77, 84, 91, 98, 105, 112, 119, 126, 133, and 140 DAP at the Lang Farm. In 2015, area under the disease progress curve (AUDPC) was calculated as described by Shaner and Finney (1977) and area under the disease stair (AUDPS) was calculated as described by Simko and Piepho (Simko and Piepho, 2012).

Canopy reflectance measurement. Canopy reflectance was measured 147 DAP in 2015 at the Gibbs Farm and 140 DAP in both years at the Lang Farm. An active sensor reflectance meter (Crop Circle model ACS-210, Holland Scientific, Lincoln, NE) which simultaneously measures canopy reflectance in the visible (VIS, centered at 650nm) and near infrared (NIR, centered at 880nm) portions of the light spectrum was used for these measurements. For each plot, a vegetation index, presented as the normalized difference vegetation index (NDVI), was calculated using the formula:

$$\mathrm{NDVI} = (ref\mathrm{NIR} - ref\mathrm{VIS}) / (ref\mathrm{NIR} + ref\mathrm{VIS})$$

where *ref*NIR and *ref*VIS are reflectance measurements for the near infrared and visible portions of the light spectrum, respectively.

For each evaluation, the sensor was carried manually and positioned directly over the center of the row in the nadir view at a distance of approximately 1.0 m above the plant canopy. Scans were made of the entire length of both rows of each plot by walking at a speed of approximately 0.9 m/sec. Sensor readings were recorded 10 times per second, resulting in an average of approximately 125 individual sensor readings per plot. The final output of the sensor was a pseudo-reflectance value for both NIR and VIS bands and the calculated NDVI. The mean of sensor readings for NDVI was calculated for each plot, which was used for analysis and genotype comparisons.

Yield and grade determination. All plots were dug and inverted at 147 DAP at Gibbs Farm in both years, and 140 and 145 DAP at Lang Farm in 2014 and 2015, respectively. Peanut pods were harvested mechanically 7 to 11 days after inverting, and pod yields were determined by weighing harvested pods after they were dried and adjusted to 10% (wt/wt) moisture.

One 1,000-g sample of harvested pods was collected from each plot of two replications in 2014 and all replications in 2015 for grade determination from trials at the Gibbs Farm, and from all plots from the Lang Farm in 2015. In 2014 at the Lang Farm, a similar sample was collected from the bulked yield from all replications for each genotype and seed treatment combination. The samples were cleaned, and non-pod materials were weighed. A 500-g sample of cleaned pods was shelled using commercial shelling equipment for grading. Kernels were classified as sound, immature, or damaged, and the kernels in each category were weighed. The percentages of the 500-g sample represented by sound mature, immature and damaged kernels were determined according to official Federal–State Inspection Service methods (USDA-AMS, 1997). Percent total sound mature kernels (%TSMK) was calculated as the percentage of the 500-g sample that was sound mature kernels.

Data analysis. Data were analyzed using SAS v.9.4 software (SAS Institute, Cary, NC). For all variables except vigor ratings in 2014 and final leaf spot severity ratings in both years, a mixed models procedure was used with maximum likelihood estimation of variance components (Proc Mixed). The Satterthwaite method was used for computing the denominator degrees of freedom ("ddfm=satterth" in the model statement). Since trials at the Gibbs Farm and the Lang Farm differed in the genotypes evaluated, experiments at the two farms were analyzed separately. Data were analyzed across years within each location for variables that were measured similarly in both years. For trials at the Lang Farm, a preliminary factorial (two cultivars x seed treatment) analysis of the effects of seed treatments was conducted using Proc Mixed for all variables that did not use an ordinal scale. If seed treatment had no effect in either cultivar, data for each cultivar were pooled across seed treatments for the main analysis, and are presented in that form. If there was a significant effect in either cultivar, each combination of cultivar and seeding rate were analyzed as separate genotypes in subsequent analysis, and results are presented that way. Genotype was considered a fixed effect, whereas replication, year, and year*genotype interaction effects were considered random effects. Effects were considered significant when $P \leq 0.05$. Fisher's protected least significant difference (LSD) values were computed using standard errors and t-values of adjusted degrees of freedom from the lsmeans /pdiff option for Proc Mixed.

Since early season vigor ratings at the Lang Farm in 2015 and final leaf spot severity in both years and locations were evaluated using ordinal scales that do not represent continuous scales of measurement, these variables were analyzed nonparametrically based on ranks (Shah and Madden, 2004). Each trial was analyzed independently. A preliminary factorial (two cultivars x seed treatment) analysis of the effects of seed treatment was conducted for vigor ratings and final leaf spot severity ratings at the Lang Farm. If seed treatment had no effect in either cultivar, data for each cultivar were pooled across seed treatments for the main analysis, and are presented in that form. If there was a significant effect in either cultivar, each combination of cultivar and seeding rate were analyzed as separate genotypes in subsequent analysis, and results are presented that way. Relative treatment effects and their respective confidence intervals were calculated using the LD_CI macro for SAS (Brunner et al., 2002, Shah and Madden, 2004) and were used to discern differences among the genotypes. Relative treatment effect ($\hat{p}_i$) is estimated from the mean ranks according to:

$$\hat{p}_i = \frac{1}{N}\left(\bar{R}_{i\cdot} - \frac{1}{2}\right)$$

where $\bar{R}_{i\cdot}$ is the mean rank for the treatment among all observations (*N*). Relative treatment effects have a range of 0 to 1.0. Two relative treatment effects were considered different if they each lie outside the confidence interval of the other.

Relationship between NDVI and percent defoliation. Regression analysis was used to examine the linear and nonlinear relationships between NDVI and final percent defoliation for each location. Percent defoliation was calculated from Florida 1-10 severity ratings using the formula developed by Li et al. (2012):

$$\%\,Defoliation = \frac{100}{1 + e^{-\left(\frac{FLSc - 6.0672}{0.7975}\right)}}$$

where FLSc is the Florida scale value.

Nonlinear regression (Proc NLIN, SAS v.9.4) was used for piecewise regression to examine the relationship between NDVI and final percent defoliation. Goodness of fit of the piecewise regression was evaluated by calculating the linear correlation coefficient (R) for the correlation between observed versus predicted values of the model.

RESULTS

Plant vigor and final plant population. At the Lang Farm in 2014, vigor ratings for Georgia - 06G were lower with no seed treatment with treated seed (Table 1.3). Vigor ratings for Georgia 06G with seed treatment were lower than for any other genotype except GA072523-7 (Table 1.1). Vigor ratings for treated vs. nontreated seed were similar for Georgia-12Y, and both were similar to vigor ratings for GA072523-1, GA072523-4, GA072523-8, and GA072523-9, and GA072523-10 (Table 1.1). There was no difference in canopy width for treated and untreated seed within either Georgia-06G or Georgia-12Y in either year (Table 1.1). Canopy width 32 DAP was greater for all breeding lines except GA072523-7 than in nontreated plots of Georgia-06G (Table 1.1), and greater for GA072523-1, GA072523-4, GA072523-9, and Georgia-12Y than for treated plots of Georgia-06G (Table 1.1). In 2015, final population was greater for all breeding lines than for Georgia-06G with or without seed treatment (Table 1.1). In 2015, canopy width at 56 DAP was greater for Georgia-12Y and all breeding lines than for nontreated Georgia-06G, and was similar to or greater than that of treated plots of Georgia-06G in all other genotypes (Table 1.1). At the Gibbs Farm in 2015, canopy width at 56 DAP ranged from 53.9 cm in GA072523-7 to 63.7 cm in GA072523-11, but there was no significant genotype effect (Table 1.1). In that trial, final plant populations for all breeding lines were similar to those of Georgia-12Y (Table 1.1).

Leaf spot final severity, AUDPC, AUDPS and NDVI. Late leaf spot was the predominant (> 95%) foliar disease at both locations in both years. Disease severity was greater in the Lang Farm location than the Gibbs Farm in both years, with final median severity ratings over 7.0 for Georgia-12Y at the Lang Farm, and median final severity ratings 6.0 or lower for all genotypes at the Gibbs Farm in both years (Table 1.2). In 2015, epidemics were evident by 70 DAP at the Lang Farm, whereas similar levels of leaf spot were not observed until 100 DAP at the Gibbs Farm (Fig 1.1.) There were no differences in leaf spot severity, AUDPC, AUDPS, or NDVI in 2015 between seed treatments for either Georgia-06G or Georgia-12Y (Data not shown).

Based on relative treatment effects, leaf spot severity at the Lang Farm was similar for Georgia-06G and Georgia-12Y in 2014, but was higher in Georgia-06G than in Georgia-12Y in

2015 (Table 1.2). Leaf spot severity for Georgia-06G and Georgia-12Y was higher than for any of the new breeding lines in both years. There were no differences among the nine breeding lines in 2014 (Table 1.2). In 2015, GA072523-3, GA072523-7, and GA072523-11 had lower relative treatment effect values than any of the other breeding lines (Table 1.2). At the Gibbs Farm in 2014, final leaf spot ratings were lower in Georgia-12Y, GA072523-7, and GA072523-9 than in any other genotype (Table 1.2). Final leaf spot ratings did not differ among any of the other breeding lines (Table 1.2). In 2015, all breeding lines except GA072523 and GA072523-4 had final leaf spot ratings that were lower than that of Georgia-12Y (Table 1.2).

In 2015 at the Lang Farm, AUDPC and AUDPS were similar for Georgia-06G and Georgia-12Y (Table 1.3), and values for GA072523-7, GA072523-8, GA072523-9, and GA072523-11 were lower than for either cultivar, AUDPS values for GA072523-1, GA072523-3, GA072523-4, and GA072523-10 were also lower than for either of the cultivars (Table 1.3). There were no significant genotype effects on either AUDPC or AUDPS at the Gibbs Farm (Table 1.3).

At the Lang Farm in 2015, NDVI was lower for Georgia-06G than in any other genotype (Table 1.3). NDVI values were lower for Georgia-12Y than for any other genotype except Georgia-06G. Among the other breeding lines, NVDI values for GA072523-7 and GA072523-11 were higher than those of GA072523 (Table 1.5). At the Gibbs Farm, NDVI ranged from 0.777 in GA072523 to 0.805 in GA072523-7, but there were no differences among genotypes (Table 1.3).

Yield and grade. At the Lang Farm, there were no significant differences in yield or %TSMK for seed treatment in Georgia-06G or Georgia-12Y. Across years, all of the breeding lines except GA072523-11 had yields that were greater than those of Georgia-06G and similar to those of Georgia-12Y (Table 1.5). Across years at the Gibbs Farm, there was no significant genotype effect on yield (Table 1.5).

At the Lang Farm in 2014, %TSMK values from bulked samples ranged from 73.0% (Georgia-12Y) to 78.9 (GA072523-1). However, significance of differences among means was not estimable. In 2015, %TSMK, was higher for Georgia-06G than for GA072523, GA072523-8, GA072523-10, and GA072523-11 (Table 1.5), and did not differ among other entries (Table 1.4). Across years at the Gibbs Farm, %TSMK was higher for all breeding lines except GA072523-7 than for Georgia-12Y (Table 1.1).

Relationship between defoliation and NDVI. Across years and genotypes at the Lang Farm, the relationship between NDVI and final percent defoliation was described by a two linear sector piecewise regression with a break point at approximately 88.7% defoliation (Fig. 1.2). NDVI declined more rapidly after that point as defoliation increased. There was no significant regression for NDVI vs percent defoliation for the Gibbs Farm trial in 2015 (Fig. 1.2).

DISCUSSION

For organic peanut production, cultivars are needed that can produce good yields without fungicides. However, reports of evaluations of peanut genotypes primarily for use in organic production in the southeastern U.S. have been limited (Branch and Culbreath, 2013, Cantonwine et al., 2011, Holbrook and Culbreath, 2008, Wann et al., 2011), and only one runner-type peanut cultivar, Georganic, has been released primarily for use in organic production (Holbrook and Culbreath, 2008). Wann et al. (Wann et al., 2011) reported that runner-type cultivars Tifguard and Florida-07 produced higher yield than Georganic when grown without fungicide applications, even when defoliation caused by late leaf spot diseases was lower in Georganic. Branch and Culbreath (Branch and Culbreath, 2013) reported that several new cultivars and breeding lines produced higher yields than Georganic in trials without fungicides or insecticides. In one year of that study, they reported that GA072531, which was released as cultivar Georgia-12Y (Branch, 2013), produced greater yield than Georganic, Tifguard, or Florida-07, despite having more severe leaf spot than Georganic (Branch and Culbreath, 2013). Neither of those studies included Georgia-06G, the predominant cultivar currently grown in conventional production in the southeastern U.S. Results from this study indicate that the cultivar Georgia-12Y and several of advanced breeding lines have better potential for use in organic programs and limited fungicide use programs than Georgia-06G.

Based on final leaf spot severity ratings, several of the breeding lines evaluated in this study are more resistant to *C. personatum* than either Georgia-06G or Georgia-12Y. With median final leaf spot severity ratings in the Lang Farm trials of 4.8 or higher, it is evident that these breeding lines have only partial resistance to *C. personatum*. Although all of the breeding lines had lower final leaf spot severity ratings than Georgia-06G or Georgia-12Y in 2015, epidemics were evident earlier in most of the lines than in Georgia-06G or Georgia-12Y. Likely, this was the reason several breeding lines had AUDPC values that did not differ from that of Georgia-06G. AUDPS for GA072523 and Georgia-12Y did not differ from that of Georgia-06G at the Lang Farm, and there were no differences among entries for either AUDPC or AUDPS at the Gibbs Farm. Use of either AUDPC or AUDPS solely for comparison of genotypes could result in erroneous conclusions regarding best lines for use in managing leaf spot based on severity at the end of the season. Additional work is needed to characterize the effects of these breeding lines on leaf spot epidemics in the field, and to determine which components of resistance are responsible for the lower final leaf spot severity observed in this study.

Georgia-06G has shown some tolerance to defoliation by leaf spot diseases (Navia Gine, 2012). Although direct comparisons are not possible, yields of Georgia-06G in this study were similar to the higher yields reported by Branch and Culbreath (Branch and Culbreath, 2013) or Wann et al. (Wann et al., 2011) in trials without fungicides for disease control. Similarly, direct comparisons cannot be made, but for perspective, the average yield for conventional peanuts for Georgia in 2015 was 4928 kg/ha, the second highest average yield on record (Rabinowitz and Smith, 2017). Although final leaf spot severity for Georgia-12Y was lower than that of Georgia-06G in 2015, Georgia-12Y had high levels of defoliation in both years at the Lang Farm. However, it had higher yield than that of Georgia-06G, and yields that were similar to other breeding lines for which leaf spot severity was lower. This suggests that tolerance to defoliation by late leaf spot may be a factor in this cultivar. Regardless of the factors responsible for higher yield production, these results indicate that Georgia-12Y and most of the breeding lines examined have better yield potential than that of Georgia-06G when grown without fungicides.

None of the breeding lines had grades as high as Georgia-06G in 2015, but most were comparable to Georgia-12Y. Considering the yield potential without fungicides, grades obtained in most of the lines were likely adequate.

In the absence of tomato spotted wilt, runner-type peanut plants often can compensate for sparse plant populations with minimal reduction in yield. Knauft et al. (1981) reported no reduction in yield for the cultivar Florunner for plant populations of 9.8 and 6.6 plants/m of row, and no difference in yield for three genotypes across a range of 9.8 to 3.3 plants/m of row. However, plant population affects severity of tomato spotted wilt in peanut, and establishing plant populations of 13.1 plants/m or greater are recommended to minimize damage by that disease (Culbreath and Srinivasan, 2011). Stand establishment and early season vigor can be more critical in organic production systems. In addition to affecting severity of tomato spotted wilt, plant population can be a critical factor in weed management (Wann et al., 2011). Wann et al. (2011) reported that sparse stands with some genotypes resulted in complete loss of the plots to weeds even with mechanical cultivation, whereas the same cultivation methods provided weed control adequate to allow harvest with genotypes that had greater plant populations and covered the area between rows was covered more rapidly.

Few studies have addressed stand establishment and early season vigor of peanut genotypes for organic production (Tubbs et al, 2013). Cantonwine et al. (2011) reported that multiple genotypes had better seedling establishment rates and produced greater biomass than the cultivar Georganic but did not report on disease susceptibility or pod yield of those lines. The field experiments at the Lang Farm in this study indicate that Georgia-12Y and several breeding lines show better potential for stand establishment and more rapid ground coverage than the current standard cultivar Georgia-06G. Based on early season vigor ratings in 2014, final plant populations in 2015, and canopy width measurements in both years, Georgia-12Y and multiple breeding lines with no seed treatment had greater populations and vigor measurements than Georgia-06G with standard seed treatment. Rapid coverage of the ground between rows should help with weed competition in organic production where conventional herbicides are not allowed. In this study, conventional herbicide regimes were used for weed control, so the effects on weed control were not discernable. However, studies are in progress in which Georgia-06G, Georgia-12Y, and selected other lines are being compared for weed competition and response to various cultivation methods for weed control without herbicides. Stand establishment and early season vigor in Georgia-12Y and the breeding lines are especially noteworthy, considering that several cultivars released previously with excellent combinations of resistance to TSWV and leaf spot pathogens had major problems with stand establishment, even with conventional seed treatments (Thornton et al., 2011). Additional work is needed to characterize what genetic or physiological factors are responsible for the apparent increased vigor observed in Georgia-12Y and these breeding lines compared to Georgia-06G.

Although the breeding lines included in this study have similar parentage, there was some variation in their effects on resistance to leaf spot. However, differences in leaf spot severity among the breeding lines were small relative to the difference between any of the lines and Georgia-06G. There was also some variation in yield among the breeding lines, but there was no difference in yield that corresponded with difference in leaf spot severity, and all but one had yields that were greater than that of Georgia-06G.

Canopy reflectance has been used as an indication of leaf spot severity in peanut (Aquino et al., 1992, Navia Gine, 2012, Nutter et al., 1990, Nutter and Littrell, 1996). Use of canopy reflectance represents a more objective assessment than visual assessments, and one which could help minimize variability among evaluators. Although reflectance measurements in this study were obtained with a hand-carried instrument, there is potential to obtain such measurements with remote sensing. Nonetheless, there are limitations to the use of reflectance for leaf spot assessment. Navia Gine (2012) reported correlation between NDVI and defoliation caused by early leaf spot within cultivars, but NDVI values were not a good predictor of relative severity of leaf spot when defoliation levels were low. These results likewise indicated that NDVI is not useful for evaluating late leaf spot severity before defoliation is evident. In 2015, there were no differences among genotypes for NDVI at the Gibbs Farm, when defoliation levels represented by the highest leaf spot ratings were less than 50 percent (below 6.0 on the Florida 1-10 scale, Chiteka et al, 1988). In that trial, differences among entries were discernable based on visual ratings. However, results from this study indicate that NDVI may be useful for comparing leaf spot severity in different genotypes if there are differences in defoliation. Across years at the Lang Farm, with severe epidemics and a wide range of defoliation, NDVI values gave similar separation among the genotypes as visual assessment for final disease severity. All lines had higher NDVI measurements and lower final disease ratings than Georgia-06G. However, rate of decline of NDVI with increasing levels of defoliation was greater with levels of defoliation above 88% than it was with lower levels. Genotypes may differ in reflectance even with little or no leaf spot (Navia Gine, 2012), so making conclusions about resistance based solely on NDVI measurements is not advised. However, such measurements show potential for use in characterizing response to leaf spot if epidemics are severe enough to cause defoliation and appropriate confirmation of disease levels is made. To the best of our knowledge, this the first report of use of NDVI measurements for comparison of peanut genotype responses to late leaf spot. Studies are in progress in which reflectance measurements and visual assessments over time are being compared in some of these same breeding lines.

This study has implications for areas in which growers do not have access to fungicides or where fungicides are cost prohibitive, in addition to production situations such as organic production where fungicide use is limited or not acceptable. These results indicate that peanut genotypes with the combination of the potential for good stand establishment and early season vigor with resistance or tolerance to late leaf spot and good yield potential are available. In addition, these results indicate that the use of NDVI has potential for assessing leaf spot severity in peanut genotype evaluations for leaf spot resistance in trials where defoliation in more susceptible genotypes is over 50 percent.

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Table 1.1. Effect of peanut genotype on canopy width, normalized difference vegetation index (NDVI), yield and grade, University of Georgia, Gibbs Farm, Tifton, 2014-2015.

Genotype	Canopy[a] width (cm) 2015	Stand[b] Plants/m 2015	NDVI[c] 2015	Yield[d] (kg/ha) 2014-2015	% TSMK[d e] 2014-2015
GA072523	61.1	10.8	0.7767	5334	77.1
GA072523-1	55.5	10.3	0.7955	5792	77.6
GA072523-3	62.8	10.2	0.7919	5796	77.5
GA072523-4	60.1	10.6	0.7985	5587	76.8
GA072523-7	53.9	10.2	0.8049	5519	76.4
GA072523-8	62.1	10.6	0.7994	5956	77.4
GA072523-9	61.7	10.3	0.7997	5874	77.8
GA072523-10	59.4	10.8	0.8016	5668	77.4
GA072523-11	63.7	11.4	0.8009	5668	78.6
Georgia-12Y	60.8	9.5	0.8018	6133	75.2
	ns	ns	ns	ns	1.4

[a] Canopy width (cm) was measured at six arbitrarily chosen points in each plot at 56 DAP in 2015.

[b] Final plant density (plants/m of row) determined by counting taproots immediately after plants were inverted.

[c] Normalized difference vegetation index (NDVI) measured 147 days after planting, immediately before plants were dug and inverted

[d] There was no significant year*genotype interaction for either yield ($P > 0.05$) or percent total sound mature kernels ($P > 0.05$). Therefore data were analyzed across years, and means presented are from data pooled for the two years.

[e] Percentage of total percent sound mature kernels of a 500 g sample of in-shell peanuts, after drying to 10% moisture.

Table 1.2. Effect of peanut genotype on final leaf spot severity rating, area under the disease progress curves (AUDPC), and estimated relative treatment effect for severity and AUDPC, Gibbs Farm, 2014 and 2015.

	Final leaf spot severity rating[a]						AUDPC[b]		
	2014			2015			2015		
Genotype	Mean	Rte[c]	CI[d]	Mean	rte[c]	CI[d]	Mean	rte[c]	CI[d]
GA072523	4.4	0.65	0.48, 0.81	5.0	0.68	0.41, 0.94	152	0.67	0.25, 0.90
GA072523-1	4.2	0.57	0.43, 0.71	3.7	0.30	0.08, 0.52	138	0.36	0.13, 0.71
GA072523-3	4.6	0.72	0.56, 0.89	4.6	0.59	0.42, 0.77	155	0.79	0.56, 0.90
GA072523-4	4.8	0.75	0.56, 0.93	4.6	0.56	0.09, 1.0	147	0.48	0.16, 0.82
GA072523-7	3.4	0.27	0.11, 0.44	3.6	0.27	0.11, 0.43	131	0.18	0.08, 0.44
GA072523-8	4.2	0.57	0.43, 0.72	3.8	0.34	0.19, 0.50	143	0.43	0.20, 0.70
GA072523-9	3.4	0.27	0.11, 0.44	4.5	0.52	0.23, 0.82	145	0.47	0.29, 0.66
GA072523-10	4.2	0.57	0.43, 0.72	3.3	0.18	0.0, 0.39	148	0.58	0.34, 0.78
GA072523-11	4.0	0.50	0.28, 0.71	4.8	0.64	0.42, 0.86	142	0.44	0.17, 0.77
Georgia-12Y	3.0	0.12	0.08, 0.16	5.8	0.90	0.83, 0.97	150	0.60	0.21, 0.88

[a] Final leaf spot severity rating based on Florida 1-10 scale where 1 = no disease, and 10 = plants completely defoliated and killed by leaf spot (Chiteka et al. 1988).

[b] Area under the disease progress curve calculated from seven evaluations using the Florida 1-10 leaf spot severity scale.

[c] Estimated relative treatment effects was calculated by the method of Shah and Madden (2004).

[d] Confidence interval (95%) for the respective relative treatment effect.

Table 1.3. Effect of peanut genotype on vigor rating, canopy width, and final plant population, The University of Georgia Lang Farm, 2014.

		Plant vigor rating[a] 2014			Canopy width (cm)[d]		Plant density[e] (plants/m of row)
Genotype	Seed treatment	Mean	Relative treatment effect[c]	Confidence interval[d]	2014	2015	2015
GA072523	None	3.5	0.48	0.27, 0.69	25.6	83.5	11.0
GA072523-1	None	3.9	0.68	0.56, 0.80	26.5	86.5	10.8
GA072523-3	None	3.4	0.45	0.21, 0.69	25.4	86.7	10.9
GA072523-4	None	3.7	0.58	0.39, 0.77	27.3	87.9	10.9
GA072523-7	None	3.2	0.34	0.15, 0.52	23.1	82.1	11.8
GA072523-8	None	3.9	0.68	0.57, 0.80	25.8	89.3	10.7
GA072523-9	None	3.8	0.63	0.49, 0.76	27.9	86.0	11.5
GA072523-10	None	3.7	0.53	0.26, 0.79	25.7	86.7	11.7
GA072523-11	None	3.6	0.47	0.23, 0.73	25.1	82.3	10.9
Georgia-12Y	Treated	4.0	0.67	0.49, 0/85	27.9	84.3	10.9
Georgia-12Y	None	4.1	0.72	0.48, 0.96	27.5	84.7	10.9
Georgia-06G	Treated	2.9	0.21	0.14, 0.27	23.7	72.9	9.0
Georgia-06G	None	2.2	0.04	0.04, 0.08	21.3	75.1	9.3

[a] Plant vigor was assessed using a 0-5 scale where 0 = no plants emerged, and 5 = no interruption in the in the row and plants growing well.
[b] Estimated relative treatment effects was calculated by the method of Shah and Madden (2004).

[c] Confidence interval (95%) for the respective relative treatment effect.

[d] Canopy width (cm) was measured at six arbitrarily chosen points in each plot at 32 days after planting (DAP) in 2014 and 56 DAP in 2015. Since time of measurement differed by over three weeks, results from the two years are presented independently.
[e] Final plant density (plants/m of row) determined by counting taproots after plants were inverted.

Table 1.4. Effect of peanut genotype on final leaf spot disease severity in 2014-2015 and area under the disease progress curve for leaf spot epidemics in 2015, The University of Georgia, Lang Farm, Tifton, GA.

	Final leaf spot severity[a] 2014-2015			Area under the disease progress curve[b] 2015		
	Mean	rte[c]	cls[d]	Mean	rte[c]	cls[d]
GA072523	6.0	0.51	0.40, 0.63	326	0.59	0.39,0.79
GA072523-1	5.5	0.39	0.28, 0.51	324	0.53	0.25,0.79
GA072523-3	5.3	0.34	0.24, 0.45	325	0.55	0.44,0.65
GA072523-4	5.4	0.37	0.25, 0.47	328	0.60	0.40,0.77
GA072523-7	5.2	0.29	0.18, 0.44	295	0.12	0.07,0.22
GA072523-8	5.3	0.32	0.20, 0.44	308	0.25	0.14,0.44
GA072523-9	5.3	0.32	0.21, 0.46	304	0.23	0.13,0.39
GA072523-10	5.6	0.42	0.29, 0.55	329	0.61	0.34,0.82
GA072523-11	4.9	0.20	0.11, 0.36	297	0.13	0.06.0.29
Georgia-12Y	7.5	0.78	0.74, 0.81	321	0.70	0.54, 0.81
Georgia-06G	8.5	0.89	0.82, 0.91	326	0.73	0.58, 0.83

[a] Leaf spot severity ratings made 147 and 140 days after planting in 2014 and 2015, respectively, using Florida 1-10 scale where 1 = no disease, and 10 = plants completely defoliated and killed by leaf spot (Chiteka et al. 1988). Preliminary analysis indicated similar rankings for the two years; therefore data from the two years was pooled for analysis.

[b] Area under the disease progress curve calculated from seven evaluations in 2015 using the Florida 1-10 leaf spot severity scale.

[c] Estimated relative treatment effects was calculated by the method of Shah and Madden (2004).

[d] Confidence interval (95%) for the respective relative treatment effect.

Table 1.5. Effect of peanut genotype on canopy width, final plant population, normalized difference vegetation index (NDVI), yield and grade, The University of Georgia, Lang Farm, Tifton, 2014-2015.

	NDVI[a]	Pod Yield[b] (kg/ha)	% TSMK[c]	
Geontype	2014-2015	2014-2015	2014	2015
GA072523	0.7138	6380	74.0	68.9
GA072523-1	0.7386	6901	78.9	70.4
GA072523-3	0.7258	6743	75.6	72.5
GA072523-4	0.7370	6497	76.6	70.7
GA072523-7	0.7501	6555	76.0	70.4
GA072523-8	0.7294	6323	76.8	69.2
GA072523-9	0.7309	7078	76.2	70.7
GA072523-10	0.7313	6898	77.4	69.5
GA072523-11	0.7499	6093	76.3	67.9
Georgia-12Y	0.6860	6792	73.0	72.3
Georgia-06G	0.5882	5564	78.0	73.9
LSD	0.024	646	na[d]	4.0

[a] Normalized difference vegetation index (NDVI) measured 140 DAP in each of 2014 and 2015. There was no significant year*genotype interaction ($P > 0.42$) on NDVI. Therefore data from the two years were analyzed pooled across the two years.

[b] There was no significant year*genotype interaction ($P > 0.0.5$) on yield. Therefore data from the two years were analyzed pooled across the two years.

[c] Percentage of total percent sound mature kernels of a 500 g sample of in-shell peanuts, after drying to 10% moisture.

[d] Values presented for 2014 were from one sample taken from the bulked yield from all replications of each genotype. Therefore, analysis of genotype effects was not possible.

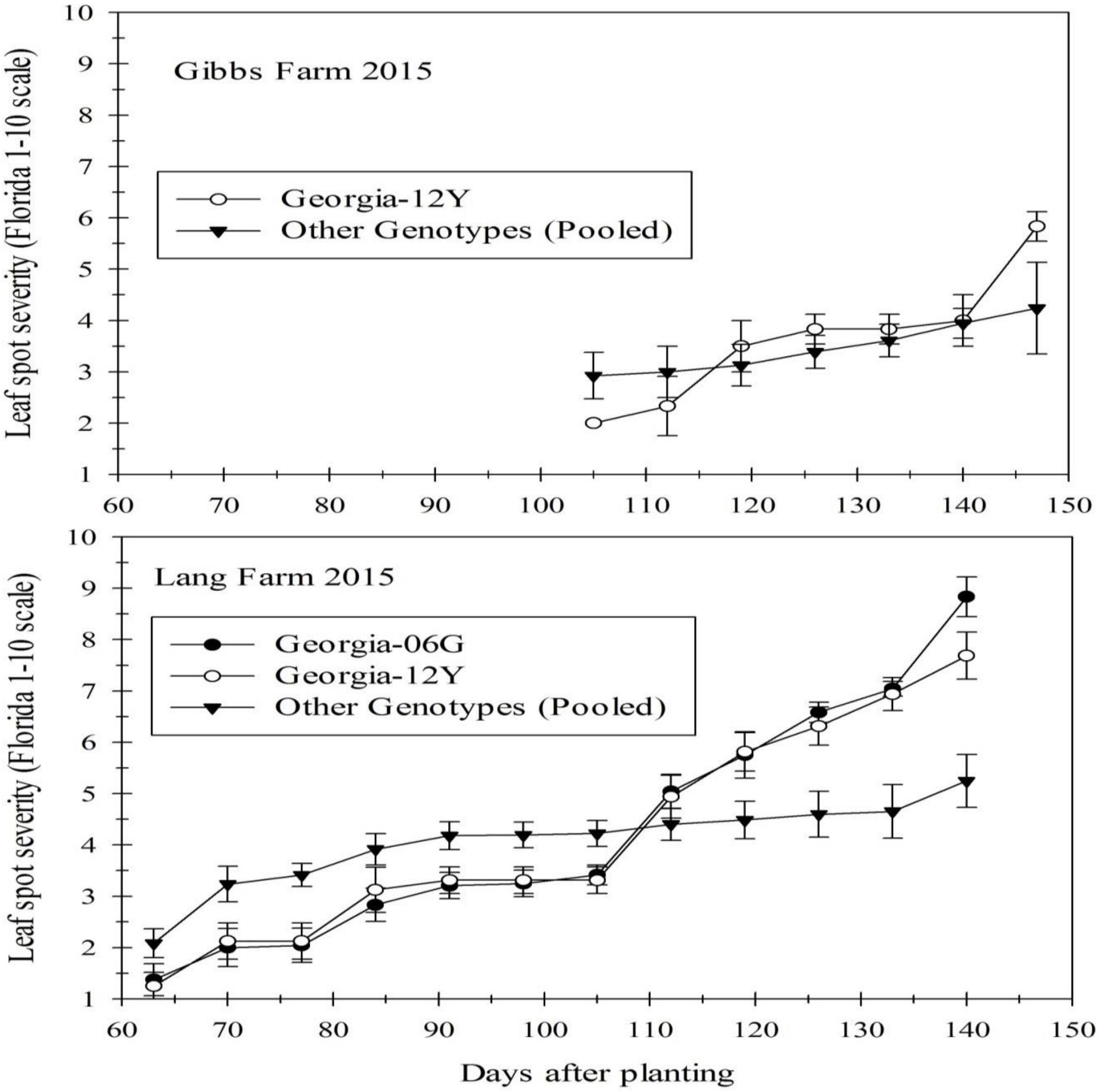

Figure 1.1: Effect of peanut genotype on disease progress of late leaf spot, caused by *Cercosporidium personatum*, at Gibbs Farm and Lang Farm locations, Tifton, GA in 2015.

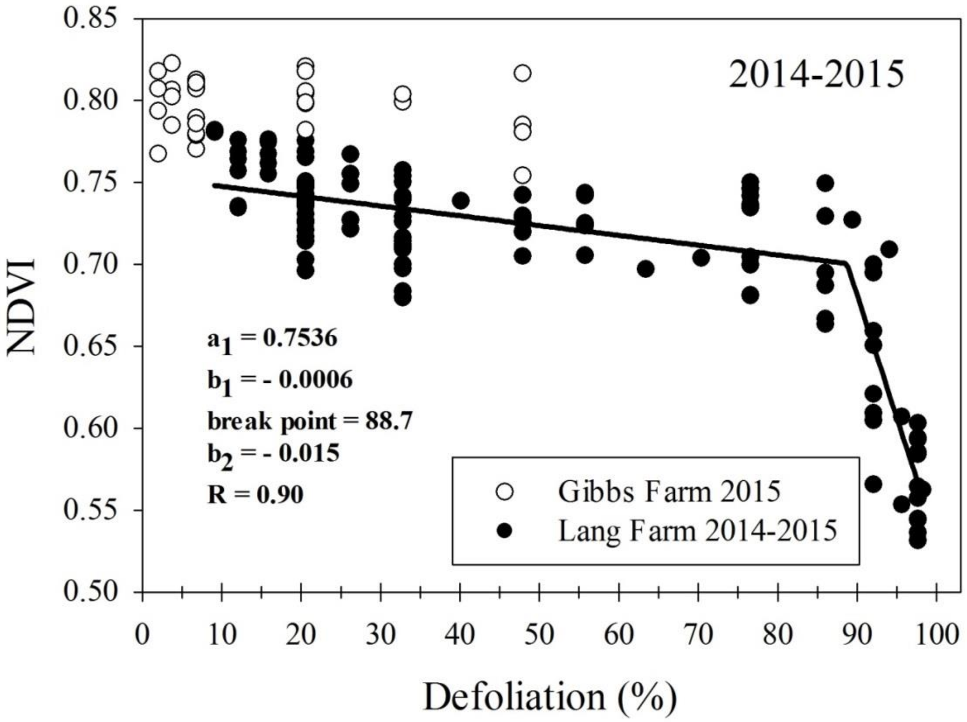

Figure 1.2: Relationship between normalized difference vegetation index (NDVI) and visually assessed percent defoliation in peanut at the Lang Farm location in 2014 and 2015 and the Gibbs Farm location in 2015, Tifton, GA.

CHAPTER 3

EFFECT OF PEANUT CULTIVAR AND PLANTING DATE ON LEAF SPOT EPIDEMICS

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ABSTRACT

Planting date can affect the risk of losses to early and late leaf spot caused by, *Cercospora arachidicola* and *Cercosporidium personatum*, respectively, of peanut, *Arachis hypogaea*, in both conventional and organic systems. The objective of this study was to characterize the effect of planting date on leaf spot epidemics and yield in new cultivars with moderate tolerance to these diseases. Field trials were conducted in 2015 and 2016 in Tifton, GA. Treatments were six planting dates (24 and 27 April, 4, 11, 19, and 26 May in 2015 and 11, 18, 25 April 2, 9, and 16 May in 2016) arranged factorially with two cultivars, Georgia-06G and Georgia-12Y. The experimental design was a randomized complete block with 4 replications. No foliar fungicides were applied. Late leaf spot was the predominant disease and epidemics were severe in plots planted at the later dates in both years. Final leaf spot ratings (Florida 1-10 scale) and AUDPC increased linearly with later planting date (Julian day) for both cultivars. Yield of Georgia-06G decreased linearly, and yield of Georgia-12Ydecreased according to a quadratic function with later planting. For most planting dates, final leaf spot severity and AUDPC were lower, and yield was higher for Georgia-12Y than for Georgia-06G. The combination of early planting with Georgia-12Y shows potential for reducing risks of losses to leaf spot and maximizing yield in situations such as organic production where fungicide use would be minimal.

Introduction

Early leaf spot and late leaf spot caused by *Cercospora arachidicola* S. Hori, and *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, respectively, are among the most destructive diseases of peanut (*Arachis hypogaea* L.) worldwide. If not managed, either disease or the combination of the two can cause complete defoliation.

Control of leaf spot diseases in the U.S. is heavily dependent on fungicides (Culbreath et al., 2009). Although numerous effective fungicides are available for use in conventional production, few effective products are available that that can be used in organic production (Cantonwine et al., 2008). Cultivars that have high yield potential and resistance or tolerance to leaf spot diseases would be of benefit to both conventional and organic production systems. Georgia-12Y (Branch, 2013) is a new cultivar with some apparent tolerance to late leaf spot (Jordan et al, 2017). Although it has only a low level of field resistance compared to the standard susceptible cultivar Georgia-06G (Branch, 2007), it produced excellent yield without fungicide application (Jordan et al, 2017) and may have potential for use in organic production.

Cultural practices such as choice of planting date can also affect leaf spot epidemics (Lassiter et al, 2016). In the southeastern U.S., earlier planting dates may allow avoidance of leaf spot inoculum and resultant epidemics. Sanden et al. (1981) reported that fewer lesions and less defoliation were associated with the earlier planting dates, 22 and 25 April, but later planting dates (21 and 23 May) were associated decreased yield (Sanden et al, 1981). In 1982, a similar study by Shokes et al. (1982) found that a late planting date (approximately May 23) had a six-fold increase in the number of lesions of late leaf spot compared to an earlier planting date. In recent years, there has been little reported on effect of planting date on leaf spot. One reason for this is that earlier planting dates often result in more severe epidemics of tomato spotted wilt, caused by Tomato spotted wilt virus (Culbreath et al, 2010). Mid- to late May planting dates typically have a much lower risk of tomato spotted wilt than earlier planting dates (Culbreath et al, 2003, Kemerait et al, 2016). On cultivars with low to moderate levels of field resistance to TSWV, choice of planting dates to minimize risk of losses to tomato spotted wilt was critical (Culbreath and Babu, 2011). However, higher levels of field resistance to TSWV, may allow planting earlier without increasing the risk of losses to TSWV (Culbreath et al, 2010). Cultivars such as Georgia-12Y (Branch, 2013) are available that have high levels of field resistance to TSWV (Culbreath et al, 2016). The combination of avoidance by planting early with moderate levels of resistance or tolerance to leaf spot in peanut cultivars might provide acceptable levels of control.

Establishment of adequate plant populations with good early-season vigor is also a challenge in organic production systems. There are few organically acceptable seed treatments available that provide consistent protection from seed rots and damping off (Tubbs et al, 2013). Emergence and vigor of most peanut cultivars are affected greatly by soil temperature (Beasley, 2008). Planting recommendations typically include having soil temperatures of > 18º C at 10 cm soil depth of for three days prior to planting peanuts (Sullivan et al, 1987). In the southeastern U.S., earlier planting dates (before 1 May) typically are associated with lower soil temperatures than later planting dates. Therefore, cultivars that tolerate cooler temperatures would be desirable for use with earlier planting dates. Similarly, cultivars with resistance to prominent damping off pathogens or that are vigorous enough to escape damage by the pathogens would be desirable for both conventional and organic production. Observations in earlier experiments and in production fields indicated that the runner-type peanut cultivar, Georgia-12Y (Branch, 2013) may have potential to improve stand establishment efficiency and reduce time until row middles are covered compared to the predominant cultivar Georgia-06G (Jordan et al, 2017).

The primary objectives of this study were to determine the effects of planting date on leaf spot epidemics and yield in Georgia-12Y and the standard cultivar Georgia-06G, with particular emphasis on whether use of early planting allows avoidance of more severe leaf spot epidemics.

A second objective of this study was to determine the effect of cultivar and planting date on early-season vigor and stand establishment.

Materials and Methods

Experimental design, and layout and treatment structure. Field experiments were conducted in 2015 and 2016 at the University of Georgia, Coastal Plain Experiment Station (UGA-CPES). Trials were conducted at the Lang Farm in 2015 the Rigdon Farm in 2016. The soil type in both fields was a Tifton sandy loam (fine sandy, siliceous thermic Plinthic Paleudult). Both fields had a history of moderate-to-heavy infestations of *C. arachidicola* or *C. personatum* in previous years when peanut was grown. The fields were rotated with cotton every other year.

A randomized complete block design was used in both years. Treatments consisted of two cultivars, Georgia-06G and Georgia-12Y, two seed treatments (conventional seed treatment and nontreated seed) in factorial arrangement with six planting dates. Four replications were used in both years. Plot length was 9.2 m in 2015 and 6.7 m in 2016. Plots were 1.8 m wide with two rows 0.9 m apart for each plot. Seed was planted at 12 seed per meter and at a depth of 4cm deep.

Environmental conditions. Soil temperatures were obtained from the University of Georgia Automated Environmental Monitoring Network (http://www.georgiaweather.net/) from a monitoring station approximately 2.9 km from the field site. The average temperature at 10.2 cm depth for six days preceding planting date was 20.6 C, 24.17 C, 20 C, 25.32 C, 27.8 C, and 29.2 C in 2015, and 18.78 C, 16.2 C, 21.56 C, 27.17 C, 23.59 C, and 27.37 C in 2016.

Rainfall and irrigation data was collected in both years. Monthly rainfall totals were 14.3, 2.3, 8.8, 32.5, 11.1, 3.9, 4.9, 11.9 and 16.1, 3.7, 1.0, 8.6, 16.1, 15.7, 0.2, 1.8 cm for the months of April through November in 2015 and 2016. Rainfall totals for the experiments were 89.7 in 2015 and 71.9 cm in 2016. All plots were irrigated as needed to maintain favorable conditions for leaf spot epidemics and for peanut growth. Total combined rainfall and irrigation for each planting date was 90.63, 90.45, 88.75, 88.11, 80.14, and 86.06 cm for April through November in 2015, and 63.63, 61.75, 75.18, 73.63, 74.37, and 74.42 cm in 2016, respectively. The historical yearly average for these locations is 119.38cm.

Plant population and vigor assessment. Early season mean stand counts were calculated by counting emerging plants in a 3 m section of row in two arbitrary locations in each plot. The 2 measurements were then averaged to get a mean stand count. The measurements were taken 14 days after planting (DAP). Plant canopy width was measured at 56 DAP in both years as a way to quantify vigor. Width of the canopy was measured at six arbitrarily chosen locations within each plot. The average of the six measurements for each plot was used for analysis. Immediately after plants were inverted, the number of plants were counted in a 3m length of row for each plot, converted to plants/m of row, and reported as the final population.

Disease assessment. Incidence of tomato spotted wilt, caused by Tomato spotted wilt virus (TSWV) was evaluated 98 DAP in 2015 and 91 DAP in 2016. Incidence was determined by counting the number of 0.3-m portions of row containing severely stunted, chlorotic, wilted or killed by TSWV for each plot and converting that number to a percentage of total row length (Culbreath et al, 1997).

Leaf spot severity was assessed visually using the ordinal Florida1-10 Leaf Spot Scale where 1=no disease, 0% defoliation, and 10=100% defoliation with plants dead, killed by leaf spot (Chiteka et al., 1988). Leaf spot ratings were made within each planting date at 90, 97, 104, 111, 118, 126, 133, and 140 DAP in 2015 and 105, 112, 119, 126, and 133 DAP in 2016. Disease progress was plotted as leaf spot severity ratings over time in days after planting. The area under the disease progress curve was calculated for each plot as described by Shaner and Finney (1977) using Florida 1-10 scale ratings.

Immediately after plots were inverted, plants were examined for damage from stem rot, caused by *Sclerotium rolfsii*. Incidence of stem rot was determined by counting the number of 0.3 m portions of row with symptoms of the disease or signs of *S. rolfsii* (Rodriguez-Kabana et al. 1975). The number of 0.3 m portions of row was converted to percent of the total row with stem rot.

Harvest, yield and quality assessments. Plots of Georgia-06G were dug and inverted 136 DAP in 2015 and 135 DAP in 2016. Plots of Georgia-12Y were dug and inverted 145 DAP in both years. In all cases except Georgia-12Y the last planting date in 2015, inverted plants were allowed to dry in the field 7 to 11 days. For the last planting date for Georgia-12Y in 2015, harvest was delayed due to wet conditions in the field. The plants were inverted on time, but were in the field for 15 days. Peanut pods were harvested mechanically. Pod yields were determined by weighing harvested pods after they were dried and adjusted to 10% (wt/wt) moisture.

A 1,000-g sample of harvested pods was collected from each plot for grade determination. The samples were cleaned, and non-pod materials were weighed. A 500-g sample of cleaned pods was shelled using commercial grading equipment. Kernels were classified as sound, immature, or damaged, and the kernels in each category were weighed. The percentage of the 500-g sample represented by sound mature, immature, and damaged were determined according to official Federal-State Inspection Service methods (USDA-AMS, 1997). The percent total sound mature kernels (%TSMK) was calculated as the percentage of the 500-g sample.

Data analysis. Data were analyzed using SAS v.9.4 software (SAS Institute, Cary, NC). For row canopy width, final plant population, incidence of spotted wilt, AUDPC for leaf spot, incidence of stem rot, percent TSMK, and yield, a mixed models procedure was used with maximum likelihood estimation of variance components (PROC MIXED). The Satterthwaite method was used for computing the denominator degrees of freedom ("ddfm=satterth" in the model statement). Since planting dates differed in the two years, experiments were analyzed separately. Cultivar, seed treatment and planting date were considered fixed effects, whereas replication, effects were considered random. Effects were considered significant when $P \leq 0.05$. Fisher's least significant difference (LSD) values were computed using standard errors and t-values of adjusted degrees of freedom from the pdiff option in PROC MIXED. Regression analysis (PROC GLM) was used to determine the relationship between these variables and ordinal planting date values.

Final leaf spot severity ratings from both years were analyzed nonparametrically based on ranks using Proc Mixed of SAS v.9.4 software (SAS Institute, Cary, NC) (Shah and Madden, 2004). Relative treatment effects and their respective confidence intervals were calculated using the LD_CI macro for SAS (Brunner et al., 2002, Shah and Madden, 2004) and were used to discern difference among treatments. Relative treatment effect ($\widehat{p}_i$) is estimated from the mean ranks according to:

$$\hat{p}_i = \frac{1}{N}\left(\bar{R}_{i\cdot} - \frac{1}{2}\right)$$

where $\bar{R}_{i\cdot}$ is the mean rank for the treatment among all observations (N). Relative treatment effects have a range of 0 to 1.0. Two relative treatment effects were considered different if they each lie outside the confidence interval of the other.

Results

Plant population. In 2015, cultivar (P < 0.0001), seed treatment (P = 0.033, planting date (P < 0.0001), planting date * cultivar (P = 0.031), and planting date*seed treatment (P < 0.0001) effects were significant for early season plant population. However, cultivar * seed treatment and cultivar * seed treatment * planting date were not significant. Early season stand counts ranged from 9-12 plants per meter for Georgia-06G and 10-13 plants per meter for Georgia-12Y. Final stand ranged from 9- 14 plants per meter of row for Georgia-06G and 11-14 plants per meter of row for Georgia-12Y. Across both cultivars, plant stand increased with planting date. (Figure 2.1)

In 2016 there was a significant effect for seed treatment at (P = 0.0006). No other factor or interaction was significant. Early season stand counts ranged from 10 to 11 plants per meter of row for untreated and treated seed, respectively. End of season stand counts ranged from 9 to 10 plants per meter for treated and untreated seed. Across cultivars, populations were higher for plots with seed treatment than those with no seed treatment.

Vigor assessment. In 2015, cultivar and planting date main effects were significant (P < 0.0001) for row width, but no other main effect or interaction was significant. Canopy width at 56 DAP ranged from 64 cm to 83 cm for Georgia-06G and 70 cm to 91 cm for Georgia-12Y over six planting dates. Across all other treatments, canopy width was 75.5 cm and 84.3 cm (LSD =

1.35) for Georgia-06G and Georgia-12Y, respectively. Across cultivars, canopy width increased linearly with ordinal planting date (Figure 2.2). In 2016, cultivar ($P < 0.001$), seed treatment ($P = 0.05$) and planting date ($P < 0.001$) main effects were significant, but no interactions were significant.

Canopy width at 56 DAP ranged from 42 cm to 63 cm for Georgia-06G and 51 cm to 68 cm for Georgia-12Y. Across all other treatments, canopy width was 55.3 cm and 60.2 cm (LSD = 2.2) for Georgia-06G and Georgia-12Y, respectively.

Across all other treatments, canopy width was 56.5 cm and 58.9 cm (LSD = 2.2) for plots with nontreated and treated seed, respectively. In both years, canopy width increased by planting date. (Figure 2.2)

Tomato Spotted Wilt: In 2015, cultivar ($P < 0.0001$) and planting date ($P =0.011$) effects were significant for incidence of tomato spotted wilt, but no other main effect or interaction was significant. Across planting dates, incidence of tomato spotted wilt was 7.6 and 2.8% in Georgia-06G and Georgia-12Y, respectively (LSD = 0.8). Across other factors, incidence of tomato spotted wilt was highest in the first two plantings and then decreased with later planting dates (Figure 2.3). In 2016, cultivar ($P = 0.004$) and planting date ($P = 0.039$) were significant, but no other main effect or interaction effect was. Across other factors, incidence of tomato spotted wilt was 4.2% and 1.6% (LSD = 0.47) for Georgia-06G and Georgia-12Y, respectively. There was no significant regression for incidence of spotted wilt on planting date. The second and third planting dates had the highest incidence of spotted wilt. After the second and third planting dates, percentage value decreased linearly by planting date (Figure 2.3).

Final Leaf Spot Severity: Late leaf spot was the predominant foliar disease (> 95%) in both years. Leaf spot epidemics began earlier in 2015 than in 2016 and were more severe. In 2015, cultivar ($P < 0.001$), planting date ($P < 0.001$), and cultivar*planting date ($P = 0.015$) effects were significant for final leaf spot ratings, but no other main effect or interaction was ($P \geq 0.23$). Based on relative treatment effects, leaf spot ratings for Georgia-12Y were lower than those of Georgia-06G within each planting date (Figure 2.4). Leaf spot ratings for both cultivars increased with each later planting date (Figure 2.4).

In 2016, cultivar ($P = 0.015$) and planting date ($P < 0.0001$) main effects were significant, but no other main effect or interaction was significant ($P \geq 0.15$). No leaf spot was observed in either cultivar for the first three planting dates. Across other factors, relative treatment effects and their respective 95% confidence intervals were rte (confidence interval) 0.441and 0.552 for Georgia-06G and rte (confidence interval) 0.449 and 0.558 for Georgia-12Y. At each of the last three planting dates, final leaf spot severity ratings increased with each later planting date (Figure 2.4).

AUDPC. In 2015, cultivar ($P < 0.0001$) and planting date ($P < 0.001$) effects were significant for AUDPC, but no other main effect or interaction was ($P \geq 0.22$). Across other factors, AUDPC was 189.69 and 178.79 (LSD = 1.88) for Georgia-06G and Georgia-12Y, respectively. Across other factors, AUDPC increased linearly with ordinal planting date (Figure 2.5).

In 2016, cultivar ($P = 0.0065$), planting date ($P < 0.0001$), and cultivar*planting date ($P = 0.045$) were significant for AUDPC, but no other main effects or interactions were significant ($P > 0.17$) AUDPC was higher in Georgia-06G than in Georgia-12Y for the last two planting dates

(Figure 2.5). After the third planting date, AUDPC values within each cultivar increased according to quadratic functions of ordinal planting date (Figure 2.5).

NDVI: In 2015, planting date effects on NDVI were significant ($P < 0.0001$), but no other main effects or interactions were. NDVI estimates of both cultivars were 0.55. Across other factors, NDVI measurements decreased according to a quadratic function of ordinal planting date (Figure 2.6).

In 2016, cultivar and planting date main effects were significant at ($P < 0.0001$), but no other main effect or interaction was significant. Across other factors, NDVI values were 0.7669 and 0.8417, (LSD = 0.015) for Georgia-06G and Georgi-12Y, respectively. Across cultivars, NDVI values decreased linearly with increasing ordinal date of planting (Figure 2.6).

Stem Rot: Little stem rot was observed in either year, with incidence of 8 % or lower in all treatments and no differences among treatments (data is not reported).

Yield and quality:

In 2015, cultivar ($P < 0.001$) and planting date ($P < 0.0001$) effects were significant for yield, but no other main effects or interactions were ($P \geq 0.55$).

Across planting dates, yield was 5339 kg/ha and 6000 (LSD = 349, $P = 0.05$) for Georgia-0G and Georgia-12Y, respectively. Across cultivars, yield decreased according to a quadratic function of later ordinal planting dates (Figure 2.7).

In 2016, cultivar effect ($P < 0.0001$) was significant for yield, but no other main effect or interaction was ($P \geq 0.45$). Across planting dates, yield was 3120 and 4568 kg/ha (LSD = 200, $P < 0.05$) for Georgia-0G and Georgia-12Y, respectively.

Discussion

Planting date effects on leaf spot observed in this study corroborated previous reports that earlier planting dates helped avoid leaf spot epidemics (Shokes et al, 1982 and Sanden et al, 1981). Shokes et al (1982) showed planting in April reduced incidence and severity of leaf spot diseases. Sanden et al (1981) reported a sixfold increase in the number of lesions when peanuts were planted late (May 21-23) versus an early planting date (April 15-25). However at the time of those studies, tomato spotted wilt was not a factor in the southeastern U.S. Since tomato spotted wilt emerged as a limiting factor to peanut production in the southeastern U.S., choice of planting date has been a key factor in an integrated regime for management that disease. Later planting dates have been used by growers to avoid early season thrips pressure and therefore higher risk of losses to tomato spotted wilt. Brown et al (2005) recommended planting after May 10 to avoid thrips infestations and reduce incidence of tomato spotted wilt. Culbreath et al. (2010) reported that avoiding early planting dates was important for a cultivar with moderate field resistance to TSWV, but that a cultivar such as AP-3, with greater field resistance to TSWV could allow more flexibility with planting date. However, Georgia-12Y has the highest level of field resistance to TSWV among currently available cultivars in the southeastern U.S. (Culbreath 2016), and earlier planting dates could probably be utilized. In the earlier studies TSWV was not a factor, and the peanut cultivars used then are no longer grown. For example, Florunner, the predominant cultivar used when those studies were conducted, is extremely susceptible to TSWV (Culbreath et al. 1992)

Results from this study indicate that planting date has potential to be used as a management tool for leaf spot epidemics by avoiding the secondary inoculum from leaf spot diseases.

Results from this study indicate an early planting date can be used as a tool to provide the yield needed from the organic industry. Early planted peanuts have been shown to have more damage from stem rot, but Georgia-12Y has shown resistance to this disease in addition to tolerance to the leaf spot diseases (Branch and Brenneman, 2015) (Jordan et al, 2016).

A good stand and early season vigor are important in both conventional and organic production systems. However, they can be especially important when no or low fungicide programs are used. Early season development as indicated by stand and canopy width measurements in Georgia-12Y have promise for quicker canopy closure than Georgia-06G. The early canopy closure should help with weed competition in both production systems. Overall, Georgia-12Y should make a good variety for organic production given its excellent disease resistance package, stand establishment, early season vigor, and yield potential.

In 2015, increasing final disease severity as indicated by final ratings, AUDPC, and reductions in NDVI with later planting dates corresponded with reductions in yield. Although other factors were likely involved, much of the yield reduction was hypothesized to be due to increases in leaf spot severity. In 2016, yields were not as high as in 2015, and there was less response with planting date. However, a similar trend of reduction in yield with later planting dates was observed. The difference in yields is likely due to differences in environmental conditions between the two years. In 2015, conditions during much of the season were favorable for peanut production and development of leaf spot epidemics. However, in 2016 a long period of dry hot conditions most likely inhibited normal pollination of the peanut plants (Chu et al, 2016), delayed canopy closure, and delayed and slowed development of the leaf spot epidemics. These results indicate that the combined use of Georgia-12Y with early planting dates has potential for avoiding or minimizing damage by leaf spot diseases and producing good yield in situations where fungicide use is limited or omitted completely.

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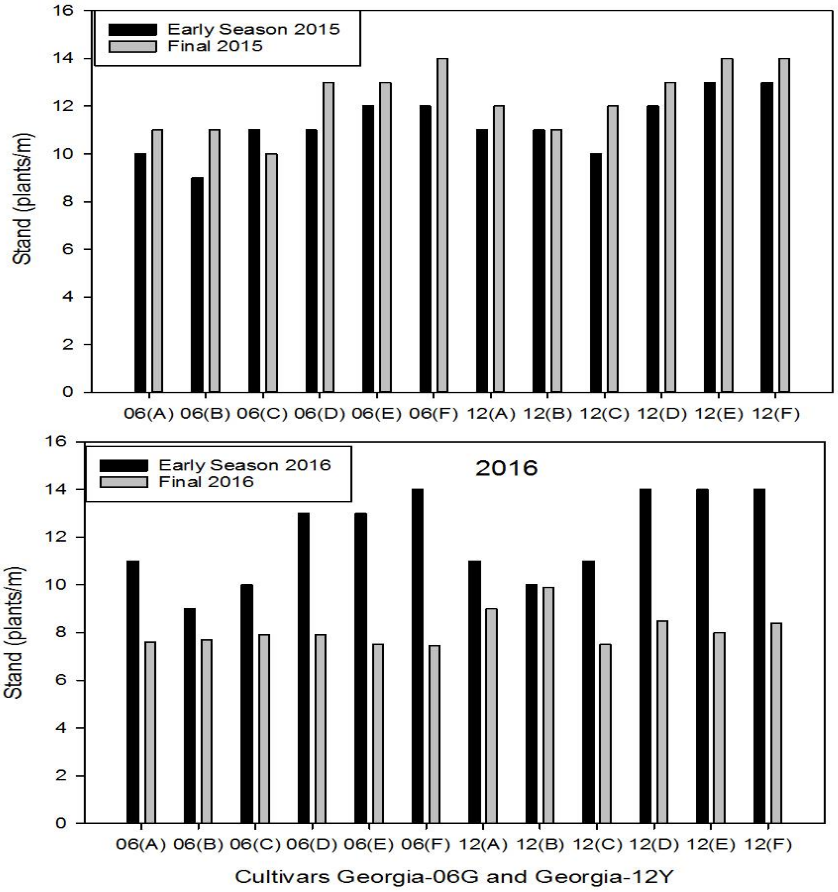
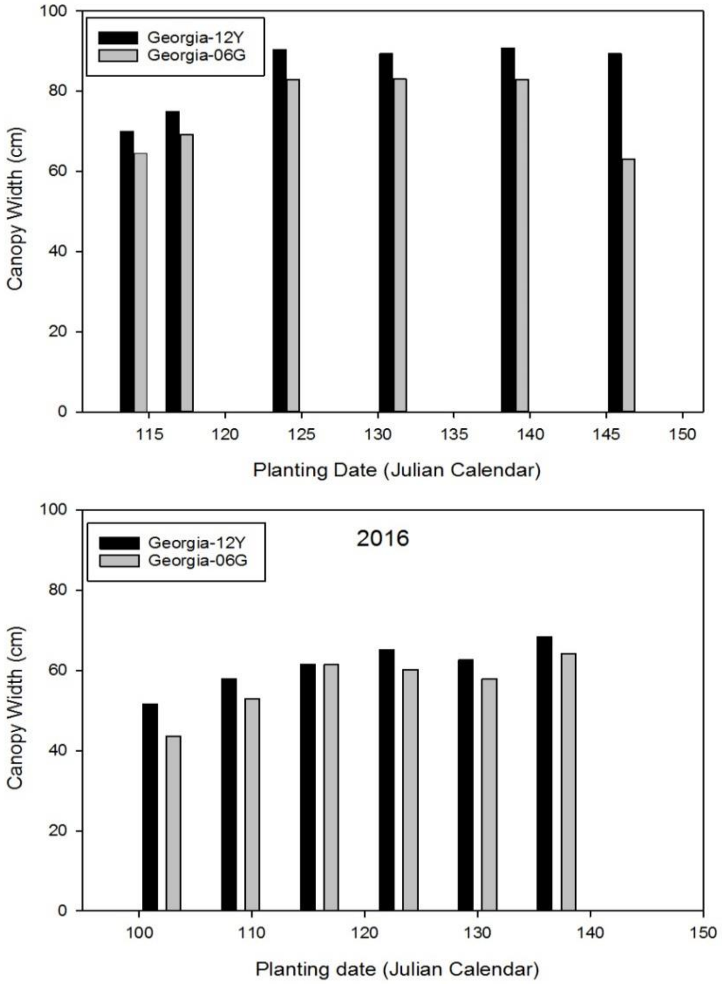


LSD= 0.87

LSD=0.55

Figure 2.1. Effect of Georgia-06G (06) and Georgia-12Y (12) cultivars and planting date on plant density (plants/m) at Lang/Rigdon Farms, 2015-2016. A=114,102; B=117,109; C=124,116; D=131,123; E=139,130; F=146,137 represent Julian calendar days for 2015 and 2016.
Early season plant density (plants/m of row) determined by counting emerging plants at 14 DAP (days after planting).



LSD=2.91

LSD=2.83

Figure 2.2. Effect of Georgia-06G and Georgia-12Y cultivars and planting date on canopy width at the Lang/Rigdon Farms 2015-2016. Bars represent the mean of canopy width measured at 56 days after planting at 6 arbitrary sites per plot.

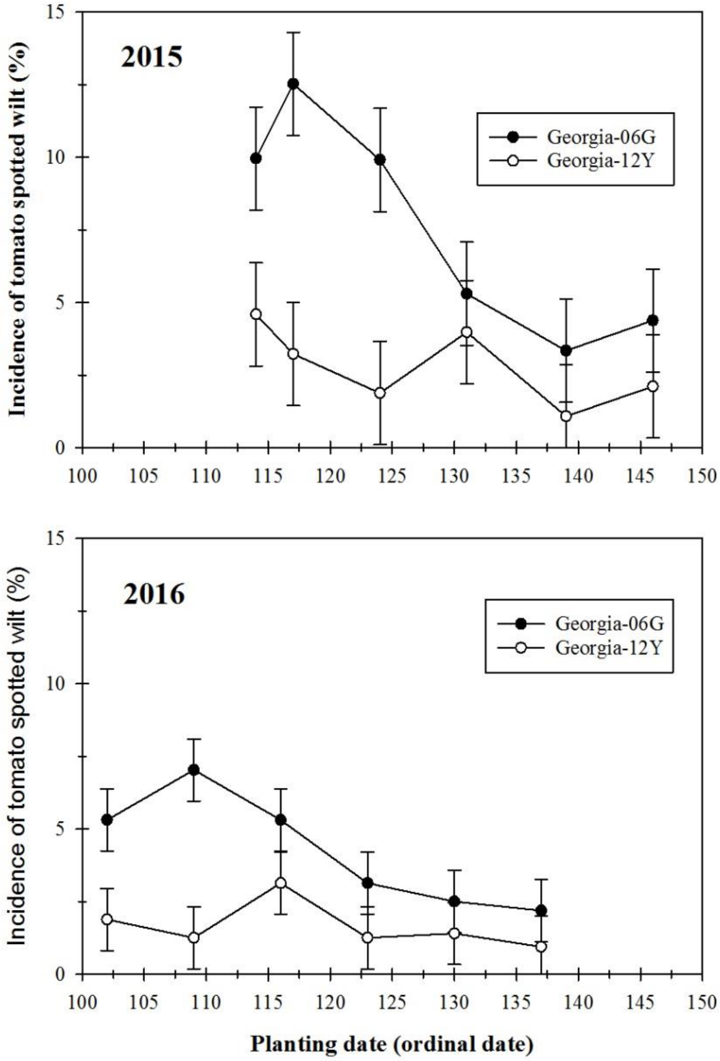


Figure 2.3. Effect of Georgia-06G and Georgia-12Y cultivars and planting date on final incidence of Tomato spotted wilt at the Lang/Rigdon Farms 2015-2016. Error bars represent standard error of the respective means.

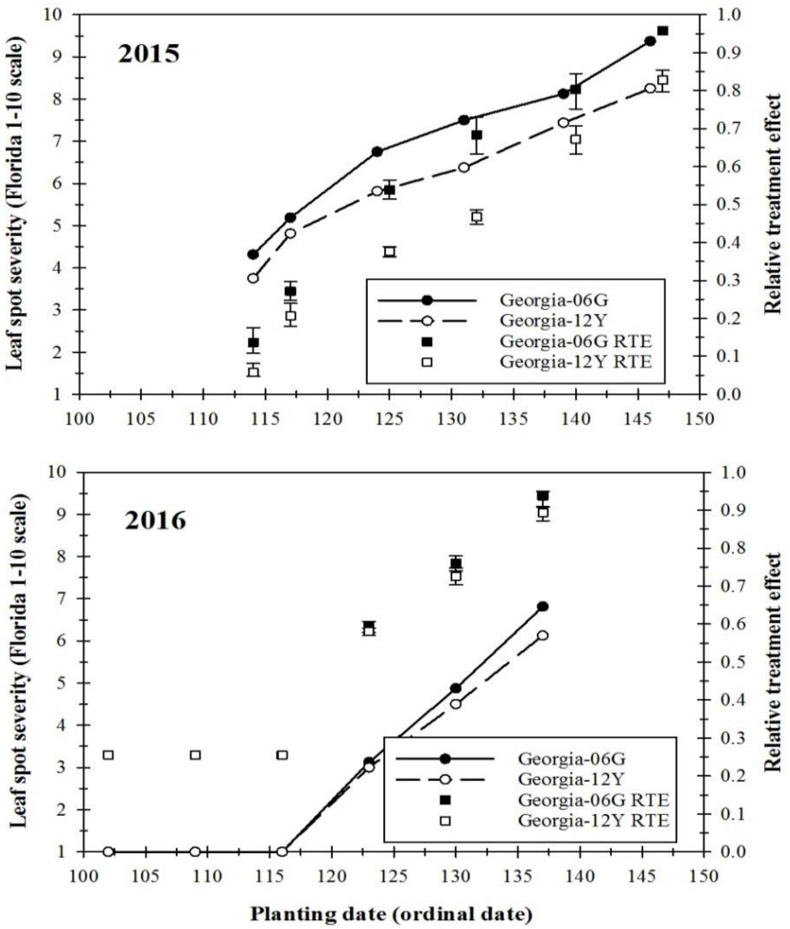


Figure 2.4.
Effect of Georgia-06G and Georgia-12Y cultivars and planting date on final severity of late leaf spot at the Lang/Rigdon Farms 2015-2016. Circular symbols represent mean final severity ratings, whereas square symbols represent relative treatment effects (RTE). Error bars represent the 95% confidence interval of the RTE. Two mean RTE values are considered significantly different if the mean value of each is outside the confidence interval of the other.

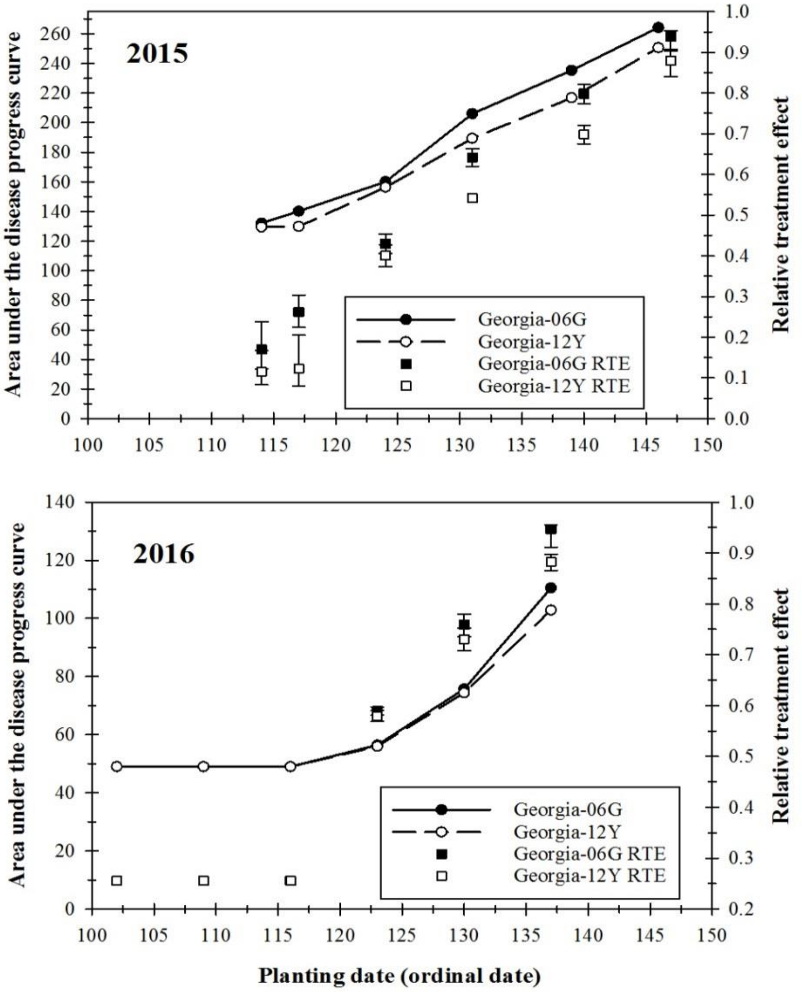


Figure 2.5. Effect of Georgia-06G and Georgia-12Y cultivars and planting date on area under the disease progress curve (AUDPC) of late leaf spot epidemics, at the Lang/Rigdon Farms 2015-2016.Circular symbols represent mean AUDPC values, whereas square symbols represent relative treatment effects (RTE). Error bars represent the 95% confidence interval of the RTE. Two mean RTE values are considered significantly different if the mean value of each is outside the confidence interval of the other.

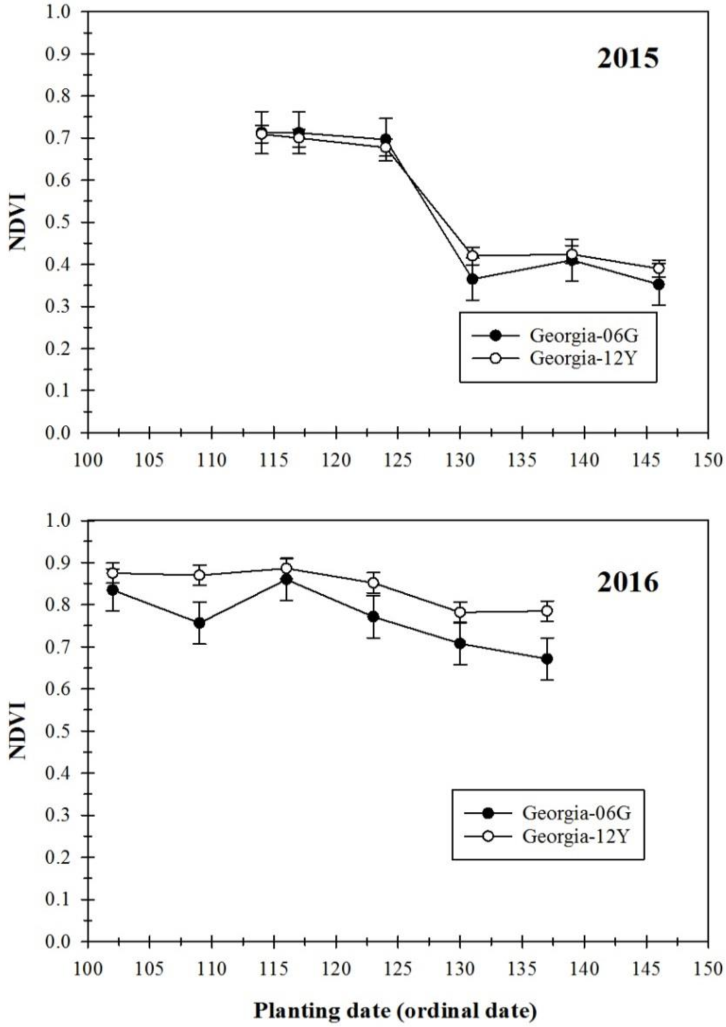


Figure 2.6. Effect of Georgia-06G and Georgia-12Y cultivars and planting date on normalized difference vegetation index (NDVI)measurements at Lang/Rigdon Farms, 2015-2016.

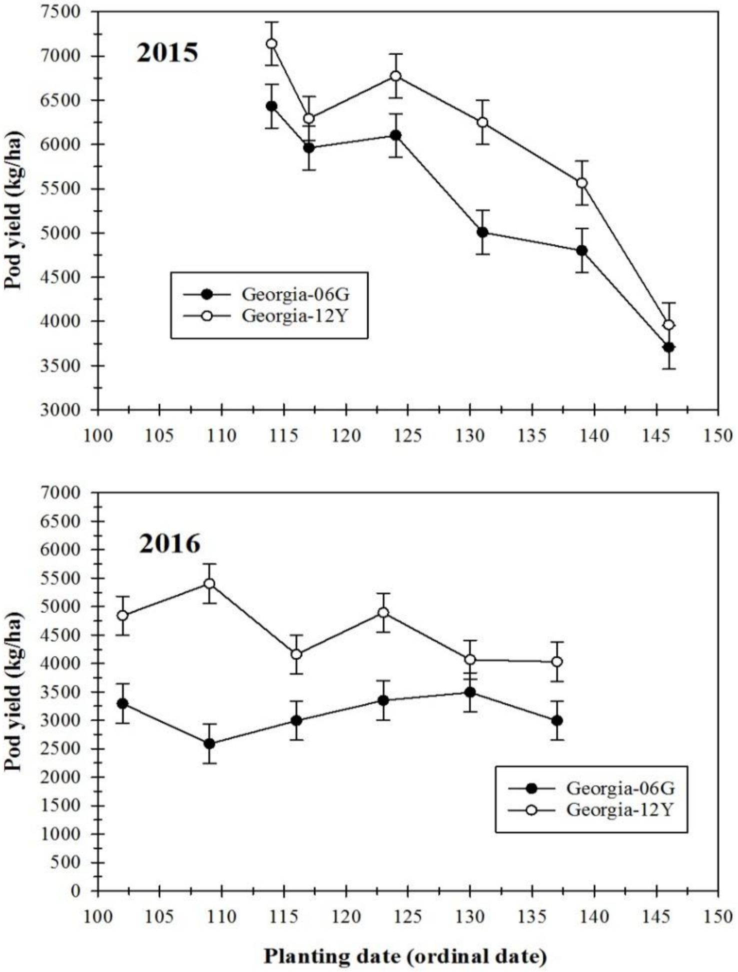


Figure 2.7. Effect of Georgia-06G and Georgia-12Y cultivars and planting date on yield (kg/ha) at Lang/Rigdon Farms, 2015-2016.

CHAPTER 4

EFFECT OF CULTIVATION METHODS ON FOLIAR AND SOILBOURNE DISEASES IN PEANUT

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Abstract

Tillage methods have the potential to influence development of soilborne diseases in peanut (*Arachis hypogaea*) production, especially stem rot, cause by *Sclerotium rolfsii*. Resistance to this pathogen might allow more aggressive cultivation without increasing disease development. Cultivar Georgia-12Y has shown potential for aggressive tillage methods due to its early season vigor. The objective of this study was to evaluate tillage methods in combination with resistant cultivars of peanut for use as an alternative to fungicides. Field trials were conducted at the Ponder and Rigdon Farms in Tifton, Georgia during 2015 and 2016 to evaluate stem rot severity and weed control from different tillage methods. Five tillage methods were used at the Ponder Farm, while the Rigdon Farm had two treatments. The Ponder Farm had little stem rot, but the Rigdon farm had severe epidemics. The tine-weeded plots had similar weed control of the hand-weeded check. Georgia-12Y yields were greater than that of Georgia-06G. The combination of the use of a tine-weeder and cultivar Georgia-12Y has the potential to reduce stem rot incidence and to maximize yields in situations such as organic production systems where fungicide and herbicide use are not allowed.

Introduction

Peanut (*Arachis hypogaea* L.*)* is one of the most economically important crops to Georgia. Currently almost all peanut production in the southeastern U.S. is produced in conventional production systems. However, there is great demand for organically produced peanuts (Smith et al, 2009)

Weed management are key component to organic production. Weeds not only reduce yield, but can be a reservoir for pathogens. Since herbicide use is limited in organic production, mechanical cultivation methods need to be refined to provide maximum weed control with minimal cost and damage to the peanut crop. Hand-weeding is generally not an option due to time involved as well as the cost for labor.

Weed control of peanuts prior to World War II was mainly cultivation. Two methods were used. The first, flat, non-dirting sweeps adjusted to skim just below the soil surface, were used to cut the roots and leave the weeds to die. The second, properly adjusted rolling cultivator was used to uproot small weeds to lay on the surface to die.(Hammons et al, 1973) After World War II, herbicides, (2,4-D) were introduced and used in combination with mechanical cultivation. (Buchanon et al, 1982) No-till farming has limited the use of cultivation after planting. In 1993, 73% of peanuts were cultivated, while only 19% were cultivated in 2003. (Johnson, 2013) Currently, three types of cultivation methods are being researched for weed control, sweeps, the rolling cultivator, and a tine weeding cultivation. The tine-weeding cultivation utilizes several tines on a tool bar that moves back and forth to lift small weeds from the soil.

"Dirting" (i.e. moving soil onto the stems and around the crowns of peanuts) may be useful to slow down growth of weeds to allow the peanut plants time to compete with the weeds. The various cultivation methods varied in amount of soil being thrown onto the plants. The amounts were not measured, but it is important to note the tine cultivation method moved the least amount of soil followed by the sweeps and then by the rolling cultivator. Aggressive "dirting" may provide additional control of weeds in the row, but has been reported to exacerbate damage by stem rot (*Sclerotium rolfsii*) (personal communication, Dr. Carroll Johnson). (Boyle and Hammons, 1956; Garren, 1961; Melouk et al, 1995) With Georgia-12Y and some of the new breeding lines, resistance to *S.rolfsii* may be sufficient to allow the hilling (excessive dirt thrown onto rows) of the peanut plants. Hilling is being investigated to provide a means of helping to suppress weed development while the peanut plants are getting established. In other studies, tine–weeding cultivation causes minimal amounts of soil displacement, and can provide effective weed control if used in a timely manner. This method provided greater yield than other methods for control (Johnson, 2014). Of the three methods introduced, the sweeps and rolling cultivators were shown to move more soil onto plants than the tine-weeding cultivation.

Managing within-row weeds is of extreme importance in an organic system. Weeds can be controlled mechanically. This method of hilling during tillage has not been recommended due to the problem of stem rot incidence. Now that we have resistant cultivars, the production model for organic peanuts may be able to be rewritten. If herbicide-resistant weeds continue to develop, conventional peanut production may have to utilize this technology as well (Dobrow et al, 2011). New cultivars with potentially higher levels of disease resistance need to be evaluated with mechanical cultivation. The bulletin used by most growers was written in the 1973. (Bulletin 340, UGA Extension)

Sclerotium rolfsii, the cause of stem rot, is one of the most important soilborne pathogens in peanut production in the southeastern U.S. Plants infected can lose all yield potential. Rotation is used as a way to suppress stem rot. (Garren, 1959) The combination of rotation and resistant cultivars represent the best way to minimize this disease in organic production as well as reduce dependency on fungicides in conventional production. Available cultivars vary greatly in their susceptibility to *S. rolfsii*. Georgia-12Y (Branch 2013) has among the best resistance to this pathogen of any commercial cultivar (Culbreath 2013). Georgia-12Y has shown potential for use in organic production, with better stand establishment, early season vigor(the combination of stand and vigorous growth habit), tolerance to leaf spot diseases, and producing greater yield than the standard cultivar Georgia-06G (Branch, 2013) in trials with no fungicides used for seed treatment or foliar disease control. Resistance to *S. rolfsii* in Georgia-12Y might allow it to tolerate deposition of soil on its stems and crown from cultivation. If so, the combination of its early season vigor and more aggressive cultivation techniques might help with weed control in organic production.

The primary objectives of this study included determining the effect of cultivation methods weed control on current cultivars, and whether cultivation methods affect stem rot. Of particular interest was whether resistance to *S. rolfsii* in Georgia-12Y would allow use of more aggressive cultivation, even if cultivation increased incidence of stem rot in Georgia-06G.

Materials and Methods

Field experiments were conducted in 2015 and 2016 at the University of Georgia, Coastal Plain Experiment Station (UGA-CPES). In each year, one trial was conducted at the Ponder Farm and one trial at the Rigdon Farm. The soil type in all fields was a Tifton sandy loam (fine sandy, siliceous thermic Plinthic Paleudult). The fields from both years had a history of moderate-to-heavy epidemics of *C. arachidicola* or *C. personatum* in previous years when peanut was grown. The field at Rigdon, used in both years has been planted to peanut for 16 consecutive years and had a history of heavy infestations of stem rot. The Ponder Farm field has been in an alternating corn/peanut rotation for several years.

A randomized complete block design was used in all trials. Treatments in the Ponder Farm trials consisted of two cultivars, Georgia-06G and Georgia-12Y in factorial combination with four cultivation treatments. Treatments for weed control included: tine cultivation, sweep cultivation, rolling-cultivator cultivation, and hand-weeded for control. Both cultivars were planted in flat and furrowed plots. No fungicides or herbicides were used in any plots.

The tine cultivation treatments were done using an Aerostar tine cultivator (Einbock GmbH & CoKG, Austria). Cultivation was initiated four days after planting (DAP, 23 May 2015 and 14 May 2016) and repeated every 7 days for six weeks. The rolling-cultivator cultivation was initiated at 3 DAP, 22 May 2015 and 13 May 2016 (corresponding with growth stage VE and concluding three weeks after VE, followed by the tine-weeder weekly for three more weeks,10, 17, 24 June 2016. Sweep cultivation was initiated four days after planting and was repeated weekly for six weeks. The hand-weeded plots were weeded weekly to be kept weed-free. No weed control was used in the non-cultivated control treatment.

In 2015, treatments at the Rigdon Farm, consisted of three cultivars, Georgia-06G, Georgia-12Y, and Bailey. In 2016 at the Rigdon farm, two cultivars, Georgia-06G and Georgia-12Y, were used with and without seed treatment.

Four replications were used at the Ponder Farm in both years. Three replications were used in both years at Rigdon. In all trials, plots were 9.17 m long by 1.8 m wide with two rows for each plot. At the Ponder Farm, planting dates were May 19 2015 and May 10 2016. Planting dates were May 20 and May 6 in 2015 and 2016, respectively at the Rigdon Farm. Soil temperatures were obtained from the University of Georgia Automated Environmental Monitoring Network (http://www.georgiaweather.net/). The average soil temperature at 10.2 cm depth for three days preceding planting date was 26.8 C in 2015, and 25.5 C in 2016 at the Ponder Farm. The average soil temperature at 10.2 cm depth for three days preceding planting date was 28.54 C in 2015 and 22.48 C in 2016.

At the Ponder Farm, standard cultivars Georgia-06G and Georgia-12Y were planted without seed treatment. In all trials, seeding density was 14.8 seed/m of row. All plots were irrigated as needed to maintain favorable conditions for leaf spot epidemics, weed growth, and for peanut growth.

In 2015 at the Rigdon Farm, treatments included all three cultivars were either non-treated tillage or tine-weeder. In 2015, furrow versus flat planting were used, but the furrow treatment was dropped in 2016. These treatments were duplicated with flat field planting and furrow planting. In 2016, two cultivars were planted with or without Tine-weeding, as well as treated and non-treated seed.

Plant canopy measurements were measured at 56 days after planting (DAP) at the Ponder and Rigdon Farms in both years. In each plot, six arbitrary locations were measured and then the mean was recorded. Canopy measurements were used as a way to quantify vigor.

Leaf spot severity was assessed visually using the ordinal Florida 1-10 Leaf Spot Florida Scale where 1=no disease, 0% defoliation, and 10=100% defoliation, plants dead, killed by leaf spot (Chiteka et al., 1988). At the Ponder Farm, leaf spot ratings were made at 63, 70, 77, 84, 93, 99, 105, 112, 119, 126 and 133 DAP in 2015 and 77, 84, 91, 99, 106, 113, 120, 127, 134, and 141 DAP in 2016. At the Rigdon Farm, leaf spot ratings were made at 63, 70, 77, 84, 91, 98, 105, 112, 119 DAP in 2015 and 79, 86, 93, 100, 107, 114, 121, 128, 135, 142 DAP in 2016.

All plots were dug and inverted 135 DAP in 2015 and 142 DAP in 2016 at the Ponder Farm and 121 DAP in 2015 and 145 DAP in 2016 at the Rigdon Farm. Immediately after plants were inverted, number of plants were counted for each plot by counting taproots, and converted to plants/m of row, reported as the final population.

Peanut pods were harvested mechanically 7 to 11 days after inverting, and pod yields were determined by weighing harvested pods after they were dried and adjusted to 10% (wt/wt) moisture.

A, 1,000-g sample of harvested pods was collected from each plot of all replications in 2015 and 2016 for grade determination from trials at the Ponder and Rigdon Farms. The samples were cleaned, and non-pod materials were weighed. A 500-g sample of cleaned pods was shelled using commercial shelling equipment. Kernels were classified as sound, immature, or damaged, and the kernels in each category were weighed. The percentage of the 500-g sample represented by sound mature, immature, and damaged were determined according to official Federal-State Inspection Service methods (USDA-AMS, 1997). Total sound mature kernels (TSMK) was calculated as the percentage of the 500-g sample that was sound mature kernels.

Data were analyzed using SAS v.9.4 software (SAS Institute, Cary, NC). For all variables except leaf spot AUDPC and final leaf spot severity ratings, a mixed models procedure was used with maximum likelihood estimation of variance components (PROC MIXED). The Satterthwaite method was used for computing the denominator degrees of freedom ("ddfm=satterth" in the model statement). Trials from both years were pooled at the Ponder Farm. Trials from the Rigdon Farm were analyzed separately since cultivars differed. Cultivars and cultivation were considered a fixed effect, whereas replication, year, and year*cultivar*cultivation interaction effects were considered random effects. Effects were considered significant when $P \leq 0.05$. Fisher's least significant difference (LSD) values were computed using standard errors and t-values of adjusted degrees of freedom from the Pdiff option of PROC MIXED.

Final leaf spot severity ratings and AUDPC values from both years were analyzed nonparametrically based on ranks using Proc Mixed of SAS v.9.4 software (SAS Institute, Cary, NC) (Shah and Madden, 2004). Relative treatment effects and their respective 95% confidence intervals were calculated using the LD-CI macro for SAS (Brunner et al., 2002, Shah and Madden, 2004) and were used to discern difference among genotypes. Treatments were considered different if their respective means were outside the 95% confidence intervals of the other.

Results

Late leaf spot was the predominant foliar disease at both locations in both years. Disease severity was much greater at the Rigdon Farm than at the Ponder Farm in both years. Stem rot were low at the Ponder Farm and was not reported. However, incidence of tomato spotted wilt and stem rot were reported for that location. Tomato spotted wilt severity was light in both locations in both years and was not reported.

Stand: In 2015 at the Ponder Farm, cultivar and cultivation were significant at ($P < 0.0001$ and $P < 0.0002$), respectively but no other main effect or interaction was.

Across treatments, final stand counts were higher for Georgia-12Y than for Georgia-06G with mean of 10.7 and 7.6 (LSD=0.49), respectively. The weedy control plots had the lowest stand counts with no differences among the remaining treatments.

In 2016 at the Ponder Farm, Georgia-12Y consistently had a higher stand count than Georgia-06G across all treatments. Only cultivar was significant at ($P < 0.0001$)., The sunken beds consistently had higher stand counts across all cultivars. In 2015 at the Rigdon Farm, Georgia-12Y had higher stand counts across all treatments than Bailey and Georgia-12Y. Cultivar and bed type were significant at ($P < 0.0001$ and $P < 0.0003$), respectively. No interactions were significant. In 2016 at the Rigdon Farm, the trial was modified due to mechanical problems from 2015. Seed treatment was added to confirm the results seen in 2015 was not from mechanical failure. Bailey was also dropped. At the Rigdon Farm, variety and seed treatment were significant at ($P < 0.0005$ and $P < 0.0001$) while an interaction was significant for variety*seed treatment at ($P < 0.0007$).

Canopy Width: In 2015 at the Ponder Farm, bed type had no effect on canopy width. The hand-weeded plots consistently had wider canopy than any of the other treatments. Cultivar and cultivation were both significant at ($P < 0.0001$), but no interactions were significant. In 2016, Cultivar and cultivation were both significant at ($P < 0.0081$ and $P<0.0001$), respectively, but no interactions were significant. Georgia-12Y had higher measurements across treatments than Georgia-06G. In 2015 at the Rigdon Farm, Georgia-12Y had higher canopy measurements than Bailey or Georgia-06G across all treatments. In 2016 at the Rigdon Farm, cultivar and cultivation were significant at ($P < 0.0001$, $P = 0.0057$), respectively. No interactions were significant. Georgia-12Y had wider canopy than Georgia-06G across treatments.

Weed control: Due to the design of the experiments, weed data was not collected from the Rigdon Farm. The Ponder farm was reported and analyzed independently by year. In 2015, yellow nutsedge and smallflower morningglory were the predominant weeds. In 2016, the weeds seen were the same as in 2015 with the addition of Texas millet. In both years, cultivation was significant at $P < 0.0001$. Variation was greater in 2016 than in 2015. No other treatment was significant. As seen in Fig. 3.2, the hand-weeded plots were all 90 percent control since they were a weed-free check with the other 10% accounting for the peanut plants themselves. Cultivation was significant at ($P < 0.0001$). Other than the hand-weeded check, the tine-weeded plots had better control of weeds than any other cultivation method in this trial.

In 2016 at the Ponder Farm, the hand-weeded check was valued at 90% control. As in the previous year, the tine cultivation method had consistently better control than the other mechanical cultivation methods, Fig. 3.2.

NDVI: NDVI measurements were not taken at the Ponder Farm in either year due to interference from weeds. NDVI was measured at the Rigdon Farm in both years. In 2015, only cultivation was significant at ($P = 0.0457$). In 2016 at the Rigdon Farm, variety was significant at ($P < 0.0001$), Fig. 3.7.

Leaf Spot: The leaf spot epidemics in 2015 and 2016 were very different due to environmental conditions. In 2015 at the Ponder Farm, mean leaf spot ranged from 5.0 to 6.5 for Georgia-06G and from 5.0 to 6.0 for Georgia-12Y. Cultivar and the cultivar*bed interaction were significant at ($P = 0.0023$ and $P = 0.0202$), respectively, Fig. 3.1. While the “proc mixed” analysis was mildly significant, the “nonparametric” analysis showed cultivar to be highly significant, as well as the cultivar*bed interaction. In 2016 at the Ponder Farm, the “proc mixed” analysis was not significant. Likewise, the “nonparametric” analysis was not significant. Leaf spot disease pressure is typically low at the Ponder Farm fields used in this trial. (Johnson, verbal communication) We attribute this to a good rotation regime. In 2015 at the Rigdon Farm, cultivar was significant for leaf spot severity at ($P < 0.0001$), Fig. 3.6. No interaction was significant. All three cultivars were different for leaf spot. Cultivar was significant at ($P < 0.0001$). The relative effects of the “nonparametric” analysis resulted in the same results as the ”proc mixed” analysis, cultivar ($P < 0.0001$).

AUDPC: Since AUDPC is dependent on leaf spot ratings, AUDPC was analyzed independently by year since the leaf spot epidemics were vastly different by year. In 2015 at the Ponder farm, cultivar was significant at ($P = 0.0017$), Fig.3.2. No interaction was significant. In the “nonparametric” analysis, results were similar with cultivar significant at ($P < 0.0001$). The tine cultivation was the highest with the exception of the hand-weeded check across all treatments, while the rolling cultivator was the lowest with the exception of the weedy check. No interaction was significant. In 2015 at the Rigdon Farm, cultivar was the only factor that was significant at ($P < 0.0001$), Fig. 3.5. No interactions were significant. In 2016 at the Rigdon Farm, cultivar was significant at ($P < 0.0001$). No other main effect or interaction was significant (Fig. 3.5).

Stem Rot: Stem rot was seen at the Ponder Farm in 2015, but was too low to evaluate in 2016. The mean number of plants per row was reported. In 2015 at the Ponder Farm, both cultivar and cultivation were significant ($P < 0.0001$ and $P = 0.0313$), respectively. Georgia-12Y had less stem rot than Georgia-06G. Data for the Ponder Farm in 2016 was not reported. In 2015 at the Rigdon Farm, cultivar was significant at ($P = 0.0012$). In 2016 at the Rigdon Farm, cultivar and seed treatment were significant ($P < 0.0001$ and $P = 0.0099$). The cultivar*seed treatment interaction was significant ($P = 0.0053$), Fig. 3.8.

Yield: Yield for both locations in both years was analyzed independently. In 2015 at the Ponder Farm, cultivar and cultivation were significant for yield($P < 0.0001$), Fig. 3.3. The hand-weeded plots yielded highest followed by the tine-weeded plots and the weedy plots yielded the lowest across cultivars. In 2016 at the Ponder Farm, cultivar and cultivation were significant for yield($P < 0.0001$). The hand-weeded plots yielded the highest while the weedy plots yielded the lowest in both cultivars. In 2015 at the Rigdon Farm, cultivar and bed type were significant for yield ($P < 0.0001$ and $P = 0.0002$), respectively. No interactions were significant. In 2016 at the Rigdon farm, cultivar and the cultivar*cultivation interaction were significant for yield ($P < 0.0001$ and $P = 0.0256$), Fig. 3.9. Seed treatment did not affect yield.

Discussion: The field experiments of this study indicate that the cultivar Georgia-12Y can withstand aggressive cultivation without increasing stem rot incidence. It should be noted that leaf spot epidemics and defoliation were more severe at the Rigdon Farm in both years. Although leaf spot epidemics were delayed in 2016 in both locations, yields were not as good in 2016 likely due to poor growing conditions such as dry conditions, high temperature, and poor pollination. Although yields differed from year to year, similar trends were observed.

A good stand and early season vigor are critical for organic production. In this study, Georgia-12Y showed the potential for use in an organic production system. The results indicates that Georgia-12Y has the ability to compete with weed pressure while not having increased incidence of stem rot. Brenneman et al (2014) reported that Georgia-12Y has resistance to *Sclerotium rolfsii* that provides suppression of stem rot similar of that provided by fungicide applications available for Georgia-06G. This study also shows that Georgia-12Y is more tolerant to leaf spot diseases.

In this study in combination with well-timed mechanical tillage, Georgia-12Y has the potential to be used without herbicides. It is intuitive to think mechanical tillage will cause more stem rot from the additional sclerotia being thrown onto the plants. However, with the resistance to *S. rolfsii* of Georgia-12Y, it may be used with minimal fear of significant loss to stem rot. From visual observation, the tine-weeded plots were comparable to the hand-weeded checks which were validated in weed percentage control and yield data.

NDVI is a useful tool to be used for an indication of leaf spot severity in the absence of other factors that may also affect NDVI. In this trial, NDVI measurements were not useful for discerning differences in leaf spot for levels with defoliation at 50% or lower. In addition the presence of weeds confounded the readings when measurements were attempted at the Ponder

Farm. It is recommended to use NDVI in combination with visual assessments due to the variation possible in plant canopy even when no disease is present. Jordan et al (2016) showed the relationship between NDVI and percent defoliation is not linear.

Although leaf spot ratings for Georgia-06G and Georgia-12Y were very similar in both years at both locations, Georgia-12Y yielded higher than Georgia-06G. This response is hypothesized to be due to the ability of Georgia-12Y to hold onto its pods even with severe defoliation. Further studies are evaluating lines for peg strength at digging under a range of defoliation.

It was shown in our trials that with resistance to *S. rolfsii*, the "dirting" effect made little difference. However, when using a susceptible cultivar like Georgia-06G, the "dirting" effect will spread the pathogen.

Georgia-12Y had better ratings for leaf spot throughout latter part the growing season than Georgia-06G. When comparing yield among the cultivars considering leaf spot severity, Georgia-12Y had high levels of defoliation but yielded very well, suggesting that tolerance to defoliation by late leaf spot may be a factor in that cultivar. Georgia-12Y consistently had greater yield than Georgia-06G. This study has implications for areas in which growers do not have access to fungicides or where fungicides are cost prohibitive, in addition to production situations such as organic production where fungicide use is limited or not acceptable.

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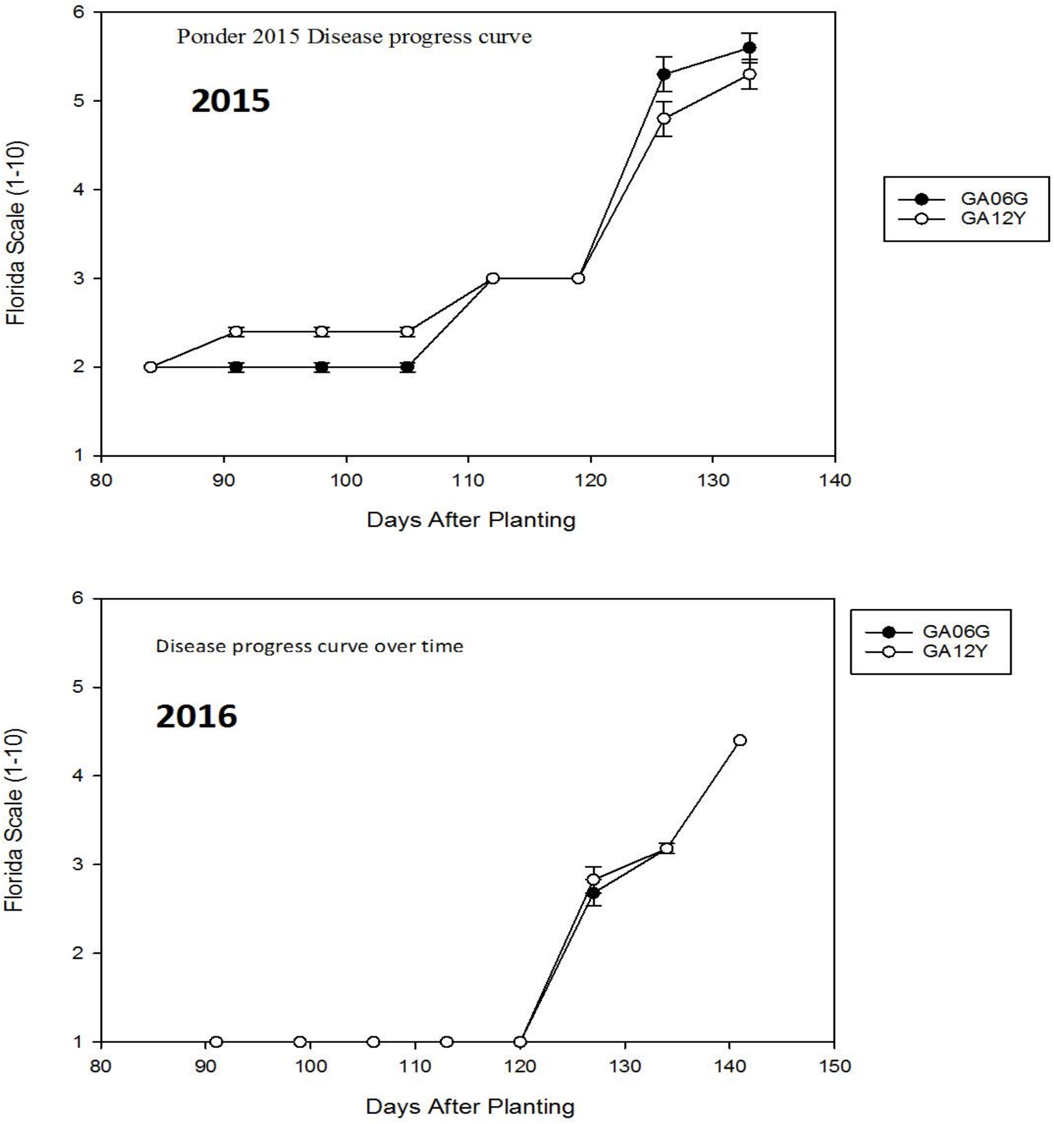

Figure 3.1. Disease progress of late leaf spot as affected by peanut cultivar at Ponder Farm. Error bars represent standard error of the leaf spot means.

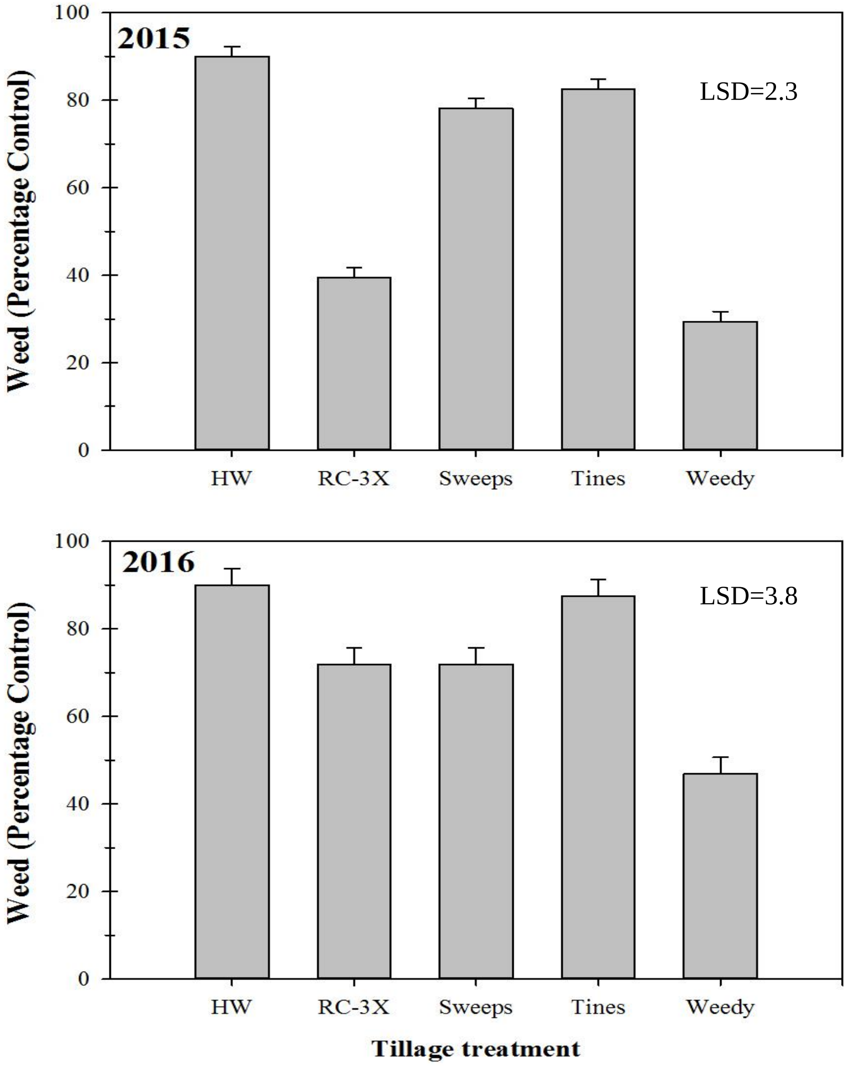

Figure 3.2. Effect of peanut cultivar and cultivation method on percentage weed control at the Ponder farm in 2015 and 2016. HW = hand-weeded plots; RC-3X = rolling cultivator 3 times; sweeps = sweeps cultivation; tines = vibrating tines cultivation; and weedy = non-weeded plots.

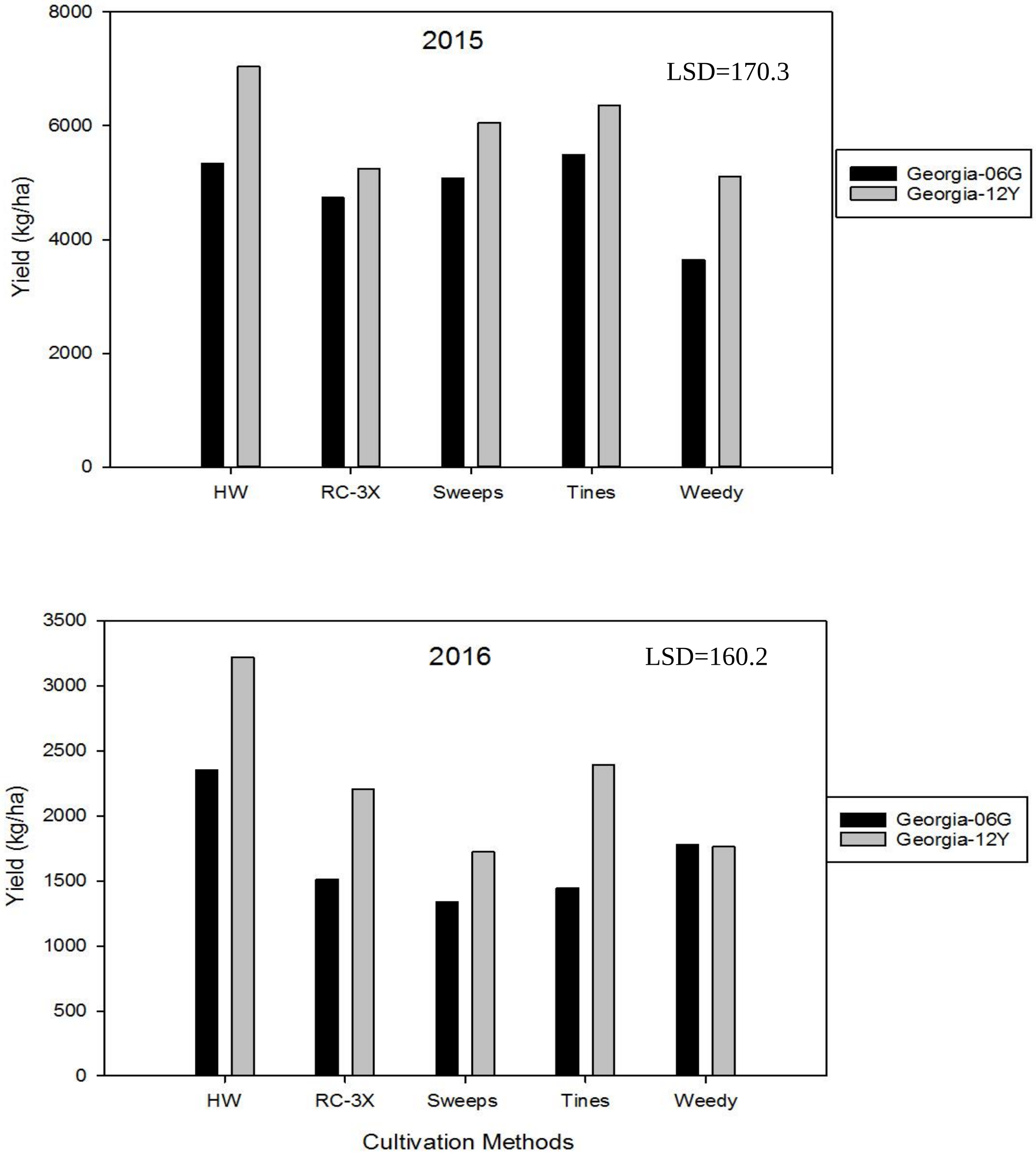

Figure 3.3. Effect of peanut cultivar and cultivation method on yield (kg/ha) at the Ponder Farm in 2015 and 2016.

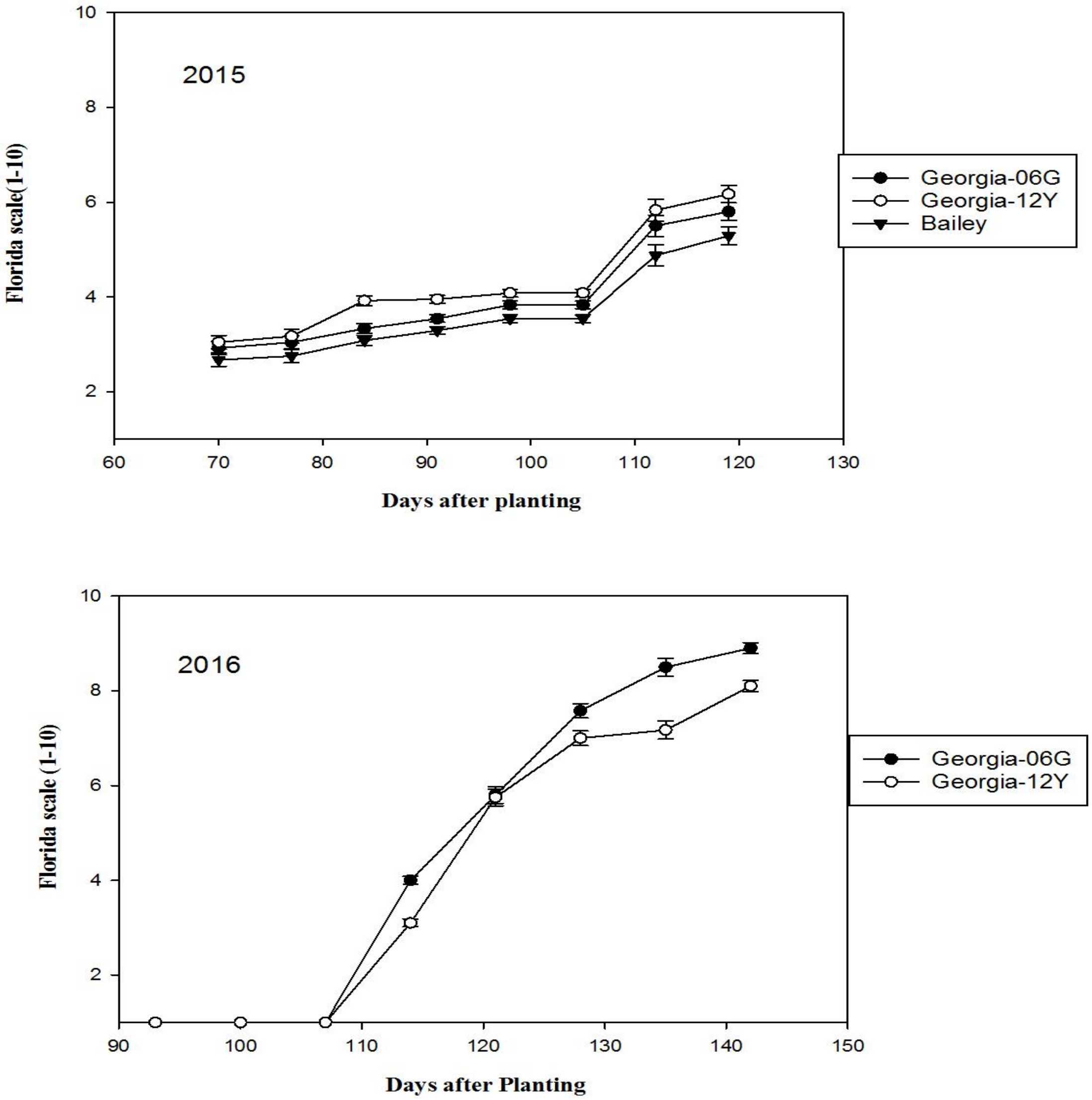

Figure 3.4. Disease progress of late leaf spot as affected by peanut cultivar at Rigdon Farm. Error bars represent standard error of the mean.

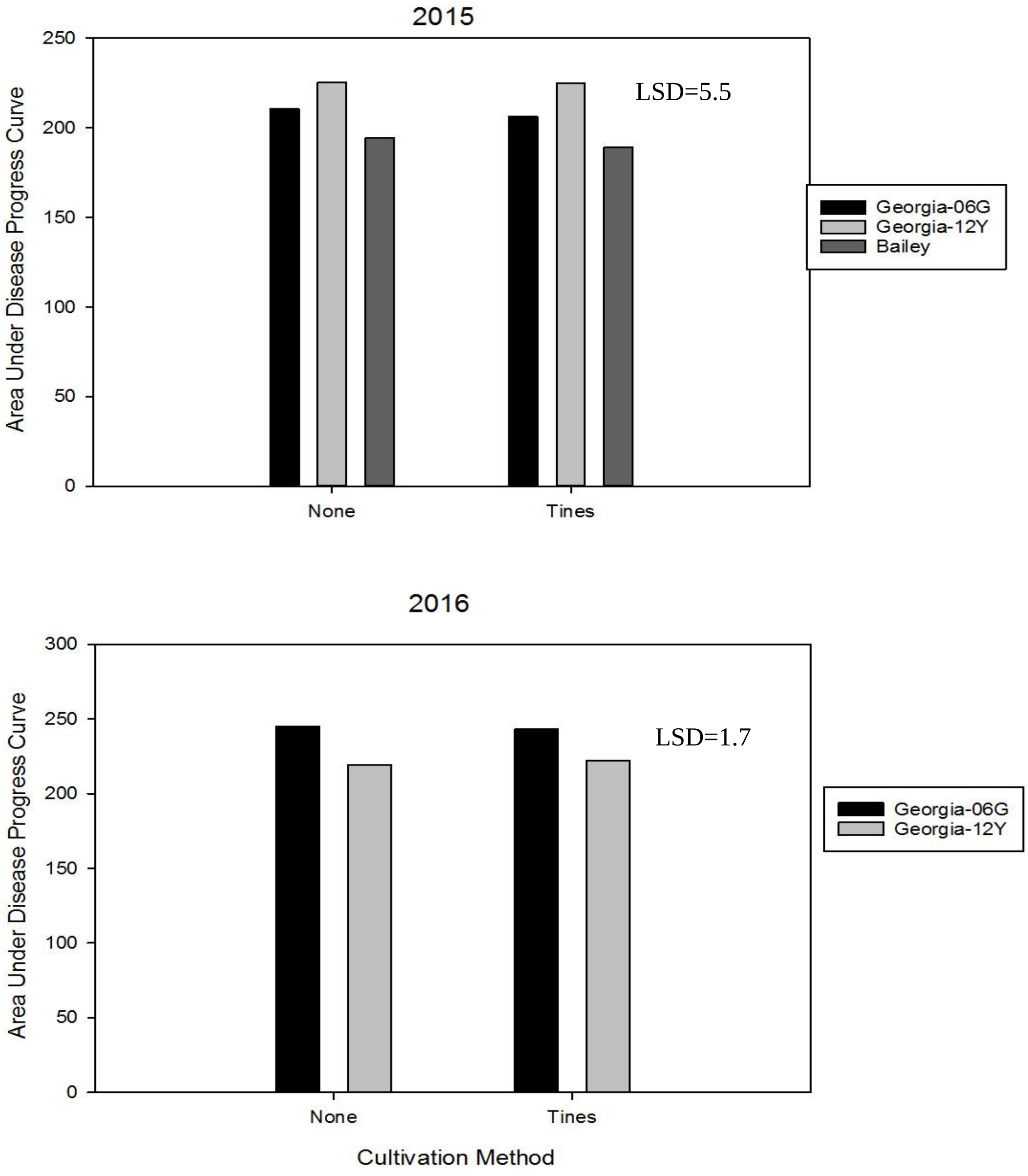

Figure 3.5. Effect of peanut cultivar and cultivation method on Area Under Disease Progress Curve (AUDPC) at the Rigdon Farm in 2015 and 2016.
Tines= tine cultivation and none= no cultivation used.

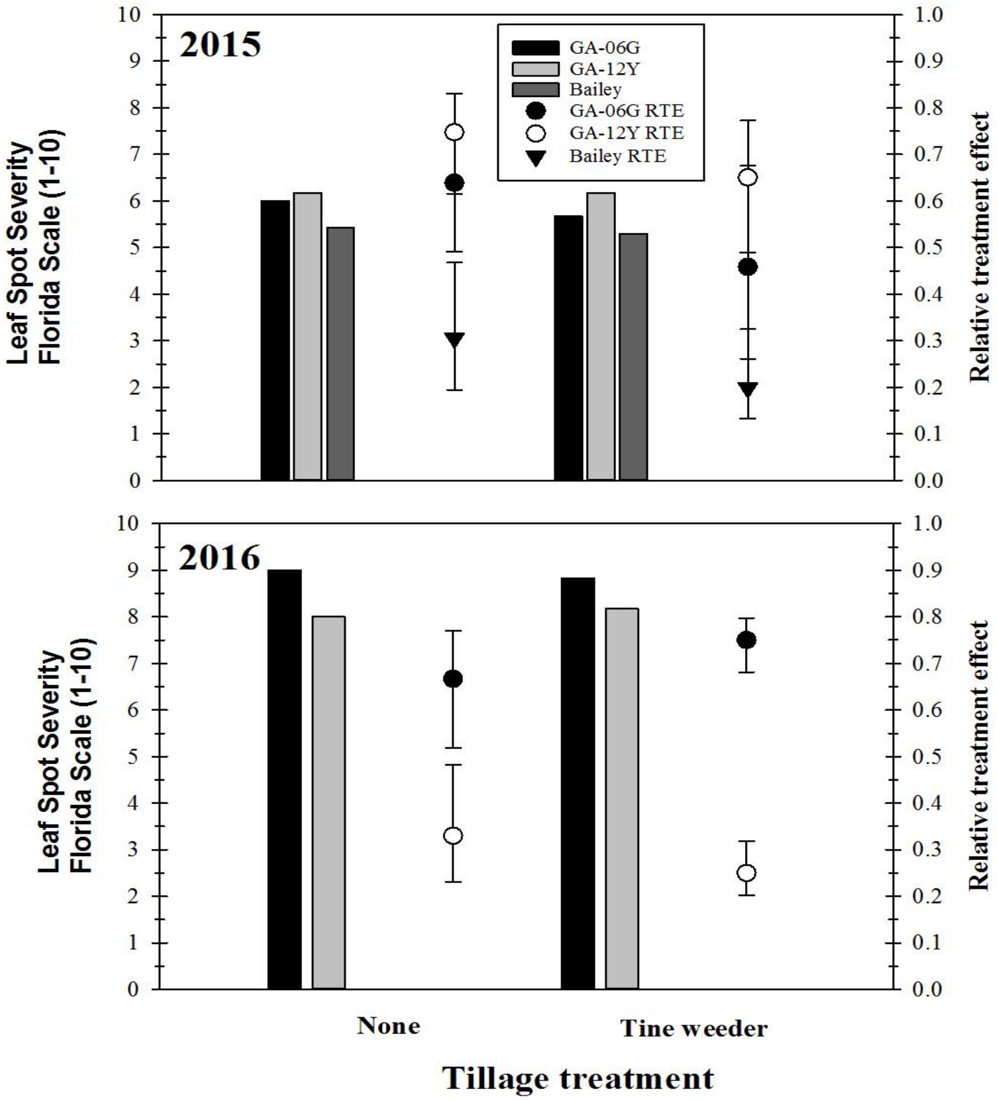

Figure 3.6. Effect of peanut cultivar and cultivation method on final leaf spot severity at the Rigdon Farm in 2015 and 2016. Bars represent the mean final leaf spot ratings. Symbols represent the relative treatment effects (RTE) of each treatment. Error bars represent the 95% confidence interval associated with the RTE. Means outside the confidence interval of each other were considered significant (P = 0.05).

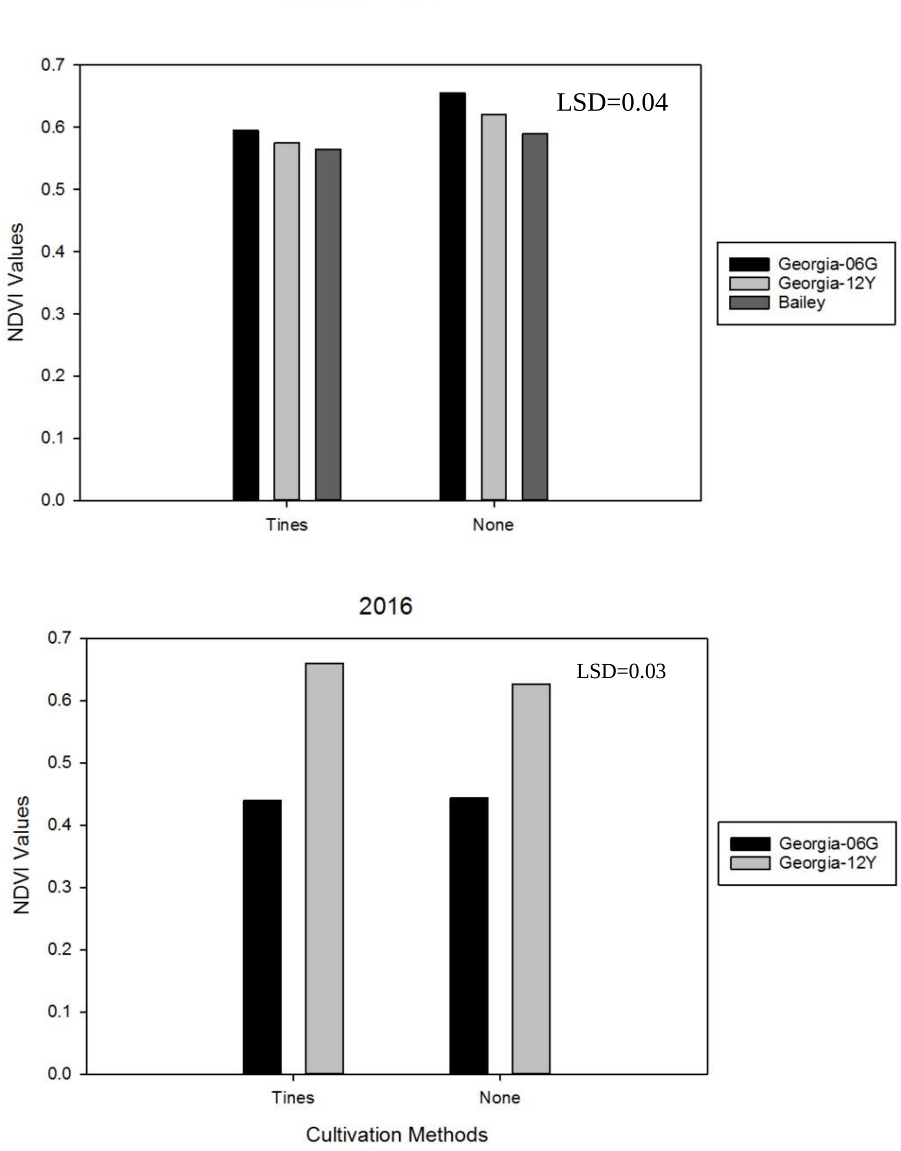

Figure 3.7. Effect of peanut cultivar and cultivation method on Normalized Difference Vegetation Index (NDVI) at Rigdon Farm in 2015 and 2016.

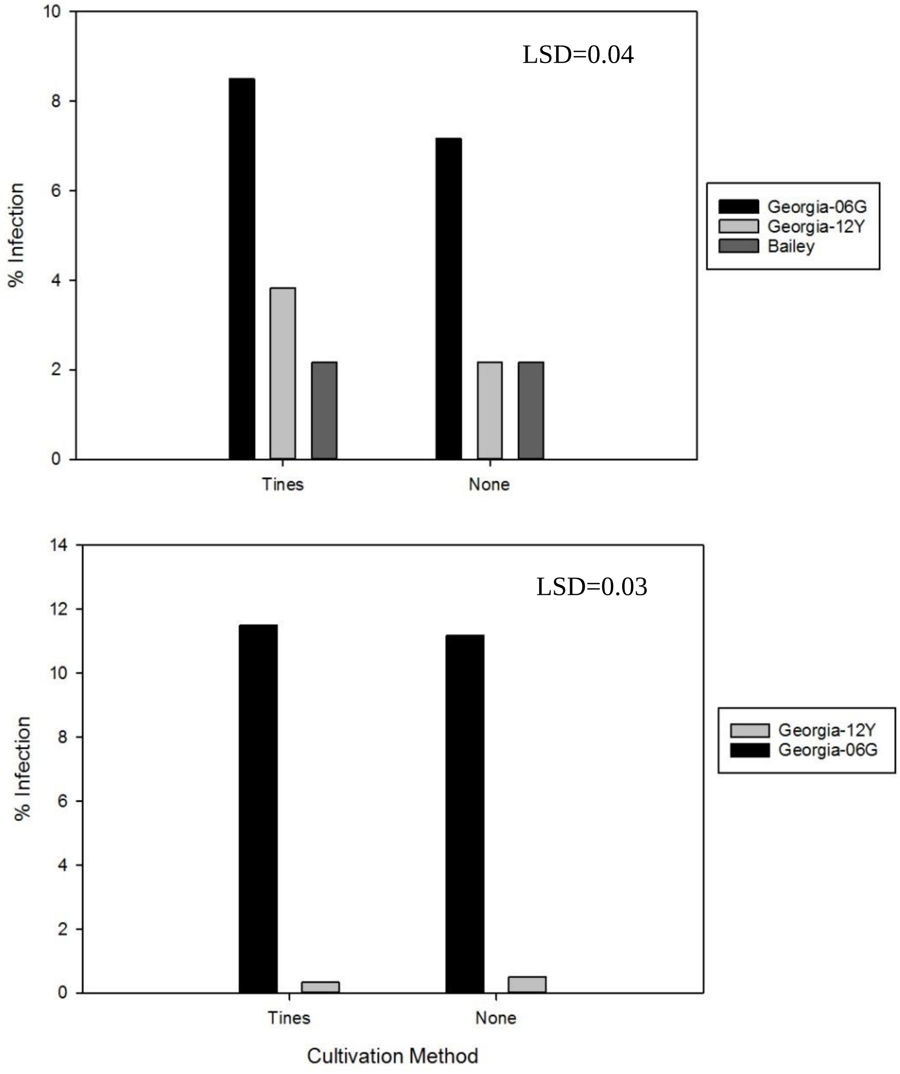

Figure 3.8. Effect of peanut cultivar and cultivation method on incidence of stem rot at Rigdon Farm in 2015 and 2016.
Tines= tine cultivation and none= no cultivation used.

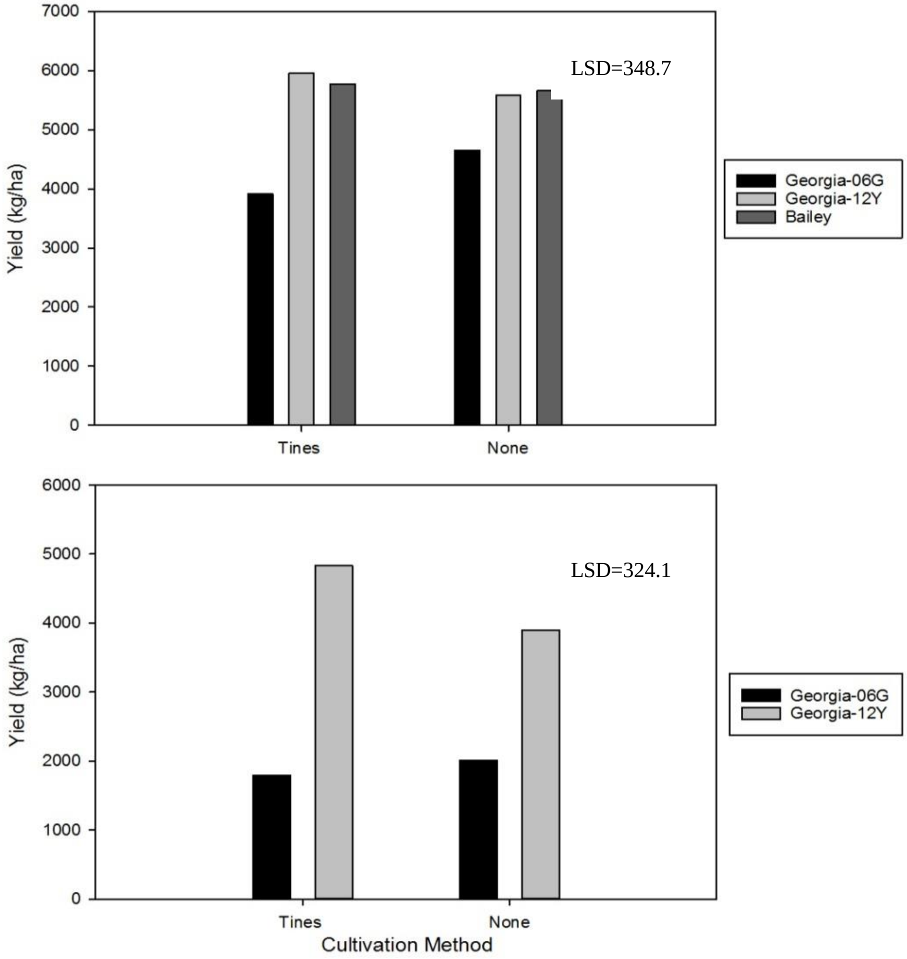

Figure 3.9. Effect of peanut cultivar and cultivation method on yield (kg/ha) at the Rigdon Farm in 2015 and 2016.

CHAPTER 5

COMPARISON OF REFLECTANCE METERS FOR EVALUATION OF PEANUT LEAF SPOT DISEASES

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ABSTRACT

Field experiments conducted in 2015 were used to examine the relationships among canopy crop sensors. Measurements were taken weekly simultaneously with visual ratings. All measurements and ratings were made in the 2015 peanut growing season at four different locations near Tifton, GA. Data showed a linear relationship between defoliation and Normalized Difference Vegetation Index (NDVI) calculated through handheld optical sensors ($R^2 = 0.82$ for Greenseeker; $R^2 = 0.91$ for Crop Circle; $R^2 = 0.82$ Greenseeker vs. Crop Circle). The Greenseeker measurements had more variation than measurements obtained from the Crop Circle. In this study, the Crop Circle had a better agreement with visual ratings. Regardless of the canopy sensor used, both devices proved to be good at estimating disease once defoliation reached greater than 50%.

Introduction

Early leaf spot and late leaf spot caused by *Cercospora arachidicola* S. Hori, and *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, respectively, are among the most destructive diseases of peanut (*Arachis hypogaea* L.) worldwide. If not managed, either disease or the combination of the two can cause complete defoliation. High levels of defoliation often result in loss of integrity of the gynophores by which pods are attached to the plant and loss of mature pods when peanut plants are inverted (Knauft et al., 1988, Teare et al., 1984). Assessments of severity of leaf spot, especially levels of defoliation caused by the diseases are important for evaluation of various treatments in research plots as well as making decisions related to digging time if epidemics are severe.

Visual estimates of percent defoliation or use of the Florida 1-10 severity scale (Chiteka et al., 1988) are effective means of assessing severity of early or late leaf spot in peanut. However, both are subjective, and estimates can vary among evaluators. Measurements of canopy reflectance in the 800 nm wavelength range have been used to assess leaf spot severity (Aquino et al., 1992, Nutter and Littrell, 1996). More recently, Navia-Gine (Navia Gine, 2012) found that a normalized difference vegetation index (NDVI) correlated more closely with percent defoliation by leaf spot in Georgia-06G than reflectance in the near-infrared range. Jordan et al, (2017) reported similar separations of genotypes with NDVI measurements as with final visual leaf spot severity ratings using a Crop Circle (Model ACS-210, Holland Scientific, Lincoln, NE) reflectance meter.

There are several commercially available reflectance meters that allow measurement of NDVI. However, there have been few reports of comparisons of the different types of meters for disease assessment, and no reports on how different meters compare for evaluation of leaf spot diseases of peanut. The objective of this study was to compare NDVI measurements obtained with the Crop Circle ACS-210 and the Greenseeker Handheld Crop Sensor (Trimble, Westminster, CO) for assessment of severity of leaf spot diseases of peanut.

Materials and Methods

Field design and plot establishment. Field experiments conducted in 2015 at the University of Georgia, Coastal Plain Experimental Station (UGA-CPES) were utilized for the leaf spot assessment comparisons. Two trials conducted at the Lang Farm, one trial at the Rigdon Farm, and one trial at the Gibbs Farm were utilized.

A randomized complete block design was used in all trials. In trials at the Lang Farm in 2015, treatments consisted of two cultivars, Georgia-06G and Georgia-12Y in factorial arrangement with treated and nontreated seed. In both years, treated seed of those cultivars were treated with azoxystrobin 0.128 g/kg of seed, fludioxanil 0.008 g/kg of seed, and mefenoxam 0.0016 g/kg of seed applied as Dynasty PD (2.5 g/kg of seed) (Syngenta Crop Protection, Greensboro, NC). In 2015, three cultivars, Georgia-06G, Georgia-12Y, and Bailey, all untreated were used at the Rigdon Farm (tillage trial). Three replications were used at the Gibbs and Lang Farms in 2015. In 2015 at the Lang and Gibbs Farms, plots were 9.17 m long by 1.8 m wide with two rows for each plot. In 2015 at the Lang Farm, six planting dates were used, consisting of April 24, April 27, May 4, May 11, May 19, and May 26. In 2015 at the Gibbs Farm and the Lang Farm (genotype trial), planting dates were on April 10 and May 20, respectively.

At the Lang Farm, cultivars Georgia-06G and Georgia-12Y were planted with and without seed treatment. In all trials, seeding density was 14.8 seed/m of row. All plots were irrigated as needed to maintain favorable conditions for leaf spot epidemics and for peanut growth.

Disease assessment. Leaf spot severity was assessed for each plot using three different methods. In 2015, leaf spot ratings were made at 133 and 140 DAP at the Lang Farm (planting date). In the 2015 tillage trial, leaf spot ratings were made at 119 DAP. In 2015 at the Lang Farm (genotype trial), leaf spot ratings were made at 105, 112, 119, 126, 133, and 140 DAP. In 2015 at the Gibbs Farm (genotype trial), leaf spot ratings were made at 140 and 145 DAP.

For each evaluation date, leaf spot severity was assessed visually using the Florida 1-10 leaf spot severity scale where 1=no disease, 0% defoliation, and 10=100% defoliation, plants dead, killed by leaf spot (Chiteka et al., 1988). Percent defoliation was calculated from Florida 1-10 severity ratings using the formula developed by Li et al. (2012):

$$\% \, Defoliation = \frac{100}{1 + e^{-\left(\frac{FLSc - 6.0672}{0.7975}\right)}}$$

where FLSc is the Florida scale value.

For each evaluation date, canopy reflectance was measured using active sensor reflectance meter (Crop Circle model ACS-210, Holland Scientific, Lincoln, NE) and a hand-held Greenseeker crop sensor (Trimble, Westminster, CO) which simultaneously measures canopy reflectance in the visible (VIS, centered at 650nm) and near infrared (NIR, centered at 880nm) portions of the light spectrum was used for these measurements. For each plot, a vegetation index, presented as the normalized difference vegetation index (NDVI), was calculated using the formula:

$$NDVI = (ref\text{NIR}-ref\text{VIS}) / (ref\text{NIR}+ref\text{VIS})$$

where *ref*NIR and *ref*VIS are reflectance measurements for the near infrared and visible portions of the light spectrum, respectively.

The Greenseeker emits bursts of red and infrared light and then measures the amount of light that reflects back at the sensor. The unit continues to sample the scanned area as long as the trigger remains engaged. The unit automatically averages the NDVI rating and the average is displayed as soon as the trigger is released. NDVI readings can range from 0.00 to 0.99.

Sensor readings were collected at Gibbs Farm on 147 DAP in 2015 and 140 DAP in 2015 at the Lang Farm (genotype trial). Sensor readings were collected for the planting date trials at 140 DAP in 2015 at the Lang Farm.

Sensor ratings were collected for the tillage trials at the Rigdon Farm in 2015 at 119 DAP. For each evaluation, the sensor was carried manually and positioned directly over the center of the row in the nadir view at a distance of approximately 1.0 m above the plant canopy. Scans were made of the entire length of both rows of each plot by walking at a speed of approximately 0.9 m/sec. For the Crop Circle, sensor readings were recorded 10 times per second, resulting in an average of approximately 125 individual sensor readings per plot. The final output of the sensor was a pseudo-reflectance value for both NIR and VIS bands and the calculated NDVI. The mean of sensor readings for NDVI was calculated for each plot, which was used for analysis and genotype comparisons.

Regression analysis was used to examine the linear and nonlinear relationships between NDVI and final percent defoliation for each location.

Proc GLM (SAS v 9.4) was used to examine linear and quadratic relationships among percent defoliation and NDVI measured by the two meters. Nonlinear regression (Proc NLIN, SAS v.9.4) was used for piecewise regression to examine for the relationship between NDVI and final percent defoliation. Goodness of fit of the piecewise regression was evaluated by calculating the linear correlation coefficient (R) for the correlation between observed versus predicted values of the model.

Data were analyzed using SAS v.9.4 software (SAS Institute, Cary, NC). Relationships were evaluated between Greenseeker and visual ratings, Crop Circle and visual ratings, and a comparison of Greenseeker to the Crop Circle.

Results

Gibbs Farm. In the Gibbs Farm trial, NDVI measured with the Green Seeker instrument decreased linearly with increasing percent defoliation (Figure 4.1 A). There was no significant regression for the relationship between NDVI measured with the Crop Circle instrument and percent defoliation ($P < 0.36$) (Figure 1B)or the relationship between NDVI measured between the two instruments ($P < 0.58$) (Figure 4.1).

Rigdon Farm. At the Rigdon Farm, NDVI values ranged from 0.425 to 0.690, 0.6549 to 0.8175, and 3.5 to 7 for the Greenseeker, Crop Circle and, visual ratings, respectively. Plotted values for the Greenseeker compared to % defoliation resulted in an R-squared value of 0.3980 while the Crop Circle compared to % defoliation resulted in an R-squared value of 0.0000. When the NDVI values for both devices were plotted against each other, the R-squared value was again 0.0000.

Lang Farm. In the vigor trial at the Lang Farm, NDVI as measured with the Green Seeker meter decreased linearly with increasing percent defoliation (Figure 4.2).

NDVI as measured with the Crop Circle reflectance meter was described by a two linear sector piecewise regression with a break point at approximately 73.9% defoliation (Fig. 4.2). NDVI declined more rapidly after that point as defoliation increased. The relationship between NDVI measured with the Crop Circle meter increased according to a quadratic function of NDVI measured with the Green Seeker instrument (Figure 4.2).

In the planting date trial at the Lang Farm, NDVI as measured with the Green Seeker instrument decreased with increasing defoliation as described by a two linear sector piecewise regression with a break point at approximately 49% defoliation (Fig.4.3). NDVI as measured with the Crop Circle instrument decreased with increasing defoliation as described by a two linear sector piecewise regression with a break point at approximately 91.% defoliation (Fig.4.3). NDVI measured with the Crop Circle instrument increased with increasing NDVI measured with the Green Seeker instrument according to a two linear sector piecewise regression with a break point at approximately 0.53 NDVI measured with the Green Seeker instrument (Fig.4.3).

Both devices had a higher correlation to visual leaf spot ratings when defoliation was greater than 50%. The Crop Circle had a better fit than the Greenseeker when compared to visual ratings in the regression across all ratings. In the Lang Vigor trial, the variation was much greater before defoliation occurred in the leaf spot epidemic. Both the Rigdon and the Gibbs trials had a poor fit in the regression analysis.

Discussion

The canopy reflectance in the visible and near infrared regions is influenced by the amount of green tissue present. In the case of peanut leaf spot, defoliation was likely the greatest reason for a decrease in NDVI values. Since the Crop Circle and the Greenseeker have slightly different NIR wavelengths, 770 for Greenseeker and 880 for Crop Circle, the NDVI values were not equal.

Two active canopy sensors were compared to visual leaf spot ratings using the Florida Scale (Chiteka et al, 1988) in 2015 across four trials. To our knowledge, the Greenseeker and Crop Circle have not been compared for the purpose of evaluating leaf spot in peanut. It was observed that variation occurs between cultivars and among individual cultivars. The variation is likely due to canopy growth differences among cultivars and variation in growth throughout the canopy. Variations in measurements by both devices were greater before defoliation occurred. Once defoliation started, the variation was greatly reduced.

In this study, neither device correlated well with visual estimates at the Gibbs Farm. At the Gibbs farm, a brief epidemic of Choanephora leaf spot was observed. The epidemic resulted in dead foliage that remained in the upper canopy throughout the growing season. This may have been partially responsible for the lack of fit from this field. However, at the Rigdon Farm, poor stand was a problem throughout the season. Although defoliation was higher than that at the Gibbs Farm, the bare ground between plants may have skewed the data for the individual plots. As observed at the Rigdon and Gibbs Farms, many factors can cause the data to be skewed when using the two canopy sensors.

Although both sensors gave NDVI ratings that were correlated with visual ratings, the Crop Circle had less variation than the Greenseeker. The Greenseeker made it easier to acquire data than the Crop Circle. The Greenseeker automatically figures a mean value for NDVI while the data from the Crop Circle must be downloaded and means have to be computed. The Greenseeker is less expensive than the Crop Circle. The Crop Circle device can be linked with global positioning system equipment and allows mapping.

Both devices provided NDVI estimates that correlate peanut leaf spot, but only when there is an adequate range of defoliation. Both devices show potential for use for leaf spot assessment. However, results from this study indicate that neither should be used as a sole means of evaluating leaf spot.

Acknowledgements

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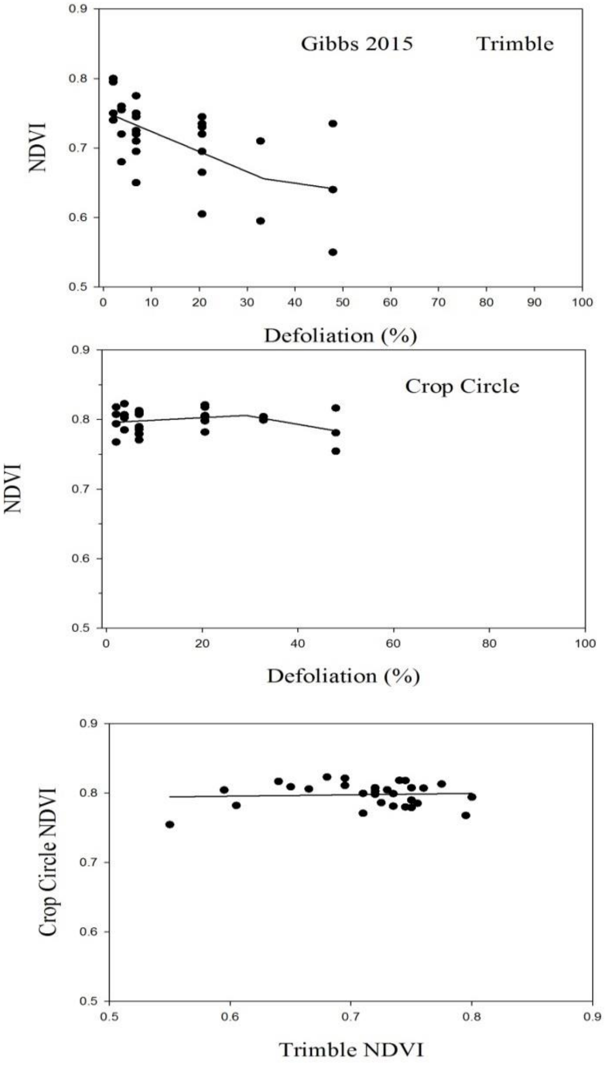
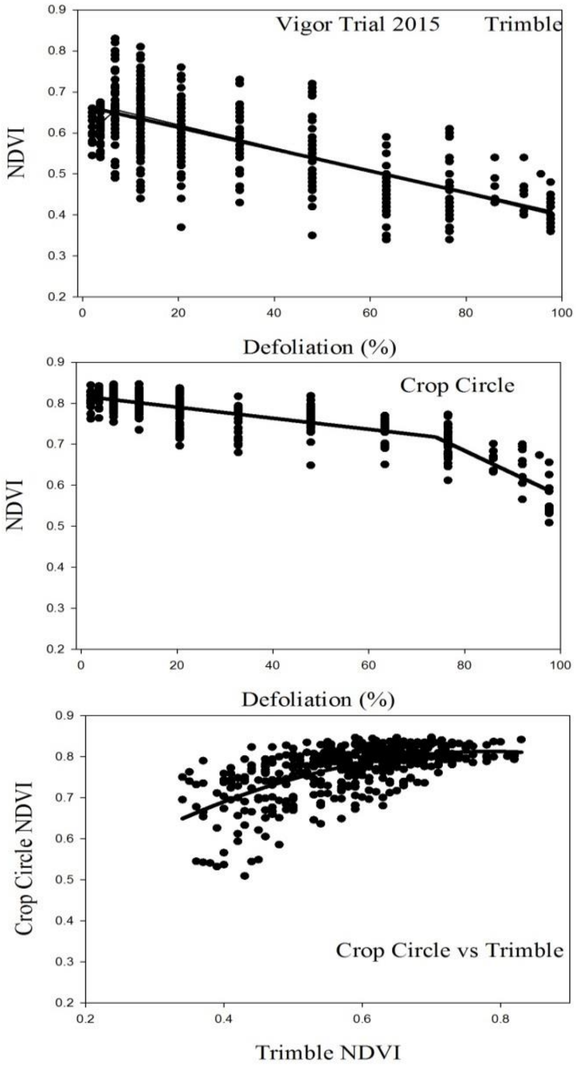


NDVI=0.7495-0.025*% def
$P<0.0001$
$R^2=0.42$

NS=$P>0.36$

NS= $P>0.58$

Figure 4.1. Regression of NDVI values as determined by Trimble and Crop Seeker reflectance meters on percent defoliation, and regression of NDVI determined with the Crop Circle meter on that determined with the Green Seeker meter. Data is from across peanut genotypes, Gibbs Farm, 2015

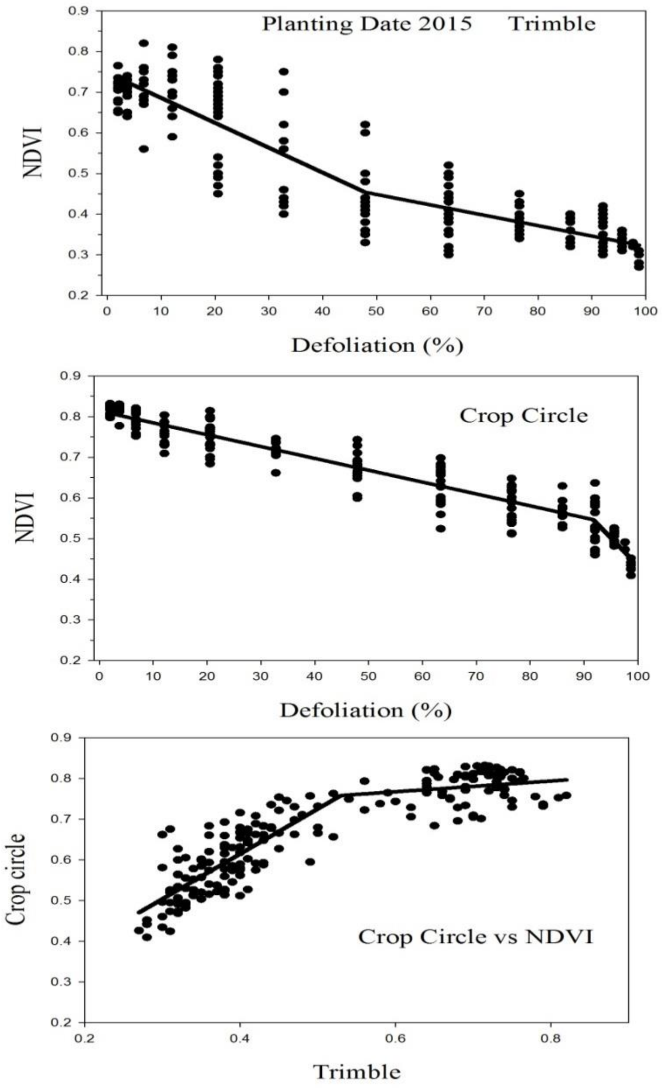


NDVI=0.6667-0.0027* % def., $P < 0.0001$,
R^2=0.48

NDVI=0.8150-0.0013% def for (0-73.9)
NDVI=0.7178-0.0050% def for >73.9
Breakpoint = 73.9
$P<0.0001$
R=0.87

CC = 0.6653 + 0.2695*TR

Figure 4.2. Regression of NDVI values as determined by Trimble and Crop Seeker reflectance meters on percent defoliation, and regression of NDVI determined with the Crop Circle meter on that determined with the Green Seeker meter. Data is from across peanut genotypes, Lang Farm, 2015.



NDVI=0.7373-0.006* def
for (0-47.889)
NDVI= 0.4477-0.00235*
def for >47.889
Breakpoint= 47.889
P<0.0001
R=0.84

NDVI= 0.8079-0.0028* def
for (0-91.72)
NDVI= 0.5466-0.0116 *
def >91.7243
Breakpoint= 91.724
P<0.0001
R=0.91

NDVI=0.4705-0.543*
NDVI CC for NDVI GS (0-
0.5294)
NDVI= 0.7580-0.816*
NDVI CC for NDVI GS >
0.5294
Breakpoint= 0.5294
P<0.0001
R=0.82

Figure 4.3. 2015 Regression of NDVI values as determined by Trimble and Crop Seeker reflectance meters on percent defoliation, and regression of NDVI determined with the Crop Circle meter on that determined with the Green Seeker meter. Data is from across peanut cultivars and planting dates, Lang Farm, 2015.

CHAPTER 6

CONCLUSION

In the United states, control of stem rot and leaf spot diseases caused by *Sclerotium rolfsii*,*Cercospora arachidicola* and *Cercospordium personatum*, respectively, are critical for peanut, *Arachis hypogaea*, production in both conventional and organic situations. Cultivars with resistance and/or tolerance to these pathogens could reduce direct losses to these diseases when effective fungicides are not available and reduce cost of control when fungicides are available. The goal of this research was to identify low input disease management methods for peanut in conventional and organic situations. The research focused on IPM management strategies for foliar and soil borne diseases of peanut.

Field experiments were conducted to evaluate advanced breeding lines for possible use in organic production or situations where fungicides are not available or cannot be afforded. In field studies conducted over 2014-2015, several advanced breeding lines, as well as cultivar Georgia-12Y, were identified as possible cultivars to be used in any situation where fungicides are not allowed or not available. In all production systems, but especially organic systems, resistance is one of the first places to start when selecting cultivars.

Planting date was evaluated as a way to avoid secondary inoculum from the leaf spot pathogens. Currently, late planting is utilized due to risk of tomato spotted wilt incidence. However, resistance/tolerance to TSW allows growers to utilize the early planting dates without worry of loss to TSW. Georgia-12Y produced greater yield than Georgia-06G in all planting dates without the use of foliar fungicides. The early season vigor and resistance shown with

Georgia-12Y allows it to take advantage of the early planting dates to avoid leaf spot pathogens. The research conducted has shown the leaf spot epidemic can be partially or even completely avoided by utilizing a planting date as early as April 10. In this study, yield was highest and leaf spot epidemics were lowest with early planting dates. In conventional systems, fungicides are used to control leaf spot epidemics. Since fungicides are not allowed in organic systems, avoidance is one method organic producers can use to deal with leaf spot.

Mechanical cultivation methods were evaluated for weed control and possible implications for loss to stem rot. In organic production, weeds are responsible for high yield losses. This trial evaluated different mechanical methods of weed control, while evaluating the "dirting" effect for increases of incidence of stem rot caused by *Sclerotium rolfsii*. The study provided evidence of the "dirting" effect increasing stem rot in susceptible cultivars while no effect was seen when using resistant cultivars such as Georgia-12Y. Even when exposing Georgia-12Y to excessive amounts of inoculum, this cultivar's resistance held. The mentioned effect was witnessed in a field study of continuous peanut for approximately 15 years. This study showed resistance of Georgia-12Y to *S. rolfsii* can stand up to the increased pressure from "dirting" and in fields that lack a good rotation regime, although poor rotation is not suggested.

While collecting data for the existing field experiments, the opportunity arose to evaluate handheld crop canopy sensors for evaluating leaf spot diseases. The devices evaluated were the Greenseeker (Trimble, Westminster, CO) and the Crop Circle (Holland Scientific, Lincoln, NE). Both devices were compared to visual ratings (Florida Scale 1-10) with all measurements and ratings taken on the same day throughout the 2015 growing season. When compared to visual ratings, both devices showed the potential to be used after defoliation occurs, but the Crop Circle had less variation in this study. While the devices were useful after defoliation, they were not very helpful when defoliation was less than 50% or when other factors interfere with readings of peanut plants. Of the four fields evaluated, two of them did not correlate well in the comparison, most likely due to bare ground and other diseases influencing the NDVI ratings. It was also apparent at the Ponder Farm weed trial, the interference of weeds confounds the results and is not recommended when weed pressure is high. Overall, the devices are not useful until defoliation is apparent in the upper canopy. At this time visual ratings are recommended as the primary method of evaluation of peanut leaf spot. However, after defoliation, less trained personnel can use the devices compared in this study with very little guidance. The reflectance meters can be used in combination with visual ratings, but the meters are not recommended as a stand-alone method for evaluating leaf spot.

The findings in this study suggest that alternative methods, such as planting date, mechanical tillage, and cultivars with good resistance and high yield potential have the ability to reduce fungicide use in organic and situations where fungicides are not available or affordable. This will also impact the profit margin of growers due to high cost of fungicide applications, as well as the need to limit use for the benefit of fungicide resistance.

Future field studies will need to focus on resistance to the many pathogens of peanut. As new cultivars become available, trials focusing on alternative management strategies will need to be revisited.