CHARACTERIZATION OF THE RELATIONSHIP BETWEEN LEAF SPOT SEVERITY AND YIELD IN NEW PEANUT RUNNER-TYPE CULTIVARS AND EFFECTS OF NEW PEANUT GENOTYPES ON LEAF SPOT EPIDEMICS

by

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(Under the Direction of Albert K. Culbreath)

ABSTRACT

New peanut (*Arachis hypogaea*) cultivars 'Florida-07', 'Georgia-06G', 'Georgia-07W', and 'Tifguard' were combined with four different fungicide treatments in multiple field trials in 2010 and 2011 to examine the relationship between percent defoliation, caused by *Cercospora arachidicola* or *Cercosporidium personatum,* and pod yield. Decline in yield was no more than 14.4 kg per % increase in defoliation in all cultivars and trials, which was lower than previously reported. Canopy reflectance was correlated with percent defoliation in most cases. Field trials were conducted in Tifton, GA and Marianna, FL to evaluate field reactions of new peanut genotypes developed as part of the USAID Peanut CRSP program. Four genotypes (97x45-HO1-2-B2G-1-2-1-2, 98x64-2-2-1-2b4-B, 96x72-HO1-10-2-1-b4-B, and CRSP 1048-192T) showed moderate levels of field resistance to *C. personatum*. Incidence of stem lesions caused by *C. personatum* was higher for Florida-07 than for Georgia-07W or Tifguard.

INDEX WORDS: *Cercosporidium personatum,* late leaf spot, yield losses, cankers, resistance.

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DEDICATION

This work is dedicated to my family (Alejandra, Luna, Mile, and Nahir) for giving me the pathway to follow, for brightening my way, and for keeping me going.

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TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS...v

LIST OF TABLES...vii

LIST OF FIGURES ix

CHAPTER

1 INTRODUCTION AND LITERATURE REVIEW 1

2 RELATIONSHIPS AMONG DEFOLIATION CAUSED BY LEAF SPOT, CANOPY REFLECTANCE, POD YIELD, AND GRADE IN NEW RUNNER-TYPE PEANUT CULTIVARS 27

3 EFFECT OF RUNNER-TYPE PEANUT CULTIVARS AND ADVANCED BREEDING LINES ON SEVERITY OF LATE LEAF SPOT AND POD YIELD...63

4 INCIDENCE OF STEM LESIONS CAUSED BY *CERCOSPORIDIUM PERSONATUM* IN NEW RUNNER-TYPE CULTIVARS 81

5 CONCLUSIONS 93

LIST OF TABLES

Page

Table 1.1: Area planted in Georgia in 2010 to produce foundation, registered and certified seed 22

Table 1.2: Florida leaf spot disease rating scale 23

Table 2.1: Pearson's correlation coefficients of the relationship among percent defoliation, yield, TSMK, and dollar value tests A and B. Tifton, GA 2010. 46

Table 2.2: Pearson's correlation coefficients of relationship among percent defoliation, NDVI, NIR, VIS, yield, TSMK, and dollar value. Test C Tifton, GA 2011. 47

Table 2.3: Pearson's correlation coefficients of relationship among percent defoliation, NDVI, NIR, VIS, yield, TSMK, and dollar value. Test D Attapulgus, GA, 2011. 49

Table 2.4: Pearson's correlation coefficients of relationship among percent defoliation, NDVI, NIR, VIS, yield, TSMK, and dollar value. Test E. Plains, GA, 2011. 51

Table 3.1: Pedigree, relative maturity, and oleic acid content of peanut genotypes evaluated for yield and leaf spot resistance in 2010 and 2011 77

Table 3.2: Effect on peanut genotypes and fungicide treatments on severity of late leaf spot and pod yield, Tifton, GA 2010 78

Table 3.3: Effect on peanut genotypes and fungicide treatments on severity of late leaf spot and pod yield, Tifton, GA 2011 79

Table 3.4: Effect on peanut genotypes on severity of late leaf spot, percent defoliation, and pod yield, Marianna, FL 2010 and 2011 80

Table 4.1: Effect of cultivar on incidence of stem lesions, defoliation, and pod yield.................92

LIST OF FIGURES

Page

Figure 1.1: *Cercospora arachidicola* (A) and *Cercosporidium personatum* (B) lesions. 24

Figure 1.2: *Cercospora arachidicola* conidiophores (A) and conidia (B)..................................25

Figure 1.3: *Cercosporidium personatum* conidiophores (A) and conidia (B).............................26

Figure 2.1: Disease progress curves for defoliation caused by late leaf spot (*Cercosporidium personatum*) in the non-treated plots of the cultivar Georgia-06G in 2010 and 2011 53

Figure 2.2: Relationships of yield (kg/ha) (A) and crop value ($/ha) (B) in function of final percent defoliation in Trial A, Tifton, GA 2010 54

Figure 2.3: Relationships of yield (kg/ha) (A) and crop value ($/ha) (B) in function of final percent defoliation in Trial B, Tifton, GA 2010 55

Figure 2.4: Relationships of yield (kg/ha) (A) and crop value ($/ha) (B) in function of final percent defoliation in Trial D, Attapulgus, GA 2011..57

Figure 2.5: Relationships of yield (kg/ha) (A) and crop value ($/ha) (B) in function of final percent defoliation in Trial C, Tifton, GA 2011 59

Figure 2.6: Relationships of yield (kg/ha) (A) and crop value ($/ha) (B) in function of final percent defoliation in Trial E, Plains, GA 2011...60

Figure 2.7: Yield (kg/ha) increased linearly with increasing levels of NDVI for Florida-07 and Georgia-06G in Tifton, GA 2011. Yield (kg/ha) increased linearly with increasing levels of NDVI for Florida-07, Georgia-06G, and Georgia-07W in Attapulgus, GA 2011........62

CHAPTER 1

INTRODUCTION - LITERATURE REVIEW

Peanut, *Arachis hypogaea* L., is a very important crop worldwide. It is important to the global diet, and is used for food for people from poor countries as well as developed countries. Peanuts can be eaten raw, used in recipes or consumed as peanut butter. Peanut also has other uses. It can be crushed for oil, solvents and medicines; it can also be used for animal feed, to make textile materials, and many other uses. The cultivated peanut is a native South American legume (Hammons, 1982). After the discovery of America, peanut was disseminated to Europe, Africa, Asia, and to the Pacific Islands. Eventually it traveled to the colonial seaboard of the present southeastern United States (Hammons, 1982) where it has been grown since. The United States is the third largest producer of peanut in the world with 444,182 ha harvested in 2011 (USDA, 2012). Major production areas in the United States are located in Georgia, Florida, Alabama, Texas, Mississippi, North Carolina, South Carolina, Virginia and Oklahoma. Georgia has the largest peanut production, accounting for 41.6% of the peanut production in the U.S. for 2011 (USDA, 2012). There are approximately 25,000 peanut farmers in the major producing areas (Anonymous, 2012), and they produced an estimated 1.81 million tons of peanuts on approximately 1.14 million acres in 2011 (USDA-NASS, 2012). Most of the peanut crop produced in the United States is shelled and is processed as peanut butter, salted peanuts, and confections (Porter, 1997a).

The peanut plant exhibits a range of growth habits, from erect to prostrate. Typically it is sparsely hairy, and it may grow to a height of 15-60 cm or higher. It has a prominent well-developed taproot with many lateral roots (Porter, 1997a). Peanut leaves are alternately arranged on the stems. Each leaf has four leaflets, approximately 2-10 cm long, in opposing pairs. The flowers are typically yellow and located in the axils of leaves at nodes not occupied by branches (Shokes and Melouk, 1995). Flowers are self-pollinated around sunrise and within one week of fertilization a pointed gynophore, also known as a geocarpophore but most commonly referred to as a "peg", develops and elongates. The fertilized ovaries are located behind the tip of the peg. The peg grows into the soil to a depth of 2-7 cm. The tip orients itself horizontally, the ovary enlarges rapidly, and the pod begins to grow (Porter, 1997a). Mature pods may contain one to five seeds or kernels. The testae, or seed coats, vary in color depending on the cultivar but are typically tan, pink, or red (Shokes and Melouk, 1995).

In the U.S. peanuts are typically grown in sandy, loamy soils from April to October, depending on the variety. Peanuts require 120-160 frost free days. They need an abundance of sunlight and temperatures that range from 21-30 °C with night temperatures not falling below 10 °C (Ketring and Reid, 1995). Peanut plants need approximately 83 cm of rainfall, depending on dispersion through the season, to reach optimum growth. Adequate soil moisture is needed the entire season, but adequate moisture is most critical during fruiting and pod fill (Henning et al., 1982). Optimal soil pH is between 6.0 and 7.0 (Ketring and Reid, 1995). The peanut plant fixes its own nitrogen and grows well and produces good yields by using residual phosphorus and potassium applied to other crops in the rotation. The plant needs boron to ensure kernel quality (Ketring and Reid, 1995), and it has a unique need for calcium, which seems to increase with the kernel size of the type grown (Cox and Sholar, 1995).

There are four market types accepted in the market. The most common type grown in the U.S is the runner type which is used primarily for the manufacture of peanut butter. The large kerneled virginia type is marketed mainly as snack peanuts and in-shell peanut products. The spanish type, with rounder and smaller kernels, is used for snack peanuts, peanut butter and confections. The longer podded valencia type, containing three to five kernels in each shell, is marketed mostly in the shell for roasting or boiling. Certain spanish and valencia types may require only 95 to 100 days to reach optimum maturity while some runner and virginia types may require 140 days or more (Henning et al., 1982).

As with any other row crop, peanuts need special management to ensure that conditions are optimal for the health of the plant. The most important factors to take into account are physiological and environmental disorders, weeds, pre-harvest and post-harvest insects, viral diseases, foliar pathogens, soil borne fungal pathogens, nematodes and mycotoxin-producing fungi. Because of the increasing importance of the peanut as a food, feed and oil crop, more attention has been given to improved crop management practices, especially in the areas of pest control, tillage, crop rotation, irrigation, and new cultivars.

P**eanut foliar diseases**. The most important foliar diseases of peanut in the southeastern U.S. are early leaf spot, caused by *Cercospora arachidicola* Hori (teleomorph = *Mycosphaerella arachidis* Deighton), and late leaf spot, caused by *Cercosporidium personatum* (Berk. & M. A. Curtis.) Deighton (teleomorph = *Mycosphaerella berkeleyi* Jenk.), respectively. These two diseases and peanut rust, caused by *Puccinia arachidis* Speg. are widely distributed throughout the world. Although peanut rust causes severe problems in some fields and intermittently across wider areas, problems with the leaf spot diseases are much more prevalent. Early and late leaf spot can be very destructive on susceptible cultivars if effective fungicides are not applied (Porter et al., 1982). In the U.S., use of fungicides is the primary management practice used to control these diseases. Without fungicidal control on susceptible cultivars, yield losses from these diseases may approach 70% (Nutter and Shokes, 1995). Symptoms of early and late leaf spots are small necrotic flecks that enlarge and become light-brown to black circular spots ranging from 1-10 mm or more in diameter (Porter et al., 1982). However, all above-ground plant parts are subject to infection and late in the season during severe epidemics, lesions occur on leaf petioles, gynophores, central stems, and lateral branches (Nutter and Shokes, 1995) (Fig.1.1). Lesions for early and late leaf spot often are very similar on the upper (adaxial) side of the leaf. Early leaf spot lesions are usually light tan to reddish brown on the underside (abaxial surfaces) of leaflets (Shokes and Culbreath, 1997) and are typically surrounded by conspicuous yellow halo (Porter et al., 1982). Lesions of late leaf spot are usually dark brown to black on the underside, but the presence of a halo is not consistent. The early leaf spot fungus sporulates primarily on the adaxial surface, and the late leaf spot fungus usually sporulates on the abaxial surface of the leaflet (Porter et al., 1982). Conidia of *C. arachidicola* (35-110 x 3-6 ųm) are thin, elongated, subhyaline, olivaceous, obclavate, with three to twelve septa. Conidia of *C. personatum* (20-70 x 4-9 ųm) are thicker, curved, “cigar shaped”, medium olivaceous, cylindrical, and obclavate, and have one to nine septa (Shokes and Culbreath, 1997) (Fig. 1.2, 1.3).

Favorable environmental conditions for infection of early leaf spot range from 16 - 25 °C with long periods of relative humidity greater than 90% (Nutter and Shokes, 1995; Shokes and Culbreath, 1997). Conditions favorable for late leaf spot epidemics include periods of leaf wetness with temperatures of 20 - 26 °C (Shokes and Culbreath, 1997). New spores on lesion surfaces will be produced during warm, wet weather. Late leaf spot has the potential to cause more damage over a shorter period of time than early leaf spot. This is because *C. personatum* produces more spores per lesion despite of having a longer incubation period (10 to14 days compared to six to eight days for *C. arachidicola*) (Shokes and Culbreath, 1997; Nutter and Shokes, 1995). Smith and Crosby (1973) reported that the number of conidia increased with the onset of rainfall. They also obtained evidence for the vertical dissemination of *C. arachidicola* conidia to heights of 2.7 m above the soil surface in a peanut field. Conidia can be dispersed by wind, splashing water, insects and farm implements and infect healthy plants in the field. Repeated cycles of the diseases occur during the cropping season.

Fungi causing early and late leaf spot infect only peanut and both pathogens survive between cropping periods in plant debris. Therefore, deep plowing and crop rotation will result in decreased survival of leaf spot inoculum in the soil (Nutter and Shokes, 1995). However, use of conservation tillage also suppressed leaf spot epidemics (Porter and Wright, 1991; Monfort et al., 2004; Cantonwine et al. 2006, 2007), likely because undisturbed soil and previous crop debris impedes splash dispersal of conidia from the soil (Cantonwine et al., 2007). The selection of cultivars, fungicides, and tillage systems can all have an impact on disease development (Nutter and Shokes, 1995).

An integrated management system can be effective for controlling leaf spot diseases, allowing for reduced dependence on fungicides for disease control. The use of fungicides is the primary practice for control of leaf spot. For over two decades prior to 1994, peanut growers in the southeastern U.S. relied almost exclusively on chlorothalonil (Culbreath et al., 2002) which is a broad spectrum, multiple-site protectant fungicide with little or no risk of resistance developing in the leaf spot pathogens. The traditional application of chlorothalonil was based on a calendar schedule, beginning at 30-40 days after planting and continuing at 10-14 day intervals until 14-21 days before harvest (Shokes and Culbreath, 1997). However, chlorothalonil has little or no efficacy against some other fungal diseases such as stem rot caused by *Sclerotium rolfsii*

(Culbreath et al., 1992a). Therefore, the use of fungicides such as tebuconazole, azoxystrobin, (Culbreath et al., 2002; Hagan et al., 2010), flutolanil (Rideout et al., 2008), and others in alternation or combination with chlorothalonil is a common practice among the peanut growers.

The typical use pattern for chlorothalonil was seven applications, made at approximately 14-day intervals. Today few growers use only chlorothalonil for leaf spot control. Most of the other fungicides used are “at risk” for leaf spot pathogens becoming less sensitive, or resistant to them. After tebuconazole was labeled in 1994, it displaced chlorothalonil as the prevalent fungicide used on peanut in the southeastern U.S. However, resistant populations of both *C. arachidicola* and *C. personatum* have developed (Stevenson, 2006). Although tebuconazole is still effective against *S. rolfsii*, it is has reduced efficacy against one or both of the leaf spot pathogens in many fields.

Several fungicides are available that are effective against leaf spot and one or more soilborne pathogens. However, they are expensive, and the cost associated with fungal disease control (cost of fungicides plus the cost of application) represents one of the highest input costs in peanut production. Several studies have been conducted to reduce fungicide inputs through the use of weather-based application strategies (Johnson et al., 1985; Rideout et al., 2008; Hagan et al., 2010), reduced rates and extended spray intervals (Culbreath et al., 2002; Cantonwine et al. 2006; Gremillion et al, 2011; Monfort et al., 2004), and reduced calendar programs (Hagan et al., 2010) with good results. A risk assessment tool, Peanut Rx, has been developed that helps growers to decide how many fungicide applications are needed for control of foliar and soilborne diseases based on relative risks associated with factors such as crop rotation, cultivar choice, tillage system, planting date, and irrigation (Kemerait et al., 2011). This has prompted many growers to use reduced fungicide regimes in situations where full regimes are not needed. However, many still use a full conventional calendar program.

One of the most desirable ways to improve control of leaf spot diseases and reduce the dependence on fungicides is the development and deployment of cultivars with resistance to both *C. arachidicola* and *C. personatum*. Development of leaf spot resistant cultivars has been a priority for peanut breeders for many years. The first leaf spot resistant runner-type cultivar was 'Southern Runner' developed by Gorbert et al. (1987), and several others with similar or higher levels of partial resistance have been released. 'Florida MDR-98' (Gorbet and Shokes, 2002), 'C-99R' (Gorbet and Shokes, 2002), 'Georganic' (Holbrook and Culbreath, 2008), 'Georgia-01R' (Branch, 2002), 'DP-1' (Gorbet and Tillman, 2008), and 'York' (Gorbet and Tillman, 2011) all have moderate levels of resistance to one or both of the leaf spot pathogens. In previous studies significant differences in leaf spot severity were noted between 'Florunner', a susceptible cultivar, and resistant cultivars/breeding lines. The pod yield of resistant genotypes was double that of susceptible lines when no fungicides were applied (Gorbet et al., 1990). Those results indicated that it was possible to develop cultivars with leaf spot resistance that reduced the need for fungicide control of leaf spot diseases. To date, those cultivars have not been widely accepted by the industry because most have a later maturity than standard cultivars such as Florunner, and problems with seed germination and seedling vigor have been common with leaf spot resistant lines. Georganic has red testae which are not acceptable for conventional production (Holbrook and Culbreath, 2008). Therefore, commercial success of leaf spot resistant cultivars has been limited (Tillman, 2009).

New runner-type peanut cultivars. In the late 1980s and early 1990s, tomato spotted wilt, caused by *Tomato spotted wilt tospovirus* (TSWV), emerged as a new problem in peanut in the southeastern U.S. (Culbreath et al., 1992b; Culbreath and Srinivasan, 2011). By the mid-1990s it had become one of the most important diseases of peanut in that region (Culbreath et al., 1992b, Culbreath and Srinivasan, 2011). Among other complications brought about by tomato spotted wilt, the disease caused an abrupt shift in the emphasis of peanut breeding programs. The leaf spot resistant cultivar Southern Runner was found to have moderate field resistance to TSWV (Culbreath et al. 1992b). Although Southern Runner was not adopted widely for production, it proved to be a valuable parent in breeding for resistance to TSWV. The cultivar 'Georgia Green' (Branch, 1996) had Southern Runner as a parent and had field resistance to TSWV that was similar to that of Southern Runner (Culbreath et al. 1996). Georgia Green became an integral part of an integrated program for management of TSWV (Culbreath et al.,1992b; Culbreath and Srinivasan, 2011; Tillman, 2009).

After Georgia Green, several other runner-type cultivars were released with greater yield potential and higher levels of field resistance to TSWV. The first cultivar released with a higher level of field resistance to TSWV than Southern Runner or Georgia Green was C-99R (Gorbet et al, Wells et al., 2002). Since 2006, several new cultivars have been released with good field resistance to TSWV and excellent yield potential. Among the most prominent of those are the new runner-type cultivars assessed in this current study, 'Georgia-06G', 'Georgia-07W', 'Florida-07', and 'Tifguard'.

Georgia-06G (Branch, 2007) was released in 2006 by the Georgia Agricultural Experiment Stations. It was developed at The University of Georgia, Coastal Plain Experiment Station, Tifton GA. This is a high yielding, TSWV resistant cultivar with excellent grade (Total Sound Mature Kernels - TSMK) potential, large seeded with tan testa color. This cultivar originated from a cross between Georgia Green (Branch, 1996) x C-99R (Gorbet and Shokes, 2002). This cultivar has been adopted by the Georgia peanut growers since its release due to the yield, grade potential, and kernel quality. Georgia-06G has displaced Georgia Green as the standard peanut cultivar; in 2011 67.4% of the area planted for seed production in Georgia was planted to Georgia-06G (Beasley et al., 2011) (Table 1.1).

Georgia-07W (Branch and Brenneman, 2008) was released in 2007 by the Georgia Agricultural Experiment Station. It was developed at The University of Georgia, Coastal Plain Experiment Station, Tifton GA. This is a high yielding, large seeded peanut cultivar with resistance to TSWV and white mold (*Sclerotium rolfsii*). This cultivar was selected from a cross between C-99R (Gobert and Shokes, 2002) x Georgia Green (Branch, 1996). This cultivar is planted in Georgia in locations with high white mold incidence and was planted to 5.6% of the seed acreage for 2011 (Beasley et al., 2011) (Table 1.1).

Florida-07 (Gorbet and Tillman, 2009) was developed by the University of Florida, Florida Agricultural Experimental Station, North Florida Research and Education Center, Marianna FL, and approved for release in 2006. This cultivar has excellent pod yield potential, competitive kernel grade, high-oleic fatty acid oil chemistry, and resistance to TSWV and white mold (*Sclerotium rolfsii*). This cultivar originated in a cross between C-99R with the breeding line 89xOL4-11-1-1-1b2-B, which had ‘Marc I’ (Gorbet et al., 1992) as a parent. This cultivar is planted in Georgia and Florida, the planted acreage for seed for 2011 reached 6.6% (Beasley et al., 2011) (Table 1.1).

Tifguard (Holbrook et al., 2008) was released by the USDA-ARS and the Georgia Agricultural Experiment Stations in 2007. This cultivar is high yielding and resistant to the peanut root-knot nematode (*Meloidogyne arenaria*) and TSWV. Tifguard was developed from a cross between C-99R and COAN. Tifguard is the first cultivar that has resistance to both pathogens (Holbrook et al., 2008). After its release, Tifguard was found to have moderate resistance to *C. arachidicola* and *C. personatum* (Yan Li, 2012). This cultivar is planted in Georgia in locations with high incidence of root-knot nematode; the acreage planted for seed in 2010 was 7.4% (Beasley et al., 2011) (Table 1.1).

With the exception of Tifguard, there is no indication of resistance to the leaf spot pathogens in the cultivars mentioned above; Florida-07, Georgia-06G, and Georgia-07W, are classified among susceptible cultivars in the current Peanut Rx. Risk assessment index (Kemerait et al., 2011) . However, yield losses associated with high levels of leaf spot, particularly significant defoliation, have not been characterized for any of these new cultivars.

Yield loss assessment. Crop loss, or yield loss to disease, is considered to be the difference between actual yield and the potential for yield obtained in absence of disease (Madden et al., 2007). Although there are many factors that influence yield loss, including a wide spectrum of harmful organisms and environmental stress factors, this research is concerned with the yield in relation to leaf spot epidemics. Sometimes it is necessary to convert yield and yield-loss values into economic terms and to quantify the effects of diseases in terms of costs (Madden et al., 2007). In some cases yield losses to a particular disease may not justify the cost control. The most common way of showing the impact of the epidemic on yield is to plot yield versus disease intensity at one time during the epidemic. For peanuts the typical time to assess this situation is at the end of the season (Backman and Crawford, 1984; Nutter and Littrell, 1996). However the most appropriate methods to relate disease severity or host productivity and yield often are not easily discerned. Often no single method can achieve both satisfactorily. In addition, plant pathogens and disease development are relevant to considerations of yield response (Gaunt, 1995). Therefore causality and correlation between disease and yield require careful interpretation.

Backman et al. (1984) assessed the relationship between yield and severity of early and late leaf spot. In a four-year study of the cultivar Florunner they found that yield was reduced by an average of 57 kg/ha for each percent increase in defoliation by leaf spot and that all levels of defoliation resulted in yield loss. No difference in loss producing potential was observed between *C. arachidicola and C. personatum*. In that study, disease severity assessment was made calculating percent defoliation from samples of 10 central stems of the two center rows of each plot and dividing total leaflets lost by total leaflets (Backman et al 1984). Later, several studies involved with crop loss assessments lead to use of the duration of healthy area or healthy leaf area duration (HAD), proposed by Waggoner and Berger (1987), to predict yield of manually defoliated and leaf spot defoliated peanut (Aquino et al., 1992). In field experiments with Florunner naturally infected with *C. personatum* and *C. arachidicola*, ranges of disease severity were established by varying levels of fungicide applications. It was found that HAD, calculated from the integral of healthy leaf area during the season, was correlated positively with yield and this concept was more closely related to absorption of insolation than to leaf area itself (Waggoner and Berger, 1987). Later experiments found that HAD has lower power of prediction for yield with Southern Runner, a leaf spot resistant cultivar, because this cultivar has more leaf production and lower partitioning of photosynthates to pods compared to Florunner (Aquino et al. 1992). In the same study and a previous study (Nutter, 1989), canopy reflectance of 800-nm wavelength measured with a hand-held multispectral radiometer (CROPSCAN, Inc, Fargo, ND) was used to assess disease severity gradients and provided a rapid and objective measurement of disease intensity and the amount of green area contributing to pod yield. When remote sensing assessments were compared to visual assessments using the 1 - 10 Florida Scale (Chiteka et al., 1988) to measure fungicide efficacy for the control of leaf spot (Nutter et al., 1990), percent reflectance-based measurements had lower coefficients of variation than did visually based assessments. Higher coefficients of determination (R^2) and lower standard errors were obtained when percent reflectance values were regressed on yield. That report also pointed out that numerical rating scales do not offer the broad and continuous range of possible scores afforded by remote sensing. Later, yield loss was assessed using defoliation-based assessments and percent-reflectance assessments. Results indicated that measurements of healthy green leaf area (estimated by percent reflectance) had a better relationship with pod yield than did defoliation-based assessments (Nutter et al., 1996). Percent reflectance measurements explained 81 - 93.8% of the variation in pod yield, while percent defoliation explained 71.6 - 92.8% of the variation in pod yield. However, there are some disadvantages to reflectance measurements obtained by the multispectral radiometer (CROPSCAN). Canopy reflectance may be affected by factors other than canopy stress such as amount of incident radiation, sun angle, time of the day, leaf wetness, sensor height, soil reflectance characteristics, soil pH, relative humidity, and others (Guan and Nutter, 2001).

Remote sensing. The development of new remote sensing devices has increased the last decade; several new sensors are available for scientific research, for example the optical sensor Model PhD 600 (Patchen, Ukiah, CA), the GreenSeeker®-505 (NTech Industries Inc., Ukiah, CA), and the Crop Circle™ ACS-210 (Holland Scientific, Lincoln, NE). These instruments remove the effect of ambient and process only the energy emitted by the integrated sources (Bell et al, 2002). These sensors incorporate its own light source which emits red, near infrared and visual wavelengths. The light is directed toward a plant canopy and a portion is reflected back to the sensor, plant tissue readily absorbs light in the visible portion of the spectrum (and reflects a small amount typically 2% to 10%) and reflects NIR light (35% to 60%) due to a discontinuity in the refractive indexes between cell walls and intercellular air gaps (Anonymous, 2004). These sensors usually have a data logger and calculate the normalized difference vegetation index (NDVI). NDVI has been related to absorbed photosynthetically active radiation in wheat (*Triticum aestivum* L.; Asrar et al., 1984), has been associated with leaf area index in maize (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr; Daughtry et al., 1992], has been used to measure drought stress (Fenstermaker-Shaulis et al., 1997), turf chlorophyll content (Howell, 1999), and turf injury and quality (Trenholm et al., 1999; Bell et al., 2000), and lately to assess detection of tomato spotted wilt and Cylindcocladium black rot in peanut (Isaev, 2012).

Stem lesions assessment. In addition to the familiar lesions on the leaves, during severe epidemics of late leaf spot, *C. personatum* also produces lesions on the petioles, and lateral and main stems. The presence of stem lesions, interrupts translocation along laterals, accelerates maturity, and subsequently kills branch stems (Hemingway, 1954). Culbreath et al. (1991) made a quantitative comparison of stem lesions in Florunner (Norden et al., 1969) and Southern Runner (Gorbet et al., 1987) peanut cultivars. For stem lesion assessment 12 lateral branches were collected from each plot by random selection from each row along the length of the bed. The length of each stem was measured, and stem lesions were counted. Number of lesions per dm of stem length was calculated for each stem to take into consideration differences in internode and stem length between the two cultivars and variation in length among stems within the two cultivars. Their results show that fewer stem lesions developed on Florunner than on Southern Runner under similar conditions. Fewer stem lesion formation may help to prevent weakening of stems and pegs, allowing greater retention of pods at harvest and therefore better yield, in addition fewer stem lesions may decrease initial inoculum for future crops (Culbreath et al., 1991). Since that report, however, incidence of stem lesions typically has not been considered in evaluation of peanut cultivars and breeding lines for resistance to *C. personatum*. Results from Florunner and Southern Runner indicated that incidence of stem lesions was reflective of the relative severity of late leaf spot on the leaves (Culbreath et al., 1992). However it has not been determined whether there are differences in susceptibility to stem lesions within peanut genotypes that are susceptible to leaf infections.

Genotype leaf spot resistance field assessment. Development of a commercially acceptable cultivar with a high level of resistance to leaf spot diseases is a common goal for various breeding programs. However many breeding lines with resistance to leaf spot have unacceptably poor yields or other undesirable characteristics (Smith et al., 1994). The breeding efforts are still going on and a resistant peanut cultivar to *C. arachidicola* and *C. personatum* is not available yet. Therefore several studies have been developed to evaluate breeding lines and its resistance to leaf spot pathogens (Hassan and Beute, 1977; Knauft et al., 1988; Chiteka et al., 1988; Gorbet et al., 1990; Smith et al., 1994; Holbrook and Anderson, 1995; Gremillion, 2011; among others). The methodology used to assess genotype resistance to leaf spot may vary, but resistance in field situations may be the most important because that is the final goal, some plant introductions were resistant to leaf spot in greenhouse but not in the field (Hassan and Beute, 1977). There are several techniques to assess leaf spot severity in the field: 1) Defoliation ratio is a technique that measures the lower limbs randomly selected and calculates a ratio of the distance between the base of the limb and the first leaf (Hassan and Beute, 1977); 2) Lesion count is a technique that selects random leaves and counts the lesions formed on each leaflet (Hassan and Beute, 1977; Chiteka et al., 1988); 3) Leaf area infected, estimated using an intensity grade scale with pictorial diagrams developed by Sulaiman and Agashe (1965) (Hassan and Beute, 1977); 4) Percent necrotic area per leaf, used with a standardized pictorial chart (Chiteka et al., 1988); 5) Visual estimations, this technique has several variations and has been changing in time to reach the Florida Scale used by Chiteka (1988) and Kauft et al. (1988) (Table 1.2), since then this scale is widely used to assess disease severity in peanut cultivars (Gorbet et al., 1990; Smith et al., 1994; Holbrook and Anderson, 1995; Gremillion, 2011).

Research objectives. The overall goal of this work was to provide information on the relationship between leaf spot severity and yield that will be useful in making decisions onnecessary management inputs to minimize losses to leaf spot diseases. Specific objectives included: *i*) characterization of the relationships among yield, defoliation by leaf spot, peanut grade, crop value and canopy reflectance for new runner-type peanut cultivars, and *ii*) development of a simple model for predicting yield losses to leaf spot based on percent defoliation at the end of the season. Additional objectives include iii) characterization of the effects of new runner-type cultivars on incidence of stem lesions caused by *C. arachidicola* or *C. personatum*. It is proposed to relate these responses to the effects of these stem lesions to the severity of foliar symptoms caused by each pathogens, and *iv*) evaluation of the field response of new breeding lines developed as part of a USAID-CRSP project for developing peanut cultivars with multiple pathogen resistance for use in the U.S. and in developing countries in the western hemisphere to *C. arachidicola* and *C. personatum*.

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Table 1.1. Area planted in Georgia in 2010 to produce foundation, registered, and certified seed for 2011.

Cultivar	**Hectares**	**% of Area**
Georgia-06G	30,551	67.4
Georgia Greener	4,665	10.3
Tifguard	3,332	7.4
Florida-07	3,000	6.6
Goegia-07W	2,555	5.6
Georgia-02C	860	1.9
Georgia-09B	148	
AT-215	121	
Georgia Green	64	
Georgia-10T	1	
Total	45,298	

Source: Georgia Crop Improvement Association (Beasley et al. 2010)

Table 1.2. Florida leaf spot disease rating scale

Rank	Description
1	No disease
2	Very few lesions (none on upper canopy)
3	Few lesions (very few on upper canopy)
4	Some lesions with more on upper canopy and slight defoliation noticeable
5	Lesions noticeable even on upper canopy with noticeable defoliation
6	Lesions numerous and very eveident on upper canopy with significant defoliation (50%+)
7	Lesions numerous un upper canopy with much defoliation (70%+)
8	Upper canopy covered with lesions with high defoliation (90%+)
9	Very few leaves remaining and those covered with lesions (somre plants completely defoliated)
10	Plants dead

Source: (Chiteka et al., 1988)

Fig. 1.1 *Cercospora arachidicola* (A) and *Cercosporidium personatum* (B) lesions. Lesions on the stems (C), lesions on the petioles (D).

Fig 1.2. Conidiophores of *Cercospora arachidicola* (A) and conidia (B). Conidia are thin, elongated, subhyaline, olivaceous, obclavate, and have three to twelve septa (35-110 x 3-6 ųm).

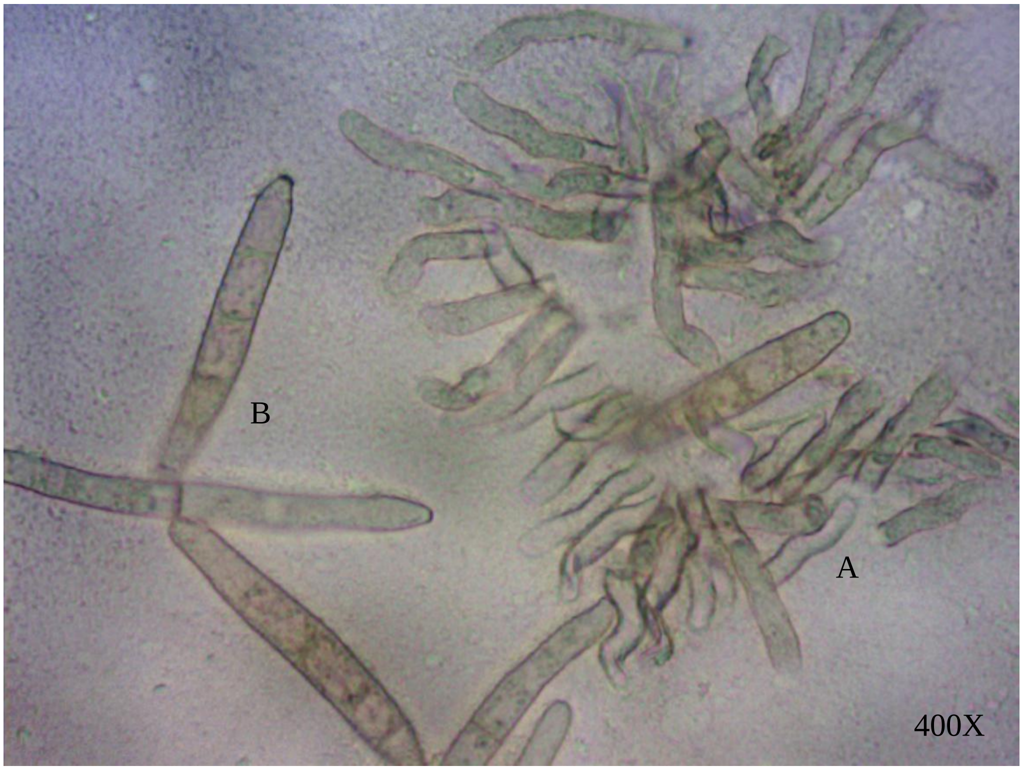

Fig 1.3. Conidiophores of *Cercosporidium personatum* (A) and conidia (B). Conidia are a little bit thick, slightly curved, cigar shaped, medium olivaceous, cylindrical, and obclavate, and have one to nine septa (20-70 x 4-9 ųm).

CHAPTER 2

RELATIONSHIPS AMONG DEFOLIATION CAUSED BY LEAF SPOT, CANOPY REFLECTANCE, POD YIELD, AND GRADE IN NEW RUNNER-TYPE PEANUT CULTIVARS[1]

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1 Navia Gine, P. A., Culbreath, A. K, Tillman, B. A., Kemerait, R. C., Holbrook, C. C., Branch, W. D., and Smith, N. B. To be submitted to *Plant Disease.*

ABSTRACT

Early and late leaf spot caused by *Cercospora arachidicola* and *Cercosporidium personatum*, respectively, can cause severe losses on susceptible peanut (*Arachis hypogaea* L.) cultivars. Losses to leaf spot have been correlated with defoliation late in the season and canopy reflectance measured in the near-infrared wavelengths. Recently, several new peanut cultivars have been released with excellent yield potential and field resistance to Tomato spotted wilt virus. However, the relationships among late-season defoliation, canopy reflectance and yield have not been characterized for these cultivars. To examine this relationship, field experiments were conducted in 2010 in Tifton GA, and 2011 in Attapulgus, Plains, and Tifton, GA. In four experiments, four cultivars, Florida-07, Georgia-06G, Georgia-07W, and Tifguard, were combined in split-plot arrangement with four fungicide treatments, 7, 4, and 3 applications of 1.26 kg ai/ha of chlorothalonil with initial applications ca. 35 days after planting, and subsequent applications ca. 14 day intervals. A fifth experiment was conducted on Georgia-06G with the same fungicide treatments. Applications of 1.12 kg ai/ha of flutolanil were made at ca. 60 and 90 days after planting in each trial to minimize effects of *Sclerotium rolsii* on yield. Multiple visual leaf spot ratings were made to estimate the levels of defoliation. On each evaluation date in 2011, canopy reflectance in the visible and infrared light spectrum was also measured using a Crop Circle Crop Scanner with an ACS-210 active sensor. Late leaf spot was the predominant foliar disease in all trials. All of the cultivars evaluated were able to maintain good yields even with moderate-to-heavy defoliation, with percent yield losses to leaf spot less than previously reported from late leaf spot on the previous standard cultivar, Florunner. Significant negative linear relationships were observed between final percent defoliation and yield for Georgia-06G in all trials except Plains, 2011, for Georgia-07W in two of four trials, and for Florida-07 in one

of four trials. There were no significant regressions for percent defoliation and yield for Tifguard. Percent defoliation was correlated with canopy reflectance in the infrared and visible bands and with the normalized difference vegetative index calculated from those two measurements.

Keywords: *Cercosporidium personatum*, late leaf spot, yield losses,

Late and early leaf spot caused by *Cercospora arachidicola* S. Hori, and *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, are among the most destructive diseases of peanut (*Arachis hypogaea* L.) in the southeastern United States (Hagan, 1998), causing direct losses in yield and losses through costs of control. In the southeastern U.S., annual yield losses due to leaf spot have averaged 5% even with the use of fungicides (W. J. Grichar, 1998), whereas peanut losses would likely approach 50 % without fungicides (Smith, 1984; Nutter and Shokes, 1995). These diseases cause defoliation, reduce yield, and increase incidence of certain soil-borne diseases such as stem rot (Hagan, 1998). Losses are primarily due to loss of peg integrity and loss of mature pods when peanut plants are inverted (Teare et al., 1984; Knauft et al., 1988). Losses to both diseases have been correlated with levels of leaf spot induced defoliation late in the season, often with steep linear declines in yield with increasing defoliation (Shokes et al., 1982; Backman and Crawford, 1984; Nutter and Littrell, 1996 Aquino et al., 1992).

In fields with severe leaf spot epidemics, growers may dig and invert the crop earlier than normal in an effort to minimize pod losses to leaf spot. However, digging before optimum maturity may result in lower grades (percentage of total sound mature kernels or TSMK) (Knauft et al., 1988) and lower price per kilogram. Therefore, even if maximum yield is preserved with early digging, the value per hectare for the crop may still be reduced. Knowledge of the relationship between leaf spot severity and both yield and grade would be useful in making decisions on whether early digging and harvest is the best option in fields with severe leaf spot epidemics. Knowledge of the relationship between defoliation and yield can be useful in determining levels of fungicide inputs needed to prevent losses to these diseases. The peanut disease management decision aid, "Peanut *Rx*" provides numerical values for the relative risk of peanut cultivars to losses from leaf spot diseases (Kemerait et al, 2011), and fungicide regimes are adapted for fields with low, medium and high risk. Values for current cultivars are based primarily on foliar ratings for leaf spot severity. Characterization of the relationships between yield and disease severity could help determine whether relative susceptibility classification based on foliar disease severity is reflective of risk of losses of yield to leaf spot, and help improve the accuracy of risk classification assignment if it is not.

Earlier investigations addressing the correlation between leaf spot severity (primarily defoliation) and yield were done with the previous standard runner-type peanut cultivar 'Florunner' (Shokes et al., 1982; Backman and Crawford, 1984; Nutter and Littrell, 1996, Aquino et al., 1992). However, this cultivar is no longer grown commercially in the southeastern U.S. Recently, several new peanut cultivars have been released with excellent yield potential and field resistance to Tomato spotted wilt virus. The cultivar 'Tifguard' (Holbrook et al., 2008) has a moderate level of resistance to early and late leaf spot pathogens (Li, et al., 2012; Culbreath et al., 2009), but new cultivars 'Georgia-06G' (Branch, 2007), 'Florida-07'(Gorbet and Tillman, 2009), and 'Georgia-07W' (Branch and Brenneman, 2008) are susceptible to infection by one or both pathogens (Culbreath et al., 2009). The relationship between late-season levels of defoliation by leaf spot and yield has not been characterized for these cultivars. In previous studies (Aquino et al., 1992; Nutter and Littrell, 1996), canopy reflectance in the near infrared wavelength at 800 nm was correlated with levels of defoliation caused by *C. arachidicola,* and

C.personatum. Those studies were also conducted on Florunner cultivar. Canopy reflectance relationships with level of defoliation by leaf spot diseases have not been characterized for the new runner-type cultivars. The objective of this research was to characterize relationships of leaf spot disease severity measured by percent final defoliation and canopy reflectance with pod yield, kernel quality, and dollar value/ha for the yields for four new runner-type cultivars.

MATERIALS AND METHODS

Two experiments were conducted in 2010 at the University of Georgia, Coastal Plain Experimental Station, Lang Farm, Tifton, GA (Trial A and Trial B). In 2011, trials were conducted at the Coastal Plain Experimental Station, Rigdon Farm, Tifton GA (Trial C), at the University of Georgia, Attapulgus Research and Educational Center (Trial D), and at the University of Georgia Southwest Georgia Research and Education Center, Plains, GA, (Trial E). The soil type in Tifton at both the Lang and Rigdon farms was a Tifton sandy loam (fine sandy, siliceous thermic Plinthic Paleudult). The soil type at the Attapulgus site was a Norfolk loamy sand (fine loamy, siliceous thermic Typic Kandiudult), and the soil type at the Plains site was a Greenville clayey loam (clayey, kaolinitic, thermic Rhodic Kandiudult) (Hodges et al., 1995). All the fields from both years had a history of moderate-to-heavy infestations of *C. arachidicola* and *C. personatum* in previous years when peanut was grown.

In all experiments, varying numbers of applications of chlorothalonil (Bravo WeatherStik, Syngenta, Greensboro, N.C.) were used to create a range of levels of leaf spot intensity. A split-plot experimental design with factorial arrangement of the four cultivars and four fungicide treatments was used for Trials A, C, D, and E. Whole plot treatments consisted of four cultivars, Georgia-06G, Georgia-07W, Florida-07, and Tifguard. Four sub-plot treatments consisted of: a) seven; b) four; and c) three applications of 1.26 kg/ha of chlorothalonil; and d) a non-treated control. A randomized complete block design experiment with the same four fungicide treatments on one cultivar, Georgia-06G, was used for Trial B. Five, seven, five, four and six replications were used for Trials A-E, respectively. Plots were 10 m long by 1.8 m wide with two rows for each plot. Peanuts were planted 26 May 2010 for Trial A, 4 June 2010 for Trial B, 2 June 2011 for Trial C, 1st June 2011 for Trial D, and 17 May 2011 for Trial E. All fungicide regimes had an initial application ca. 30 days after planting with subsequent applications made at ca. 14 day intervals for the duration. All plots were traversed by the tractor-mounted boom sprayer during each fungicide application so that tractor traffic effects would be the same for all plots.

At Tifton and Plains, fungicides were applied using a multiple-boom tractor mounted CO_2-propellant sprayer. Each boom was equipped with three Hypro TR80-03 flat fan nozzles per row. Fungicide was delivered in 187 liters of water/ha at 310 kPa. At Attapulgus, fungicide treatments were applied using a Lee compressed air mobile sprayer (LeeAgra, Inc., Lubbock, TX). The sprayer was equipped with one Teejet 8002 EV5 flat fan nozzle per row. Fungicide was delivered in 140 liters of water/ha at 276 kPa.

All plots were coversprayed two times with 1.12 kg ai/ha of flutolanil (Convoy, Nichino America Inc., Wilmington, DE), at approximately 60 and 90 days after planting (DAP), for control of stem rot (white mold) caused by *Sclerotium rolfsii* to minimize this disease as a confounding factor for determining leaf spot and yield correlations.

To increase the potential for leaf spot epidemic development, Trial C at Tifton in 2011 was inoculated with leaves infected with *C. personatum* at approximately 90 DAP. Infected leaves were dispersed by hand into foliage of plants in the border lines. All plots were irrigated as needed to maintain favorable conditions to develop leaf spot epidemics.

Leaf spot severity was assessed visually using the 1-10 Leaf Spot Florida Scale (1= no disease, 0% defoliation, and 10=100% defoliation, plants dead (Chiteka et al., 1988). Leaf spot assessments were made on 76, 103, 117, 128, and 142 DAP in 2010 for Trials A, and B; 111, 116, 124, 134, 139, and 148 DAP for Trial C; 110, 118, 137, and 146 DAP for Trial D; and 115, 137, and 147 DAP for Trial E. Percent defoliation was calculated using the data from the Florida Scale ratings using the equation developed by Li, et al. 2012:

$$\% \text{ Defoliation} = 100/(1+e^{(-(FLSc-6.0672)/0.7975)})$$

where FLSc is the Florida scale value.

In 2011, canopy reflectance was also assessed several times at different stages of the epidemic development during the season for Trials C, D, and E. An active sensor reflectance meter (Crop Circle model ACS-210, Holland Scientific, Lincoln, NE) which measures canopy reflectance in the visible (VIS, centered at 650nm) and near infrared (NIR, centered at 880nm) portions of the light spectrum. A vegetation index, presented as the normalized difference vegetation index (NDVI), was calculated from the formula:

$$\text{NDVI} = p\text{NIR}-p\text{VIS} / p\text{NIR}+p\text{VIS}$$

Sensor readings were collected in 2011 at 53, 76, 111, 124, 139, and 147 DAP for Trial C Rigdon farm (Tifton); 56, 77, 110, 118, 137, and 146 DAP for Trial D (Attapulgus); and 57, 77, 115, 137, and 147 DAP for Trial E (Plains). The sensor was carried manually and positioned directly over the center plot row in the nadir view at a distance of approximately 1.0 m above the crop 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 4000 individual sensor readings per plot. The data were saved on an SD Memory card. The final output of the sensor was a pseudo-reflectance value for both NIR and VIS bands and the calculated NDVI. The means of sensor readings for NIR, VIS, and NDVI were calculated for each plot.

All plots were dug and inverted at 141, and 145 DAP for the Trials A and B in 2010, and 148 DAP, 146 DAP and 147 DAP for Tifton, Attapulgus, and Plains, respectively in 2011. 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 for grade determination. 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 percentages of the 500-g sample represented by sound mature, immature and damaged kernels were determined according to official Federal–State Inspection Service methods. Pod grades were recorded as percent total sound mature kernels (TSMK). Dollar value/ha was calculated to evaluate impact of leaf spot severity on crop value. Price was determined for each plot using the USDA loan value formula derived from the 2010 and 2011 peanut marketing assistance loans (MAL's) and loan deficiency payments (LDP's), notices published by USDA Farm Service Agency (USDA - FSA, 2010-2011):

- For 2010: P = [(TSMK * $ 5.346) + (OK * $ 1.543)] - [(FM - 4) * $ 1.1]
- For 2011: P = [(TSMK * $ 5.364) + (OK * $ 1.543)] - [(FM - 4) * $ 1.1]

Price (P) was based on the $390.8/kg loan rate adjusted for grade in 2010 and $390.78/kg for 2011. Other kernels are defined as OK, and foreign material is defined as FM. Discounts on FM and sound splits only occurred when exceeding 4%. There was no deduction for damaged kernels below 2% of damaged kernels.

The individual plot data collected each year was transferred to a statistical discovery software (JMP; SAS Institute Inc., Cary NC) and was subjected to analysis of variance to evaluate treatment effects on leaf spot severity, reflectance measurements, TSMK, yield and crop value. Data from each location were analyzed independently. Cultivar and fungicide effects were considered fixed effects and replication was considered a random effect. Fisher's protected least significant difference (LSD) values were used for comparison among the individual treatments and cultivars. Pearson's correlation coefficients were calculated to examine correlations between leaf spot severity, reflectance measurements, yield, grade and dollar value within each cultivar and trial. Regression analysis was conducted for each cultivar in each trial to examine linear and quadratic models to describe relationships between defoliation and yield, TSMK, crop value, and in 2011, canopy reflectance.

RESULTS

Late leaf spot was the predominant foliar disease by the end of the season in all trials, although early leaf spot was present earlier in the season in each trial. Leaf spot epidemics began relatively late in the season in all trials, and severity varied greatly among trials. Disease progress curves from non-treated plots planted to Georgia-06G for the different trials (Fig 2.1) showed that infestations were moderate to heavy on non-treated plots for Trials A and B at Tifton in 2010, Trial C at Tifton in 2011 and for Trial D at Attapulgus in 2011. However infestation was light in Trial E at Plains in 2011. Epidemics began earlier in 2010 than in 2011. In 2011, leaf spot was evident by approximately 100 DAP. In all trials except Trial E, plants in non-treated plots of one or more cultivar were moderately to heavily defoliated at harvest time. The fungicide treatments allowed development of a range of leaf spot disease intensities.

For Trial A (Tifton - 2010) fungicide effects on final leaf spot severity were significant, but there was no significant effect of cultivar or cultivar x fungicide treatment effects. In Trial B (Tifton - 2010) there was a significant treatment effect. In Trial C (Tifton - 2011) cultivar, fungicide treatment and cultivar x treatment effects were significant for leaf spot severity. Within non-treated plots, Georgia-06G (defoliation = 92%; LSD = 17.3) had the highest disease severity, and Tifguard had the lowest (defoliation = 28%; LSD = 17.3). In Trial D (Attapulgus - 2011) cultivar, fungicide treatment, and cultivars x fungicide treatment effects were significant for final leaf spot severity. Within non-treated plots, leaf spot severity was higher for Georgia-06G and Georgia-07W than other cultivars (defoliation = 90%, 86%; LSD = 21.7), and lowest in Tifguard (defoliation = 45%; LSD = 21.7). In Trial E (Plains-2011) there were significant cultivar and treatment effects on final leaf spot severity, but cultivar x fungicide treatment interaction effects were not significant. Across fungicide treatments the lowest final leaf spot severity was given by the seven-spray treatment (defoliation = 0.5%; LSD = 4.7) and the highest among treatments was in the non-sprayed control (defoliation = 21%; LSD = 4.7).

In Trial C (Tifton – 2011), cultivar and fungicide treatment effects were significant for NDVI, but not for cultivar x fungicide interaction. Within plots that received seven fungicide applications, NDVI values were 0.745, 0.729, 0.772, and 0.784 (LSD = 0.045), for Florida-07, Georgia-06G, Georgia-07W, and Tifguard, respectively. In Trial D (Attapulgus - 2011) cultivar and fungicide treatment main effects and interaction effects were significant for NDVI. Within plots that received seven fungicide applications, NDVI levels were 0.776, 0.784, 0.799, and 0.801 (LSD = 0.062) for Florida-07, Georgia-06G, Georgia-07W, and Tifguard, respectively. In

Trial E (Plains - 2011) cultivar and fungicide treatment effects on NDVI were significant, but interaction effects were not. Within plots that received seven fungicide applications, NDVI levels were 0.708, 0.73, 0.75, and 0.726 (LSD = 0.026) for Florida-07, Georgia-06G, Georgia-07W, and Tifguard, respectively.

Treatment main effects and interaction effects, where applicable, were also analyzed for TSMK, yield, and crop value. However, since the emphasis of this study was to relate each of these to defoliation by leaf spot and canopy reflectance measurements, specific treatment effects are not presented.

Coefficients for correlations among percent defoliation, yield, TSMK, and crop value for each cultivar in both trials in 2010 are shown in Table 2.1. Percent defoliation was negatively correlated with yield and crop value in Georgia-06G in both trials in 2010 (Table 2.1), but not for other cultivars in Trial A. Yield and crop value decreased linearly with increasing percent defoliation for Georgia-06G in both trials (Figs. 2.2 and 2.3), but there was no relationship in the other cultivars. There was no relationship between TSMK and defoliation for any cultivar in 2010 (Table 2.1).

Coefficients for correlations among percent defoliation NDVI, NIR, VIS, yield, TSMK and crop value for each cultivar in Trial C (Tifton, 2011) are shown in Table 2.2. In that trial, percent defoliation by leaf spot was correlated with yield for all cultivars except Tifguard, and was correlated with crop value for Florida-07 and Georgia-06G ($P < 0.05$) (Table 2.2). NDVI was more closely correlated with percent defoliation than was either NIR or VIS measurements. NDVI was correlated with percent defoliation for all cultivars (Table 2.2). NDVI was correlated with yield and crop value for Florida-07 and Georgia-06G. Yield and crop value decreased linearly with increasing levels of defoliation for Georgia-06G and Georgia-07W (Fig. 2.4 A and B). NDVI decreased linearly with increasing levels of defoliation for all cultivars (Fig. 2.4-C)

For Trial D (Attapulgus, 2011), correlations among NDVI, NIR, VIS, yield, TSMK and crop value for each are shown in Table 2.3. In that trial, percent defoliation was correlated with yield and crop value for Georgia-06G and Georgia-07W but the correlations were not significant for Florida-07 and Tifguard ($P > 0.05$)(Table 2.3). For this trial NDVI was more closely correlated with percent defoliation than to NIR, and was not correlated with VIS ($P > 0.05$). NDVI was correlated with yield for Florida-07 and Georgia-06G. Yield and crop value decreased linearly with increasing levels of defoliation for Georgia-06G and Georgia-07W ($P < 0.05$) (Fig. 2.5). NDVI decreased linearly with increasing levels of defoliation for all cultivars (Fig. 2.5).

For Trial E (Plains, 2011) correlations among the seven variables for each cultivar are shown in Table 2.4, There was no significant correlation between percent defoliation and yield or crop value for any cultivar (Table 2.4). NIR was negatively correlated with yield and crop value for Georgia-07W (Table 2.4). NDVI was negatively correlated with percent defoliation in Georgia-07W and Tifguard (Table 2.4). Plots of yield vs. defoliation for all cultivars are shown in Fig. 2.6. There were no significant relationships between defoliation and yield or NDVI for any cultivar. In Georgia-07W and Tifguard, NDVI decreased linearly with increasing percent defoliation (Fig. 2.6-B).

Yield decreased linearly with increasing NDVI values for Florida-07 and Georgia-06G at Tifton Trial C (Fig. 2.7-A), and for all cultivars except Tifguard at Attapulgus Trial D (Fig. 2.7-B). There was no significant relationship between yield and NDVI for any cultivar at Plains Trial E (Fig. 2.7-C).

When assessing yield loss the coefficients of determination relating final percent defoliation to pod yield for Trial C (Tifton) were 25% for Florida-07, 29% for Georgia-06G, and 26% for Georgia-07W. In the same trial the coefficients of determination relating NDVI to pod yield were 20% for Florida-07, 56% for Georgia-06G, and 17% for Georgia-07W. None of these relationships are significant for Tifguard ($P > 0.05$). For Trial D in Attapulgus the coefficients of determination accounting the relationship between final percent defoliation and pod yield were 22% for Florida-07 ($P = 0.07$), 56% for Georgia-06G, and 17% for Georgia-07W. For the same trial the coefficients of determination relating NDVI to pod yield were 31% for Florida-07, 70% for Georgia-06G, and 38% for Georgia-07W. None of these correlations were significant for Tifguard. For Trial E at Plains neither of the relationships between defoliation to pod yield or NDVI to pod yield were significant.

DISCUSSION

Results from this study indicate that there is a reduction in yield and crop value with increasing defoliation observed in one or more trials for all new runner-type cultivars except Tifguard. Georgia-06G had a linear reduction in yield and crop value with increasing defoliation in all trials except Plains in 2011. Results from Tifton and Attapulgus trials in 2011 corroborated previous reports that Tifguard cultivar has a moderate level of resistance to leaf spot (Li, et al., 2012, Kemerait et al., 2011), and indicate that Tifguard is also less prone to reduction in yield by leaf spot. However, since the ranges of defoliation levels in Tifguard were considerably narrower, it cannot be concluded that higher levels of defoliation would not result in similar losses to leaf spot. There were no consistent differences in leaf spot severity among the other three cultivars.

Backman and Crawford (1984), and Nutter and Littrell (1996) found that all levels of defoliation resulted in reductions of yield for Florunner cultivar. Slopes of their regression lines ranged from 40-79 kg/ha, and 24-98 kg/ha of yield loss for each point of percent defoliation in each respective study. However, there was no indication of such a rapid decrease in yield with increasing defoliation in this study. The greatest rate of decrease in yield observed among the new runner-type cultivars was 14 kg/ha per each point of percent of defoliation. Regressions of yield on final defoliation were significant for Georgia-06G in four of five trials, but in only two of four trials for Georgia-07W and one of four trials for Florida-07. There was no significant regression of yield or crop value on defoliation for Tifguard for any of the four trials in which it was included. In the previous studies, steepness of the slope relating defoliation or reflectance measurements to pod yield was greater when yield potential, as indicated by regression intercept values was greater (Backman and Crawford, 1984; Nutter and Littrell, 1996). In this study, based on intercept estimates from regression analysis, yield potential was higher than reported previously in the studies with Florunner and Southern Runner (Backman and Crawford, 1984; Nutter and Littrell, 1996), and there was no indication that relationship between yield and defoliation was related to yield potential.

Results from these experiments indicate that canopy reflectance measurements can provide useful assessments of relative levels of defoliation, that relate to yield as well as do visual assessments of defoliation. Canopy reflectance assessments are more objective, and should be less prone to inter-rater variability than visual assessments. Our results corroborated previous reports by Nutter and Littrell (1996), and Aquino and Shokes (1992) that canopy reflectance was correlated with levels of defoliation caused by leaf spot. In both of those previous reports, NIR correlated with defoliation by leaf spot. However with our system, the

NDVI correlated more strongly with visual estimates of percentage defoliation than the NIR or the VIS reflectance. A mobile active scan sensor was used in this study, whereas a passive stationary sensor was used in previous studies (Nutter, 1989; Nutter et al., 1990; Aquino et al., 1992; Nutter and Littrell, 1996). The active mobile sensor reads continuous data of the entire plot, in contrast to the passive sensor used and takes stationary sample readings from two inner rows of each plot (Aquino et al., 1992). The hand-held multispectral radiometer (CROPSCAN, Inc, Fargo, ND) used in previous studies takes reflectance measurements with the use of the sun light, so it is may be affected by cloud cover and the angle of light related to the plane of view (Nutter, 1989). The radiometer used in this study emits its own infrared and visual light so it measurements should be less affected by the angle or intensity of sunlight. There was no indication that NDVI could be used to differentiate among levels of leaf spot in which little or no defoliation has occurred. There were indications of differences in NDVI among cultivars in plots with little leaf spot. Aquino et al. (1992) also reported differences in reflectance between Southern Runner and Florunner cultivars in treated plots that were not attributable to defoliation. Such differences would have to be considered in any case when leaf spot severity is assessed using NDVI in multiple cultivars.

Stem rot incidence was very low in all trials in this study, presumably due at least in part to applications of flutolanil. Flutolanil has excellent activity against *S. rolfsii,* and no effect on leaf spot (Culbreath et al.,1992). Options for control of *S. rolfsii* were limited at the time of previous studies addressing relationships between leaf spot and yield. Stem rot and interactions of that disease with leaf spot on yield was not discussed in any of those studies (Backman and Crawford, 1984; Nutter and Littrell, 1996). Control of stem rot permitted analysis focused on leaf spot only. Characterization of interactions of stem rot and leaf spot severity and their effects on yield are also needed for these cultivars.

Results from this study corroborate previous reports that %TSMK is lower for Florida-07 than most other cultivars (Tubbs et al, 2011). However, there were no significant fungicide treatment effects on %TSMK, and there were no significant correlations or regression functions for the relationship between %TSMK and percent defoliation. This differs from findings of Hammond et al. (1974) who reported lower %TSMK values from plots of cultivar Florunner treated with fungicides than from non-treated plots with severe leaf spot epidemics. They hypothesized that fungicides, including chlorothalonil, applied had negative effects on TSMK. In this study, there was no indication of correlation between pod grade and percent defoliation, or since chlorothalonil was used to create the range of defoliation by leaf spot, no indication that the fungicide affected %TSMK in the cultivars used. This would indicate that decisions made regarding leaf spot control could be focused on effects on yield, without having to consider whether grade is being affected.

Although none of the cultivars evaluated in this study have high levels of resistance to either leaf spot pathogen, yield reductions with increasing defoliation observed were small compared to those previously reported for Florunner (Backman and Crawford, 1984; Nutter and Littrell, 1996 Aquino et al., 1992). Onsets of the epidemics in this study were relatively late in all experiments, so how yields of these cultivars would be maintained in situations with defoliation incurred earlier is not known. However, results from this study indicate that high levels of defoliation by late leaf spot do not necessarily result in high levels of yield loss in these cultivars.

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Table 2.1 Pearson's correlation coefficients of the relationship among percent defoliation, yield, TSMK, and dollar value Trials A and B. Tifton, GA 2010

Defoliation vs.	**Yield**	**TSMK**	**$ Value/ha**
Field A - Tifton, GA 2010			
Florida-07	r = N/S P = 0.414	r = N/S P = 0.082	r = N/S P = 0.736
Georgia-06G	r = -0.57 P = 0.008	r = N/S P = 0.46	r = -0.5 P = 0.024
Georgia-07W	r = N/S P = 0.701	r = N/S P = 0.421	r = N/S P = 0.904
Tifguard	r = N/S P = 0.964	r = N/S P = 0.06	r = N/S P = 0.86
Field B - Tifton, GA 2010			
Georgia-06G	r = -0.54 P = 0.003	r = N/S P = 0.758	r = -0.51 P = 0.005

N/S : Not significant when P > 0.05

Table 2.2 Pearson's correlation coefficients of relationship among percent defoliation, NDVI, NIR, VIS, yield, TSMK, and dollar value. Trial C Tifton, GA 2011.

	NDVI	**NIR**	**VIS**	**Yield**	**TSMK**	**Value**
Florida-07						
Percent defoliation	r = -0.86 P < 0.0001	r =- 0.78 P < 0.0001	r = N/S P = 0.623	r = -0.5 P = 0.025	r = N/S P = 0.294	r = -0.45 P = 0.047
NDVI		r = 0.89 P < 0.0001	r = N/S P = 0.361	r = 0.44 P = 0.049	r = N/S P = 0.608	r = N/S P = 0.057
NIR			r = N/S P = 0.399	r = N/S P = 0.122	r = N/S P = 0.854	r = N/S P = 0.112
VIS				r = N/S P = 0.6188	r = N/S P = 0.901	r = N/S P = 0.616
Georgia-06G						
Percent defoliation	r = -0.84 P < 0.001	r = -0.6 P = 0.005	r = N/S P = 0.278	r = -0.53 P = 0.014	r = N/S P = 0.332	r = -0.48 P = 0.03
NDVI		r = 0.63 P = 0.003	r = N/S P = 0.055	r = 0.75 P = 0.0002	r = N/S P = 0.306	r = 0.69 P = 0.0008
NIR			r = N/S P = 0.0732	r = N/S P = 0.094	r = N/S P = 0.949	r = N/S P = 0.083
VIS				r = N/S P = 0.095	r = N/S P = 0.271	r = N/S P = 0.196

…Cont. Table 2.2

	NDVI	NIR	VIS	Yield	TSMK	Value
Georgia-07W						
Percent defoliation	r = -0.86 P < 0.0001	r = -0.61 P = 0.004	r = -0.6 P = 0.004	r = -0.50 P = 0.0231	r = N/S P = 0.223	r = N/S P = 0.06
NDVI		r = 0.87 P <0.0001	r = 0.46 P = 0.042	r = N/S P = 0.068	r = N/S P = 0.185	r = N/S P = 0.151
NIR			r = N/S P = 1	r = N/S P = 0.535	r = 0.52 P = 0.018	r= N/S P = 0.871
VIS				r = N/S P = 0.0523	r = N/S P = 0.138	r= 0.48 P = 0.032
Tifguard						
Percent defoliation	r = -0.73 P = 0.0003	r = -0.52 P = 0.019	r = N/S P = 0.72	r = N/S P = 0.868	r = N/S P = 0.782	r = N/S P = 0.87
NDVI		r = 0.61 P = 0.0042	r = N/S P = 0.26	r = N/S P = 0.172	r = N/S P = 0.627	r = N/S P = 0.20
NIR			R2 = 0.59 P = 0.0061	R2 = N/S P = 0.067	R2 = N/S P = 0.836	R2 = N/S P = 0.077
VIS				R2 = N/S P = 0.50	R2 = N/S P = 0.796	R2 = N/S P = 0.487

N/S : Not significant when P > 0.05

Table 2.3 Pearson's correlation coefficients of relationship among percent defoliation, NDVI, NIR, VIS, yield, TSMK, and dollar value. Trial D Attapulgus, GA, 2011.

	NDVI	NIR	VIS	Yield	TSMK	Value
Florida-07						
Percent defoliation	r = -0.95 P < 0.0001	r = -0.88 P < 0.0001	r = N/S P = 0.151	r = N/S P = 0.067	r = N/S P = 0.131	r = N/S P = 0.123
NDVI		r = 0.87 P < 0.0001	r = 0.51 P = 0.043	r = 0.75 P = 0.024	r = N/S P = 0.339	r = 0.51 P = 0.041
NIR			r = N/S P = 0.822	r = 0.59 P = 0.017	r = N/S P = 0.495	r = 0.56 P = 0.025
VIS				r = N/S P = 0.385	r = N/S P = 0.928	r = N/S P = 0.413
Georgia-06G						
Percent defoliation	r = -0.96 P < 0.0001	r = -0.88 P < 0.0001	r = N/S P = 0.215	r = -0.77 P = 0.0005	r = N/S P = 0.747	r = -0.74 P = 0.0009
NDVI		r = 0.93 P < 0.0001	r = N/S P = 0.222	r = 0.84 P < 0.0001	r = N/S P = 0.979	r = 0.82 P = 0.0001
NIR			r = N/S P = 0.949	r = 0.85 P < 0.0001	r = N/S P = 0.872	r = 0.83 P < 0.0001
VIS				r = N/S P = 0.81	r = N/S P = 0.543	r = N/S P = 0.773

…Cont. Table 2.3

	NDVI	NIR	VIS	Yield	TSMK	Value
Georgia-07W						
Percent defoliation	r = -0.84 P < 0.0001	r = -0.92 P = 0.004	r = -0.67 P = 0.004	r = -0.83 P = 0.003	r = N/S P = 0.672	r = -0.68 P = 0.003
NDVI		r = 0.94 P <0.0001	r = 0.83 P = 0.002	r = 0.79 P = 0.01	r = N/S P = 0.847	r = 0.78 P = 0.011
NIR			r = N/S P = 0.058	r = 0.81 P = 0.006	r = N/S P = 0.825	r = 0.79 P = 0.008
VIS				r = N/S P = 0.206	r = N/S P = 0.705	r = N/S P = 0.205
Tifguard						
Percent defoliation	r = -0.92 P < 0.0001	r = -0.68 P = 0.069	r = N/S P = 0.498	r = N/S P = 0.377	r = N/S P = 0.115	r = N/S P = 0.506
NDVI		r = N/S P <0.361	r = 0.71 P = 0.045	r = N/S P = 0.712	r = N/S P = 0.144	r = N/S P = 0.86
NIR			r = 0.84 P = 0.002	r = N/S P = 0.995	r = N/S P = 0.632	r = N/S P = 0.968
VIS				r = N/S P = 0.77	r = N/S P = 0.609	r = N/S P = 0.835

N/S : Not significant when P > 0.05

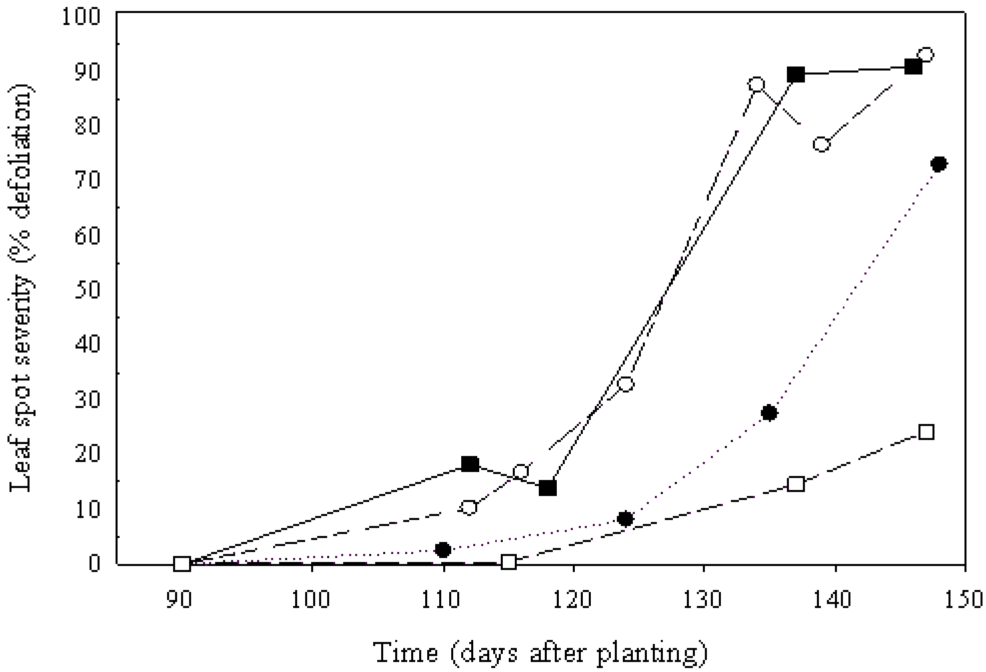
Table 2.4 Pearson's correlation coefficients of relationship among percent defoliation, NDVI, NIR, VIS, yield, TSMK, and dollar value. Trial E. Plains, GA, 2011.

	NDVI	NIR	VIS	Yield	TSMK	Value
Florida-07						
Percent defoliation	r = N/S P = 0.066	r = N/S P =0.128	r = N/S P = 0.62	r = N/S P = 0.196	r = N/S P = 0.537	r = N/S P = 0.259
NDVI		r = 0.88 P < 0.0001	r = N/S P = 0.704	r = N/S P = 0.113	r = N/S P = 0.453	r = N/S P = 0.179
NIR			r = 0.82 P = 0.0003	r = N/S P = 0.55	r = N/S P = 0.844	r = N/S P = 0.502
VIS				r = N/S P = 0.369	r = N/S P = 0.215	r = N/S P = 0.538
Georgia-06G						
Percent defoliation	r = N/S P = 0.088	r = N/S P = 0.087	r = N/S P = 0.676	r = N/S P = 0.161	r = N/S P = 0.446	r = N/S P = 0.182
NDVI		r = 0.66 P < 0.034	r = N/S P = 0.088	r = N/S P = 0.8	r = N/S P = 0.201	r = N/S P = 0.901
NIR			r = 0.83 P = 0.0002	r = N/S P = 0.817	r = N/S P = 0.812	r = N/S P = 0.812
VIS				r = N/S P = 0.67	r = N/S P = 0.47	r = N/S P = 0.736

…Cont. Table 2.4

	NDVI	NIR	VIS	Yield	TSMK	Value
Georgia-07W						
Percent defoliation	r = -0.83 P = 0.0002	r = N/S P = 0.082	r = N/S P = 0.187	R2 = N/S P = 0.463	r = N/S P = 0.402	r = N/S P = 0.371
NDVI		r = 0.66 P = 0.033	r = 0.7 P = 0.015	r = N/S P = 0.38	r = N/S P = 0.865	r = N/S P = 0.378
NIR			r = 0.75 P = 0.003	r = 0.73 P = 0.007	r = N/S P = 0.533	r = 0.74 P = 0.006
VIS				r = N/S P = 0.108	r = N/S P = 0.702	r = N/S P = 0.099
Tifguard						
Percent defoliation	r = -0.73 P = 0.008	r = N/S P = 0.457	r = N/S P = 0.587	r = N/S P = 0.172	r = N/S P = 0.87	r = N/S P = 0.191
NDVI		r = 0.79 P = 0.001	r = N/S P = 0.448	r = N/S P = 0.092	r = N/S P = 0.707	r = N/S P = 0.142
NIR			r = 0.93 P < 0.0001	r = N/S P = 0.275	r = N/S P = 0.671	r = N/S P = 0.276
VIS				r = N/S P = 0.616	r = N/S P = 0.436	r = N/S P = 0.537

N/S : Not significant when P > 0.05



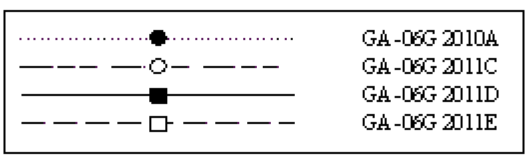


Fig. 2.1 Disease progress curves for defoliation caused by late leaf spot (*Cercosporidium personatum)* in the non-treated plots of the cultivar Georgia-06G in 2010 and 2011 at Tifton, GA (Trials A, and C), Attapulgus, GA (Trial D), and Plains, GA (Trial E) in 2011.

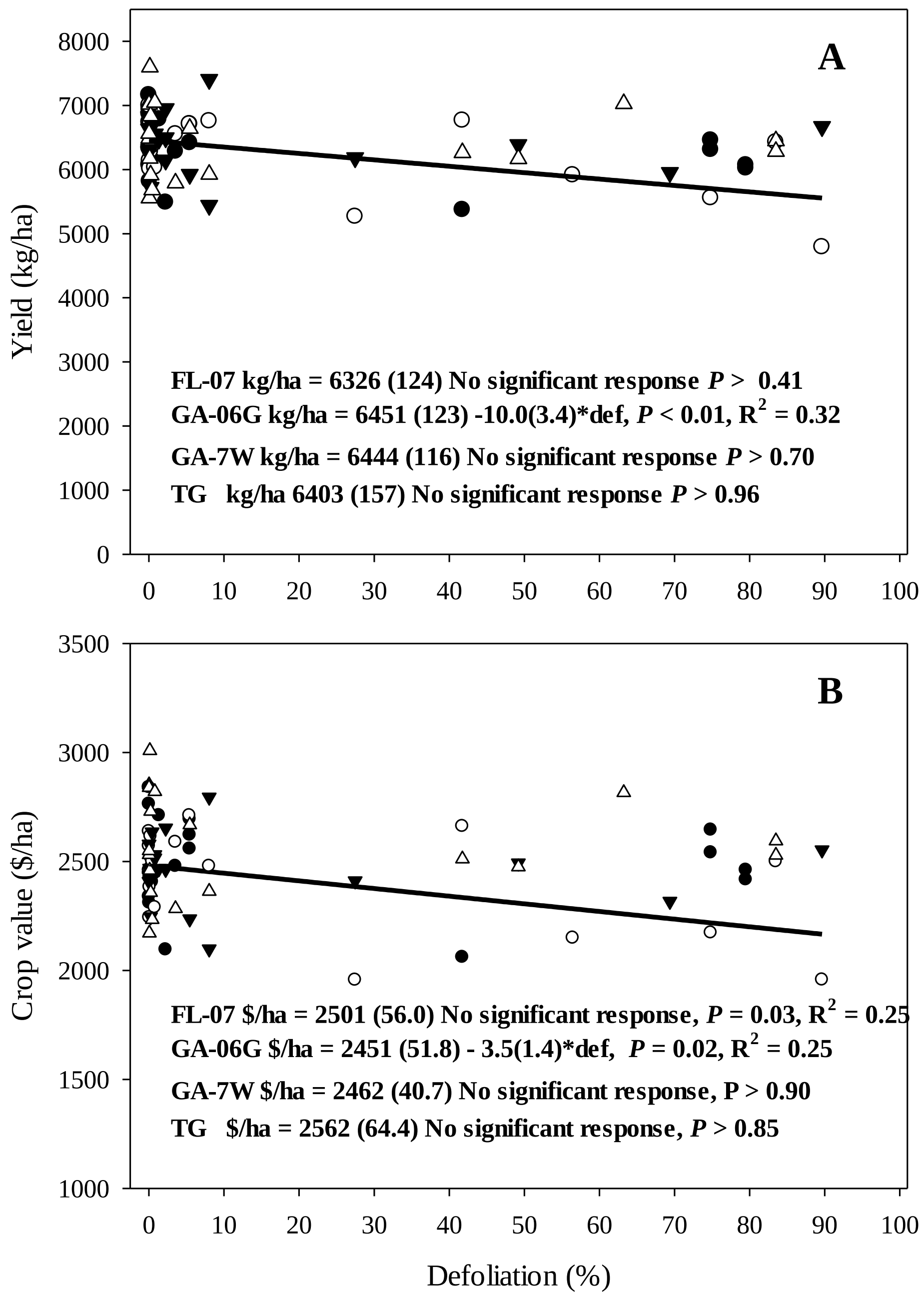


Fig. 2.2 Relationships of yield (kg/ha) (A) and crop value ($/ha) (B) in function of final percent defoliation in Trial A, Tifton, GA 2010. Florida-07 (FL-07, closed circles), Georgia-06G (GA-06G, open circles, solid line), Georgia-07W (GA-07W, closed triangles), and Tifguard (TG, open triangles).

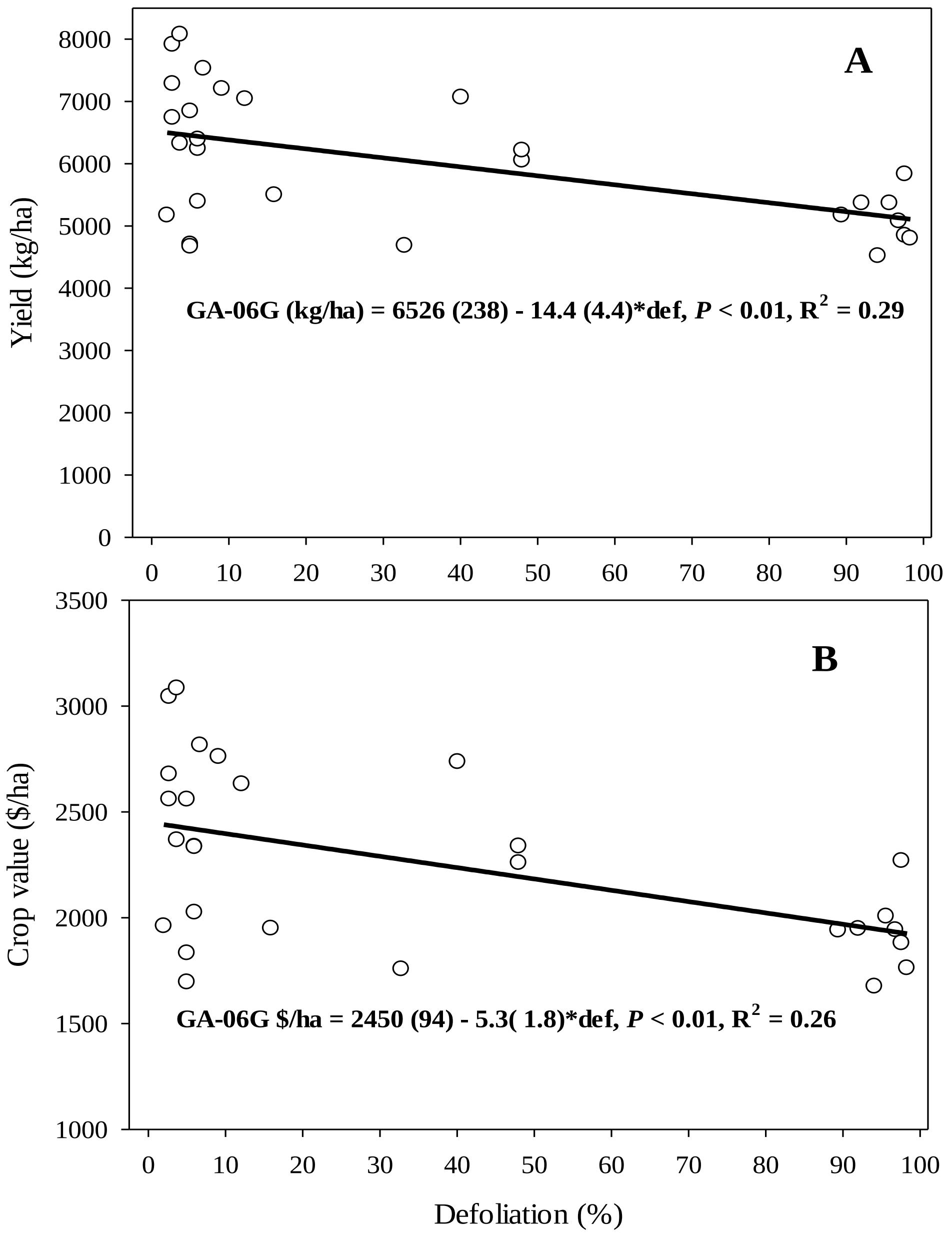


Fig. 2.3 Relationships of yield (kg/ha) (A) and crop value ($/ha) (B) in function of final percent defoliation in Trial B, Tifton, GA 2010. Georgia-06G (GA-06G, open circles, solid line).

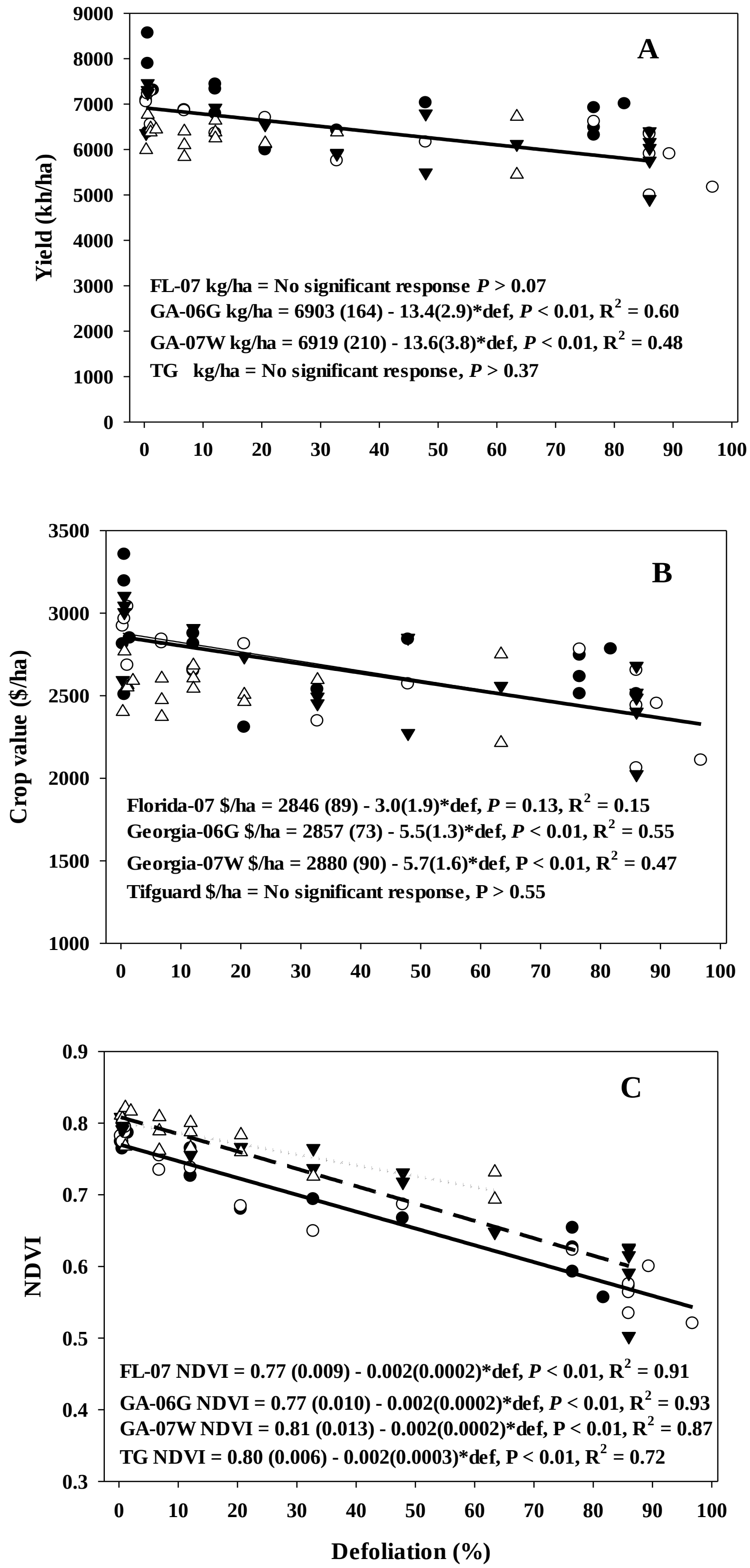

A
Yield (kh/ha)
FL-07 kg/ha = No significant response P > 0.07
GA-06G kg/ha = 6903 (164) - 13.4(2.9)*def, P < 0.01, R2 = 0.60
GA-07W kg/ha = 6919 (210) - 13.6(3.8)*def, P < 0.01, R2 = 0.48
TG kg/ha = No significant response, P > 0.37
B
Crop value ($/ha)
Florida-07 $/ha = 2846 (89) - 3.0(1.9)*def, P = 0.13, R2 = 0.15
Georgia-06G $/ha = 2857 (73) - 5.5(1.3)*def, P < 0.01, R2 = 0.55
Georgia-07W $/ha = 2880 (90) - 5.7(1.6)*def, P < 0.01, R2 = 0.47
Tifguard $/ha = No significant response, P > 0.55
C
NDVI
FL-07 NDVI = 0.77 (0.009) - 0.002(0.0002)*def, P < 0.01, R2 = 0.91
GA-06G NDVI = 0.77 (0.010) - 0.002(0.0002)*def, P < 0.01, R2 = 0.93
GA-07W NDVI = 0.81 (0.013) - 0.002(0.0002)*def, P < 0.01, R2 = 0.87
TG NDVI = 0.80 (0.006) - 0.002(0.0003)*def, P < 0.01, R2 = 0.72
Defoliation (%)

Fig. 2.4 Relationships of yield (kg/ha) (A), crop value ($/ha) (B), and NDVI (C) in function of final percent defoliation in Trial D, Attapulgus, GA 2011. Florida-07 (FL-07, closed circles, long-dashed line), Georgia-06G (GA-06G, open circles, solid line), Georgia-07W (GA-07W, closed triangles, short-dashed line), and Tifguard (TG, open triangles, dotted line). In Graph B, regression lines for Georgia-06G and Georgia-07W are very similar and are superimposed. In Graph C, regression lines for Georgia-06G and Florida-07 are very similar, and are superimposed.

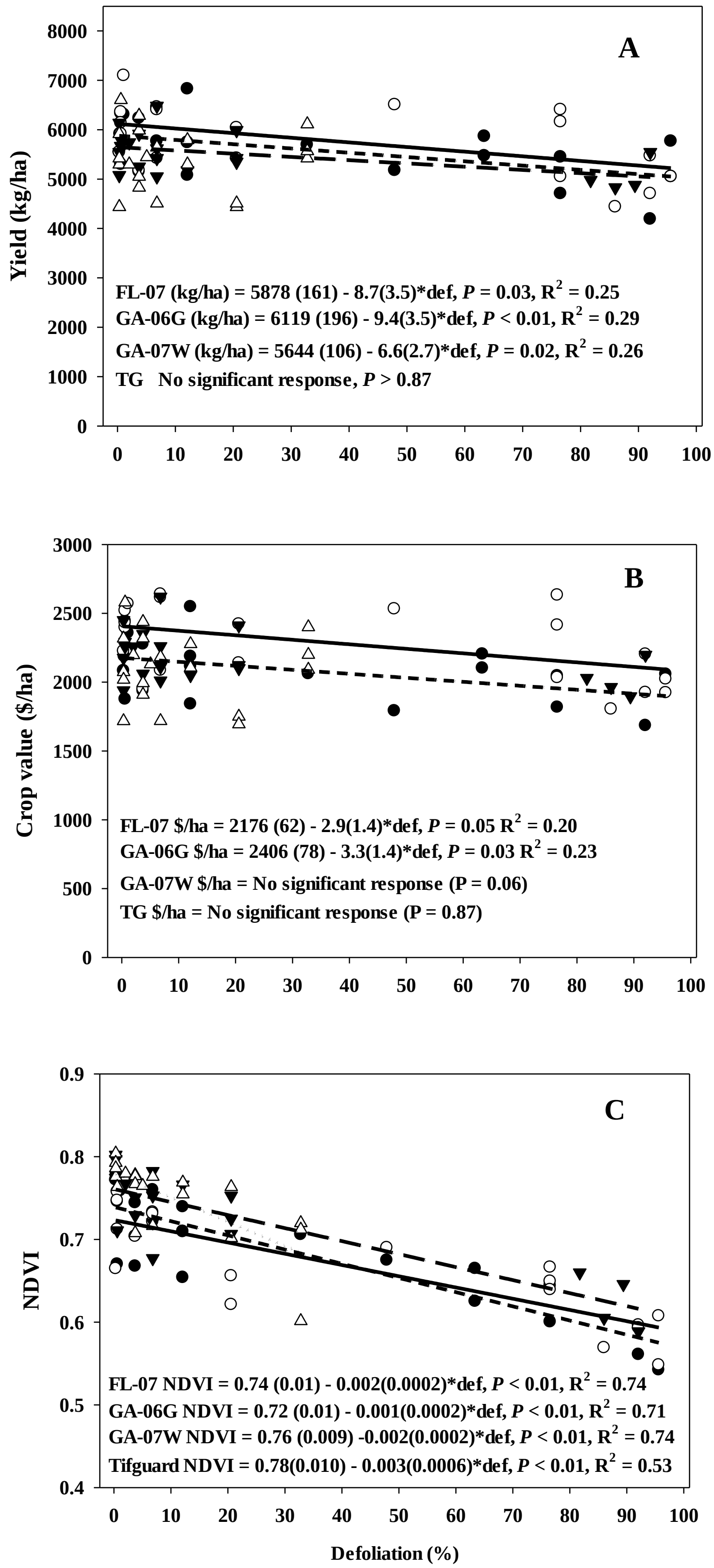

A
Yield (kg/ha)
FL-07 (kg/ha) = 5878 (161) - 8.7(3.5)*def, P = 0.03, R2 = 0.25
GA-06G (kg/ha) = 6119 (196) - 9.4(3.5)*def, P < 0.01, R2 = 0.29
GA-07W (kg/ha) = 5644 (106) - 6.6(2.7)*def, P = 0.02, R2 = 0.26
TG No significant response, P > 0.87
B
Crop value ($/ha)
FL-07 $/ha = 2176 (62) - 2.9(1.4)*def, P = 0.05 R2 = 0.20
GA-06G $/ha = 2406 (78) - 3.3(1.4)*def, P = 0.03 R2 = 0.23
GA-07W $/ha = No significant response (P = 0.06)
TG $/ha = No significant response (P = 0.87)
C
NDVI
FL-07 NDVI = 0.74 (0.01) - 0.002(0.0002)*def, P < 0.01, R2 = 0.74
GA-06G NDVI = 0.72 (0.01) - 0.001(0.0002)*def, P < 0.01, R2 = 0.71
GA-07W NDVI = 0.76 (0.009) -0.002(0.0002)*def, P < 0.01, R2 = 0.74
Tifguard NDVI = 0.78(0.010) - 0.003(0.0006)*def, P < 0.01, R2 = 0.53
Defoliation (%)

Fig. 2.5 Relationships of yield (kg/ha) (A), crop value ($/ha) (B), and NDVI (C) in function of final percent defoliation in Trial C, Tifton, GA 2011. Florida-07 (FL-07, closed circles, short-dashed line), Georgia-06G (GA-06G, open circles, solid line), Georgia-07W (GA-07W, closed triangles, long-dashed line), and Tifguard (TG, open triangles, dotted line).

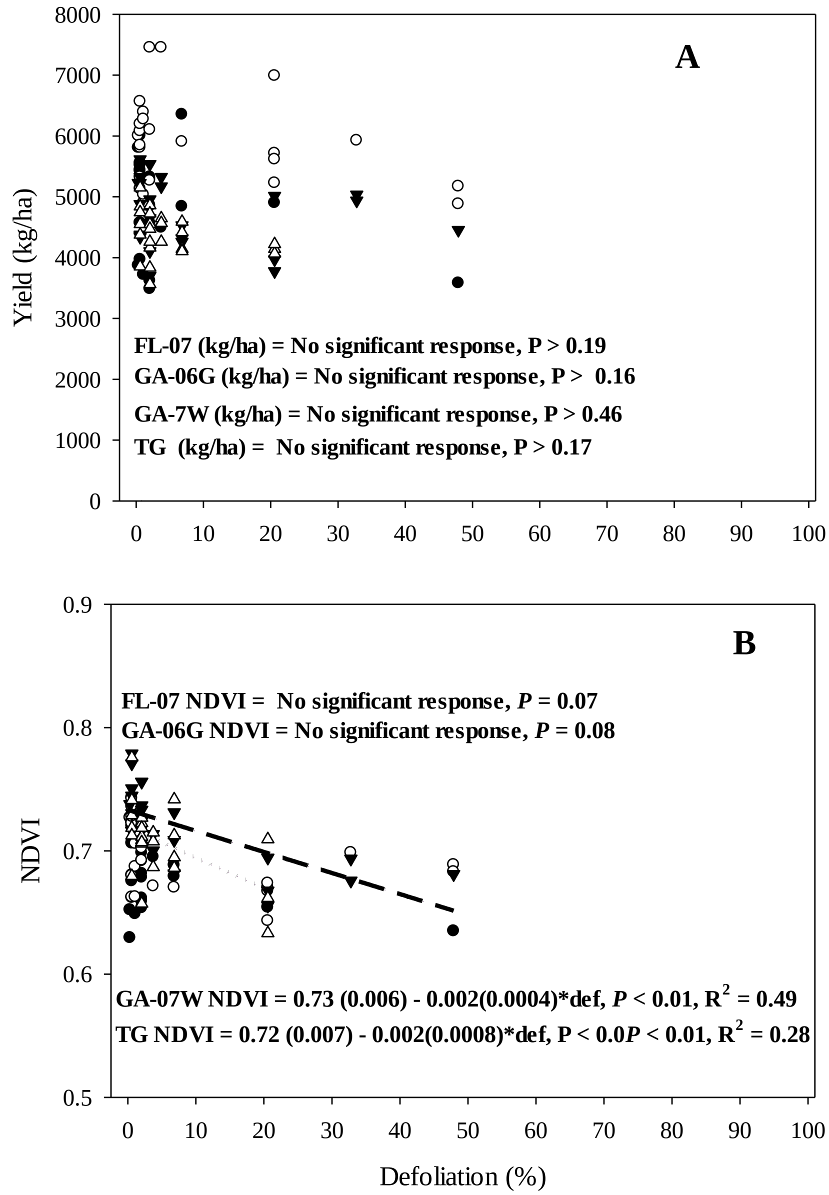


Fig. 2.6 Relationships of yield (kg/ha) (A) and NDVI (B) in function of final percent defoliation in Trial E, Plains, GA 2011. Florida-07 (FL-07, closed circles), Georgia-06G (GA-06G, open circles), Georgia-07W (GA-07W, closed triangles, long-dashed line), and Tifguard (TG, open triangles, dotted line).

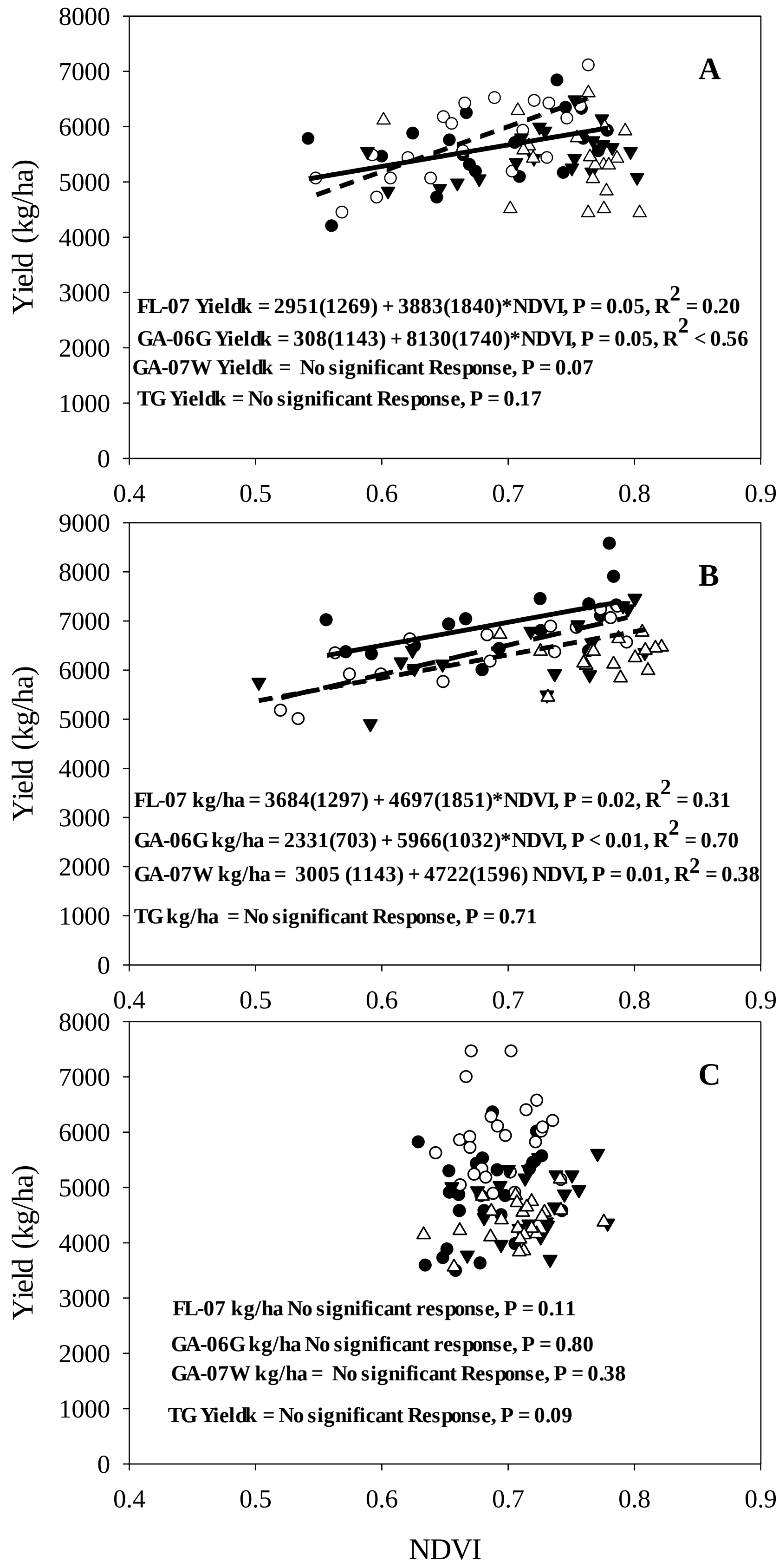

A
FL-07 Yieldk = 2951(1269) + 3883(1840)*NDVI, P = 0.05, R2 = 0.20
GA-06G Yieldk = 308(1143) + 8130(1740)*NDVI, P = 0.05, R2 < 0.56
GA-07W Yieldk = No significant Response, P = 0.07
TG Yieldk = No significant Response, P = 0.17
B
FL-07 kg/ha = 3684(1297) + 4697(1851)*NDVI, P = 0.02, R2 = 0.31
GA-06G kg/ha = 2331(703) + 5966(1032)*NDVI, P < 0.01, R2 = 0.70
GA-07W kg/ha = 3005 (1143) + 4722(1596) NDVI, P = 0.01, R2 = 0.38
TG kg/ha = No significant Response, P = 0.71
C
FL-07 kg/ha No significant response, P = 0.11
GA-06G kg/ha No significant response, P = 0.80
GA-07W kg/ha = No significant Response, P = 0.38
TG Yieldk = No significant Response, P = 0.09
Yield (kg/ha)
NDVI

Fig. 2.7 Relationships of yield (kg/ha) in function of NDVI. Florida-07 (FL-07, closed circles, short-dashed line), Georgia-06G (GA-06G, open circles, solid line), Georgia-07W (GA-07W, closed triangles, long-dashed line), and Tifguard (TG, open triangles, dotted line) in Trial C in Tifton (A), Trial D in Attapulgus (B), and Trial E in Plains, GA, (C), 2011.

CHAPTER 3

EFFECT OF RUNNER-TYPE PEANUT CULTIVARS AND ADVANCED BREEDING LINES ON SEVERITY OF LATE LEAF SPOT AND POD YIELD[1]

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[1]Navia Gine, P. A., Culbreath, A. K, Tillman, B. A., Holbrook, C. C., and Branch, W. D., Pittman, R., Todd, J. D. To be submitted to *Peanut Science.*

ABSTRACT

Field trials were conducted in Tifton, GA and Marianna, FL to evaluate field reactions of new peanut genotypes developed as part of the USAID Peanut CRSP program. Four genotypes from the University of Florida were evaluated in all four locations, and two additional genotypes developed in Georgia were evaluated in Tifton. Trials included susceptible and resistant standards. Three of the Florida genotypes (97x45-HO1-2-B2G-1-2-1-2, 98x64-2-2-1-2b4-B, and 96x72-HO1-10-2-1-b4-B) and CRSP 1048-192T showed moderate levels of field resistance to *C. personatum*. The fourth line from Florida (97x31-1-1-7-B2-5-1-2-B) showed good yield potential even with severe defoliation by leaf spot. CRSP 1048-192T combined partial resistance to *C. personatum*, early maturity and good yield potential, such combination is very promising for guiding the breeding efforts into this direction.

Keywords: *Cercosporidium personatum*, late leaf spot, advanced breeding lines, resistance.

Early and late leaf spot caused by *Cercospora arachidicola* Hori and *Cercorporidium personatum* (Berk. and Kurt.) Deighton, respectively, are major foliar diseases of peanut (*Arachis hypogaea* L.). In the U.S., management of these diseases relies primarily on fungicide applications (Smith and Littrell, 1980; Shokes, 1982; Johnson et al. 1985). However the use of cultivars with partial resistance to these pathogens has potential to reduce or eliminate the dependency on fungicides for management of these diseases (Pande, 2001; Gremillion, 2010). In other peanut producing areas of the world, fungicides may not be available, or their use may be cost-prohibitive. Therefore, breeding for resistance to early and late leaf spot pathogens is a major objective in most peanut breeding programs (Abdou, et al. 1974; Chiteka et al. 1988). Sources resistance in wild and cultivated peanut have been reported (Abdou, et al. 1974; Hassan, 1977), and a study of all the available foliar-disease-resistant genotypes for peanut at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, indiecated that approximately 84% of them originated in South America or had South American connections (Subrahmanyam et al., 1989).

Breeding efforts achieved cultivars like York (Gorbet and Tillman, 2011) and Georganic (Holbrook and Culbreath, 2008) which are considered resistant to leaf spot. However these cultivars are not accepted for conventional peanut production due to low yield potential for York and the red testa (seed coat) for Georganic. Therefore breeding goals besides resistance to leaf spot also incorporate yield potential and kernel quality in its traits (Tillman and Stalker, 2009), and resistance to tomato spotted wilt virus which has been one of the most destructive diseases for peanuts in the United States the last 20 years (Culbreath et al. 2003). After many years of research the new available runner-type cultivars like Georgia-06G and Florida-07 are not necessarily resistant to leaf spot but are resistant to TSWV and have excellent yield potential. Thus there remains a necessity to develop cultivars that have resistance to leaf spot pathogens because the cost of fungicide inputs is still very high.

One of the key countries for finding foliar-disease-resistant genotypes for peanut is Bolivia; more sources of resistance to early leaf spot were found there than in any other country (Holbrook and Isleib, 2001). Bolivia is well known for its genetic diversity for *Arachis* spp. (Subrahmanyam et al., 1989; Holbrook and Isleib, 2001; Williams, 2001; Jarvis et al., 2003; Gremillion, 2011). With the objective of developing improved cultivars for the United States and Bolivia with potential of disease resistance from Bolivia's diverse germplasm, the USDA-ARS in collaboration with Peanut Collaborative Research and Support Program (Peanut CRSP) initiated a project to develop breeding lines with Bolivian genetic material. The Bolivian cultivar

‘Bayo Grande’ has been used in crossings to get new breeding lines. The first evaluation made by this project on leaf spot resistance and yield in peanut genotypes in the United States and Bolivia was developed by Sara Gremillion and collaborators in 2004 and 2005 (Gremillion et al., 2011).

The objective of this study was to evaluate four new breeding lines developed by the University of Florida and three breeding lines developed through joint efforts of the USDA-ARS, the University of Georgia, and the University of Florida.

MATERIALS AND METHODS

Field experiments were conducted in 2010 and 2011 at two locations: the University of Georgia Coastal Plain Experiment Station, Tifton, GA (elevation 107 m), and the University of Florida, North Florida Research and Education Center, Marianna, FL (elevation 51 m). Seven breeding lines were evaluated in the study, four of them were common in all tests. These genotypes were selected to assess leaf spot resistance. Current available commercial varieties were used as controls for these experiments (Table 3.1).

A split-plot design with four replications was used in both years in Tifton and a randomized complete block design with three replications was used in both years in Marianna. Peanuts were planted 15 June 2010 and 10 June 2011 in Tifton GA, 4 June 2010 and 2 June 2011 in Marianna FL. Plots for Tifton consisted of 6.09 m-by-1.82-m plots with two rows, 0.9 m apart, and the seeding rate was 11 seed/m. Plots for Marianna consisted of 6 m-by-1.8 m plots with two rows, 0.9 m apart, and the seeding rate was 11 seed/m.

At Tifton, whole plots consisted of two fungicide treatments. Fungicide treatments consisted of a) seven sprays of chlorothalonil (Echo, Sipcam Agro USA, Roswell, GA) at 1.26 kg ai/ha, starting approximately 30 days after planting (DAP) with subsequent applications made at 14-day intervals, and b) non-treated. Sub-plots consisted of twelve genotypes in 2010 and nine genotypes in 2011. Genotypes evaluated in each year are listed in Tables 3.2 and 3.3 and include cultivars Georgia Valencia (Branch, 2001), Georgia-06G (Branch, 2007), Florida-07 (Gorbet and Tillman, 2009), and Georgia Green (Branch, 1996) as susceptible standards and Georganic (Holbrook and Culbreath, 2008) as a moderately resistant standard. Genotypes included University of Florida breeding lines 97x31-1-7-B2-5-1-2-B, 98x64-2-2-1-2-b4-B, 97x45-HO1-2-B2G-1-2-1-2, and 96x72-HO1-10-2-1-2-b4-B. Peanut CRSP breading lines CRSP 1048-192T and CRSP 1048-266T were included in both years; CRSP 1048-362T was included in 2010. These three genotypes are sister lines, developed from a cross between Georgia Valencia (Branch, 2001) and CRSP-08. CRSP-08 was developed from a cross between Florida-MDR-98 and Bayo Grande, a Bolivian land race cultivar (Gremillion et al., 2011)

At Marianna, treatments in both years consisted of 10 genotypes. These included the breeding lines 97x31-1-7-B2-5-1-2-B, 98x64-2-2-1-2-b4-B, 97x45-HO1-2-B2G-1-2-1-2, and 96x72-HO1-10-2-1-2-b4-B, developed at the University of Florida, and cultivars Florida-07 (Gorbet and Tillman, 2009), Georgia-07W (Branch and Brenneman, 2008), Tifguard (Holbrook et al., 2008), C-99R (Gorbet and Shokes, 2002), AP-4 (Tillman and Gorbet , 2009), and York (Gorbet and Tillman, 2011). The cultivar York was included as a moderately resistant standard.

All plots in Tifton were treated with 1.12 kg ai/ha of flutolanil (Convoy, Nichino, Wilmington, DE) at approximately 60 and 90 DAP to control stem rot caused by *Sclerotium rolfsii* to minimize this disease as a confounding factor. Flutolanil is not effective against leaf spot (Culbreath et al, 1992). Fungicides were applied using a multiple-boom tractor mounted CO_2-propellant sprayer. Each boom was equipped with three Hypro TR80-03 flat fan nozzles per row. Irrigation was applied as needed at all locations.

Disease assessments were made using the Florida 1 to 10 scale (Chiteka et al., 1988), where 1 = 0% defoliation and 10 = 100% defoliation, plant dead from leaf spot. In Tifton disease intensity was evaluated 135 DAP in 2010; 125 DAP and 136 DAP in 2011. In Marianna disease severity was evaluated 138 DAP in 2010, and 146 DAP in 2011. Percent defoliation was calculated from Florida Scale values (FLSc) using the formula:

$$\% \text{ Defoliation} = 100/(1+e^{(-(FLSc-6.0672)/0.7975)})$$

as reported by Li *et al.* 2012.

Peanuts were inverted in Tifton at 147 DAP in 2010 and 138 DAP in 2011. At Marianna peanuts were inverted at 147 DAP in 2010 and 153 DAP in 2011. 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.

The individual plot data collected each year was transferred to a statistical discovery software (JMP; SAS Institute Inc., Cary NC) and was subjected to analysis of variance to evaluate treatment effects on leaf spot severity and yield. Data from each location were analyzed independently. Cultivar and fungicide effects were considered fixed effects and replication was considered a random effect. Fisher's protected least significant difference (LSD) values were used for comparison among the individual treatments, and cultivars.

RESULTS

Leaf spot reactions

Late leaf spot was the predominant foliar disease in all trials. Epidemics developed relatively late in the year, but were severe by the time of the final ratings in some non-sprayed plots. Standard cultivars Georgia Green and Florida-07 were almost completely defoliated by the end of the season.

At Tifton, fungicide, genotype and fungicide X genotype effects on final disease severity ratings and percent defoliation were significant in both years. Therefore, comparisons of genotypes were made within each level of the fungicide treatments. Applications of chlorothalonil resulted in lower leaf spot severity ratings and percent defoliation for all entries in both years (Tables 3.2 and 3.3). In 2010, within non-treated plots, final leaf spot severity ratings were highest for Georgia Valencia (Table 3.2). Several breeding lines had severity ratings and percent defoliation by leaf spot that were similar to that of Georganic, and were lower than those of Georgia Green, Georgia-06G or Florida-07 standards. Within treated plots, leaf spot severity ratings and percent defoliation were highest in Georgia Valencia, and there were no differences among the other entries (Table 3.2).

In the non-treated plots in 2011, leaf spot severity was similar for Georgia Green and Georgia-06G (Table 3.3). All breeding line entries except 97x31-1-7-B2-5-1-2-B had final severity ratings lower than that of Georgia Green. Leaf spot severity was lowest in Georganic. Fewer differences were noted when comparisons were based on percent defoliation (Table 3.3). Percent defoliation was lowest in Georganic. Breeding lines 98x64-2-2-1-2-b4-B and CRSP 1048-266T had defoliation levels that were lower than that of Georgia Green, but no other entry had final defoliation lower than that of Georgia Green (Table 3.3). Applications of chlorothalonil greatly reduced disease severity and percent defoliation in all entries. Within treated plots, there were few differences among entries for disease severity ratings and no differences based on defoliation in either year.

Leaf spot epidemics were severe in Marianna in both years, and genotype effects on disease severity and percent defoliation were significant in both years. Leaf spot severity ratings were higher in Florida-07 and Georgia-07W than in any other entry in 2010, and were higher than all other entries except 97x31-1-1-7-B2-5-1-2-B in 2011 (Table 3.4). In 2010, all of the experimental breeding lines except 97x31-1-1-7-B2-5-1-2-B had disease severity ratings similar to that of York (Table 4). Genotypes 98x64-2-2-1-2-b4-B and 96X72-HO1-10-2-1-2-b4-B had leaf spot severity ratings that were similar to those of York in both years (Table 3.4). Genotype comparisons for defoliation followed similar trends as leaf spot severity, and 98x64-2-2-1-2-b4-B and 96X72-HO1-10-2-1-2-b4-B had percent defoliation estimates that were similar to those of York in both years (Table 3.4).

Pod Yield

At Tifton in 2010, yields were low in all plots, and there were few differences among genotypes regardless of fungicide treatment (Table 3.3). There were significant fungicide and genotype effects, but fungicide X genotype interaction was not significant.

At Tifton in 2011, yields were relatively low. There was a significant fungicide X genotype interaction. There were no differences in yield among entries within non-treated plots. Within treated plots, yields of 97x31-1-7-B2-5-1-2-B were higher than any other entry except Florida-07 (Table 3.3). Among the other genotypes, only 97x45-HO1-2-B2G-1-2-1-2 and 96x72-HO1-10-2-1-2-b4-B had yields higher than those of Georgia Green.

At Marianna, breeding lines 97x31-1-1-1-7-B2-5-1-2-B and 96x72-HO1-10-2-1-2-b4-B had yields that were among the highest of the entries in both years, and better than the leaf spot resistant standard cultivar, York, in both years (Table 3.4).

DISCUSSION

Fields in Marianna, FL and Tifton, GA provided suitable natural infections of *C. arachidicola* and *C. personatum*; however late leaf spot was the predominant disease for both years of study (2010-2011). Our results corroborated previous reports of field resistance in

Georganic (Tifton), and in York (Marianna), and more moderate/intermediate resistance in C-99R (Marianna) and Tifguard (Marianna and Tifton) (Monfort et al., 2004; Cantonwine et al., 2006; Holbrook and Culbreath, 2008; Gremillion et al., 2011; Gorbet and Tillman, 2011).

Under conditions of severe leaf spot disease pressure where no fungicide was applied, the Florida breeding lines (98x64-2-2-1-2b4-B, 97x45-HO1-2-B2G-1-2-1-2, and 96x72-HO1-10-2-1-2-b4-B) and one CRSP breeding line (192-T) had disease ratings that were not significantly different than resistant cultivars Georganic and York in 2010. However in 2011, a higher disease severity allowed differentiation of the breeding lines from the resistant cultivars with York and Georganic displaying significantly less defoliation. Also in 2011 in Marianna, two Florida breeding lines (98x64-2-2-1-2b4-B and 96x72-HO1-10-2-1-2-b4-B) had the same level of defoliation as Tifguard and C-99R. In our trials we found evidence that the breeding lines from Florida have moderate field resistance to *C. personatum* and that there is commercial potential for those lines. None of the CRSP lines showed a high level of resistance to *C. personatum*; however CRSP 1048-192T showed low to moderate field resistance across two years in Tifton. There is commercial potential for this line because it is early maturing (harvest occurred at 138 DAP). Two days prior to harvest, the leaf spot rating for CRSP 1048-192T was similar to later maturing cultivars like Georgia-06G and Florida-07 and the rating was lower than for Georgia Green. This finding may indicate partial resistance to late leaf spot and corroborates a previous screening study (Culbreath, unpublished data).

In this study the CRSP breeding lines were evaluated as if they had later maturities. However, preliminary information indicates they have shorter time to maturity than Georgia Green. Low levels of leaf spot resistance, when combined with shorter times to maturity, could be valuable for leaf spot management. Resistance to leaf spot pathogens in early-maturing runner-type genotypes has been rare (Branch and Culbreath, 1995). Harvesting the breeding lines beyond their optimum maturity may have decreased their yield as well (Knauft et al., 1988). Additional evaluations are needed to characterize the relative time to maturity for these lines and to evaluate the effects of leaf spot epidemics on the lines.

Yield is one of the most important breeding goals because peanut breeding is focused to farmer's needs (Tillman and Stalker, 2009). Genotypes evaluated in this study have good yield potential even without fungicides; yield potential that in some cases may exceed available cultivars. Trials in Marianna showed better pod yields than trials in Tifton, and yield potential is promising for most or all of the Florida breeding lines. One of the most promising breeding lines was 96x72-HO1-10-2-1-b4-B which was among the best yielding lines and most leaf spot resistant in Marianna in both 2010 and 2011. Breeding line 97x31-1-1-1-7-B2-5-1-2-B was also among the best yielding lines in both years in Marianna and Tifton. These breeding lines had better yields than the resistant cultivars Georganic and York, especially in 2011 when they had highest ranking yield; however leaf spot and defoliation were severe for these breeding lines.

In Tifton in 2010 yields were very low in the treated and non-treated plots due late harvest, evaluation of yield on that trial is not relevant. The Tifton test in 2011 there was a significant treatment X cultivar interaction in yield response, the genotype 97x31-1-7-B2-5-1-2-B exceeded significantly all the cultivars tested in this trial having the highest yield in the fungicide treated plots (Table 2).

Evaluation of leaf spot resistant breeding lines provided useful information on relative resistance, stability, and response to fungicide management of potential peanut cultivars. The resistant genotypes had promising levels of leaf spot resistance and some of them had early maturity. As Branch and Culbreath stated in 1995, a cultivar having disease resistance, early maturity and high yield would present tremendous advantages to the whole peanut industry. Breeding lines tested in this study show potential for this, but more trials are needed to characterize time to maturity, and evaluate combination of that maturity, leaf spot tolerance, and yield potential for these breeding lines in larger plots. The promising lines identified in this study with excellent yield potential and partial resistance or tolerance to leaf spot are: 97x45-HO1-2-B2G-1-2-1-2, 98x64-2-2-1-2b4-B, 97x31-1-1-1-7-B2-5-1-2-B, 96x72-HO1-10-2-1-b4-B. The promising breeding line with partial resistance to leaf spot, early maturity and good yield potential is CRSP 1048-192T.

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Table 3.1 Pedigree, relative maturity, and oleic acid content of peanut genotypes evaluated for yield and leaf spot resistance in 2010 and 2011.

Genotype	Pedigree	Maturity	Oleic acid content
97x31-1-7-B2-5-1-2-B	[(92xOL100-2-3-)x(84x47-2-)]	M	N
98x64-2-2-1-2-b4-B		L	H
97x45-HO1-2-B2G-1-2-1-2	((89x47-)x(89xOL28-))	L	H
96x72-HO1-10-2-1-2-b4-B	[(89xOL2)x(84x28-)]	L	H
CRSP 1048-192T	[(Georgia Valencia)xCRSP-08)]	E	N
CRSP 1048-266T	[(Georgia Valencia)xCRSP-08)]	E	N
CRSP 1048-362T	[(Georgia Valencia)xCRSP-08)]	E	N

M = medium; L = late; E = early
N = normal; H = high

Table 3.2 Effect of peanut genotypes and fungicide treatments on severity of late leaf spot and pod yield, Tifton, GA 2010.

	Disease severity[a]		Percent defoliation		Yield (kg/ha)	
Genotype/Cultivar	Nontreated[b]	Treated[b]	Nontreated	Treated	Nontreated	Treated
97x31-1-7-B2-5-1-2-B	6.4 cd	2.4 bc	57.7 cde	1.0 b	1358 ab	1640 a
98x64-2-2-1-2-b4-B	5.5 d	2.1 c	35.2 e	0.7 b	1228 bcd	1313 abc
97x45-HO1-2-B2G-1-2-1-2	5.6 d	2.3 bc	38.1 de	0.8 b	1185 bcd	1360 ab
96x72-HO1-10-2-1-2-b4-B	5.5 d	2.5 bc	34.2 e	1.1 b	1510 a	1480 ab
CRSP 1048-192T	5.8 d	2.5 bc	40.3 de	1.2 b	921 ef	905 ef
CRSP 1048-266T	7.3 bc	2.7 b	73.6 abc	1.5 b	1067 de	923 def
CRSP 1048-362T	6.5 cd	2.6 b	62.8 bcd	1.3 b	716 fg	1000 cdef
Georgia Valencia	9.3 a	4.8 a	98.2 a	16.3 a	630 g	775 f
Georgia-06G	7.4 bc	2.5 bc	83.6 ab	1.2 b	1279 bc	1289 abc
Florida-07	8.0 b	2.6 b	91.4 a	1.3 b	1248 bcd	1433 ab
Georganic	5.8 d	2.4 bc	41.2 de	1.0 b	1092 cde	1185 bcde
Georgia Green	7.9 b	2.5 bc	90.5 a	1.2 b	1095 cde	1264 bcd
LSD (*P* = 0.05)	1.0	0.4	25.3	2.1	207.4	356.5

[a] Disease severity evaluated using the Florida 1-10 scale, where 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spot.

[b] Means within the same column followed by the same letter are not significantly different ($P \leq 0.05$) using LSMeans Student's t-test comparisons.

Table 3.3 Effect of peanut genotype and fungicide treatments on severity of late leaf spot and pod yield, Tifton, GA 2011.

	Disease severity[a]		**Percent defoliation**		**Yield (kg/ha)**	
Genotype	**Non-treated**[b]	**Treated**[b]	**Non-treated**[b]	**Treated**[b]	**Non-treated**[b]	**Treated**[b]
97x31-1-7-B2-5-1-2-B	8.6 abc	4.1 a	95.7 a	9.0 a	2043 a	4340 a
98x64-2-2-1-2-b4-B	7.3 e	3.4 ab	80.8 b	3.8 c	2419 a	3131 bcd
97x45-HO1-2-B2G-1-2-1-2	7.9 cde	3.6 ab	90.2 ab	5.0 abc	2002 a	3263 bc
96x72-HO1-10-2-1-2-b4-B	8.1 bcd	3.6 ab	93.4 ab	4.4 bc	2033 a	3263 bc
CRSP 1048-192T	7.9 cde	3.5 ab	90.3 ab	5.0 abc	2175 a	2571 bcd
CRSP 1048-266T	7.5 de	3.4 ab	83.7 bc	3.8 c	1748 a	2165 d
Georgia-06G	8.8 ab	3.0 b	96.2 a	2.2 c	1870 a	2582 bcd
Florida-07	8.3 abc	3.3 b	94.4 ab	3.2 c	2267 a	3496 ab
Georganic	5.9 f	3.1 b	45.7 c	3.0 c	2277 a	2754 bcd
Georgia Green	9.0 a	4.0 a	98.0 a	8.4 ab	1555 a	2256 cd
LSD (P = 0.05)	0.7	0.7	10.2	10.2	1018.1	1043.3

[a] Disease severity evaluated using the Florida 1-10 scale, where 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spot.

[b] Means within the same column followed by the same letter are not significantly different ($P \leq 0.05$) using LSMeans Student's t-test comparisons.

Table 3.4 Effect of peanut genotypes on severity of late leaf spot, percent defoliation, and pod yield, Marianna, FL 2010 and 2011.

Genotype	**Disease severity**[a]		**Percent defoliation**		**Yield (kg/ha)**	
	2010[b]	**2011**[b]	**2010**[b]	**2011**[b]	**2010**[b]	**2011**[b]
97x31-1-1-7-B2-5-1-2-B	7.1 bc	8.0 ab	79.7 abc	92.0 ab	5713 abc	6400 a
98x64-2-2-1-2-b4-B	5.6 de	7.3 bcd	36.2 def	81.7 abcd	5139 cd	6284 ab
96x72-HO1-10-2-1-2-b4-B	5.5 e	7.0 cd	33.7 ef	75.3 cd	6245 a	6263 ab
97x45-HO1-2-B2G-1-2-1-2	5.5 e	7.5 bc	33.7 ef	84.8 abc	4926 d	6360 a
C-99R	6.6 bcd	6.8 cd	60.0 bcd	70.92 cd	5327 bcd	4774 d
Florida-07	9.3 a	8.3 a	98.3 a	94.4 ab	5446 bcd	6230 ab
Georgia-07W	9.0 a	8.5 a	97.6 a	95.0 a	5652 abc	5815 abc
Tifguard	7.4 b	7.0 cd	83.9 ab	76.5 cd	5880 ab	5771 abc
AP-4	6.3 cde	7.1 cd	55.5 cde	79.7 bcd	4763 d	5584 bc
York	5.3 e	6.6 d	28.7 f	66.98 d	5183 bcd	5056 cd
LSD (P = 0.05)	1.0	0.7	25.5	14.8	628.6	684.5

[a] Disease severity evaluated using the Florida 1-10 scale, where 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spot.

[b] Means within the same column followed by the same letter are not significantly different ($P \leq 0.05$) using LSMeans Student's t-test comparisons.

CHAPTER 4

INCIDENCE OF STEM LESIONS CAUSED BY *CERCOSPORIDIUM PERSONATUM* IN NEW PEANUT RUNNER-TYPE CULTIVARS

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[1]Navia Gine, P. A., Culbreath, A. K, Tillman, B. A., Holbrook, C. C., Kemerait, R. C., and Branch, W. D. To be submitted to *Peanut Science.*

ABSTRACT

Cercosporidium personatum, the cause of late leaf spot of peanut (*Arachis hypogaea* L.) can cause lesions on the stems in addition to the leaves of peanut plants. However, few comparisons of peanut genotypes for incidence of stem lesions have been reported. Field experiments were conducted in Tifton, GA in 2010 and 2011, Attapulgus, GA in 2011, and Mariana FL, in 2010 and 2011 to compare incidence of stem lesions in new peanut runner-type cultivars. Cultivars evaluated at Tifton and Attapulgus included Florida-07, Georgia-06G, Georgia-07W, and Tifguard, and cultivars evaluated at Marianna included Florida-07, Georgia-07W, Tifguard, and York. Stem lesions did not occur in high numbers in all trials even with high levels of defoliation. Incidence of stem lesions was higher for Florida-07 than for Georgia-07W, Tifguard and York in Mariana FL in 2010 and 2011, and higher than in Georgia-06G and Tifguard in Attapulgus GA, in 2011. Cultivars Tifguard and York with moderate levels of resistance to *C. personatum* based on foliar disease assessment also had lower incidence of stem lesions. However, at Marianna in both years, there were incidence of stem lesions was higher in Florida-07 than in Georgia-07W when both had similar high levels of defoliation due to late leaf spot. These results suggest that occurrence and incidence of stem lesions should also be considered in characterizations of genotype responses to *C. personatum*.

Keywords: *Cercosporidium personatum*, cankers, resistance, yield losses.

Early and late leaf spot caused by *Cercospora arachidicola* S. Hori and *Cercosporidium personatum* Berk. & M.A. Curtis, respectively, are common peanut (*Arachis hypogaea* L.) diseases that cause defoliation and can reduce yield by as much as 50% or more (Shokes and Culbreath, 1997). As the name implies, symptoms most often associated with these diseases are dark irregularly shaped to circular lesions that form on the leaves. However, all aboveground plant parts are subject to infection, and late in the season during severe epidemics, lesions occur on leaf petioles, gynophores, central stems, and lateral branches (Jenkins, 1938; Hemmingway, 1954; Nutter and Shokes, 1995). Lesions on the stem may interrupt translocation (Hemmingway, 1954). In severe cases, the stem may be completely girdled and killed. Yield losses associated with leaf spot often appear to be due more to loss of mature pods due to breaking of pegs during harvest than to reduction of pods formed (Knauft *et al*. 1988).

Damage to the stems may affect the integrity of the gynophores and the ability of the plant to retain pods through the digging and harvest processes. However, severity of damage by *C. arachidicola* or *C. personatum* to the stems is not commonly evaluated in leaf spot investigations.

Developing cultivars with resistance to the leaf spot pathogens or tolerance to the diseases they cause is an objective of most peanut breeding programs. Currently, only partial, rate-limiting resistance is available in runner-type peanut. Most evaluations of peanut genotype response to the leaf spot pathogens in the field are based on incidence and severity of leaf spot on the leaves and levels of defoliation incurred. However, cultivar differences in incidence of stem lesions caused by *C. personatum* have been observed (Culbreath et al, 1991).

The cultivar Southern Runner has a moderate level of resistance to *C. personatum* based on severity of leaf spot in the field (Gobert and Norden et al. 1986) and components of resistance measured in greenhouse or growth chamber experiments (Watson et al., 1998). Culbreath et al, (1991) reported that incidence of stem lesions caused by *C. personatum* was also much lower in the cultivar Southern Runner than on the leaf spot-susceptible cultivar Florunner. It was hypothesized that lower incidence of lesions on the stems was due to resistance of the stem tissue. Such resistance could minimize weakening of the stems and pegs and help minimize losses to leaf spot, even when substantial defoliation occurs. However, since that report, consideration of stem lesions has not been common in studies characterizing peanut genotype response to either leaf spot pathogen.

Since 2006 several new runner-type cultivars have been released with excellent yield potential and high levels of field resistance to Tomato spotted wilt virus. Currently the predominant runner-type cultivars grown in the southeastern U.S. include Georgia-06G, Florida-07, Georgia-07W, York, and Tifguard (Beasley et al., 2010). Tifguard and York have a moderate level of resistance to both *C. arachidicola* and *C. personatum* (Holbrook et al., 2008; Gobert and Tillman, 2011), but the other three are susceptible to both pathogens (Branch, 2006; Branch and Brenneman, 2008; Gobert and Tillman, 2009). Susceptibility of these cultivars to stem infections by either leaf spot pathogen has not been evaluated. The objective of this study was to determine the effect of stem lesions caused by *C. arachidicola* or *C. personatum* on new runner-type cultivars and to relate those responses to the severity of the diseases on the leaves.

MATERIALS AND METHODS

Field experiments were conducted at the Coastal Plain Experimental Station in Tifton, GA, at the Georgia Extension and Research Station in Attapulgus, GA, and at the North Florida Research and Education Center in Marianna, FL, in 2010 and 2011. Non-treated plots of cultivars Georgia-06G, Georgia-07W, Florida-07, and Tifguard that were part of split-plot designed field experiments with multiple-fungicide treatments in Tifton, GA and Attapulgus, GA, as described in Chapter 2, were used for stem lesion incidence comparisons. Plot length was 12.8 m at Tifton in 2010 and 12.0 m at Tifton and Attapulgus in 2011. All plots were 1.8 m wide. Five replications were used in both trials at Tifton and four replications were used at Attapulgus.

A randomized complete block design with 3 replications was used in Marianna in both years. Cultivars used were Florida-07, Georgia-07W, Tifguard, and York that were entries in a larger trial for evaluating leaf spot resistance (Chapter 3). Plots were 6 m long by 1.8 m wide for in both years.

In 2010, planting dates were 26 May at Tifton, and 4 June 2010 at Marianna. In 2011, plant dates were 2 June at Tifton, 1 June at Attapulgus, and June 2 at Marianna. All plots in Tifton and Attapulgus were cover sprayed two times with 1.12 kg ai/ha of flutolanil (Convoy, Nichino, Address), at approximately 60, and 90 days after planting (DAP), to control stem rot (white mold) caused by *Sclerotium rolfsii*. Flutolanil has no efficacy against early or late leaf spot (Culbreath et al., 1992)

For this study, leaf spot severity was assessed visually using the 1-10 Leaf Spot Florida Scale (1= no disease 0% defoliation, and 10=100% defoliation, plants dead (Chiteka et al., 1988). Leaf spot assessments were made at 142 DAP at Tifton in 2010, 138 DAP at Marianna in 2010, 146 DAP at Marianna in 2011, 148 DAP at Tifton in 2011, and 146 DAP at Attapulgus in 2011. Percent defoliation was calculated using the data from leaf spot Florida Scale ratings using the equation developed by Li et al., 2012:

$$\% \text{ Defoliation} = 100/(1+e^{(-(FLSc-6.0672)/0.7975)})$$

For evaluation of lesions on the stems, 12 lateral branches were collected from each plot. Lateral stems were collected by arbitrary selection, with samples taken from the center of the row along the length of the bed. In 2010, samples were collected 13 October at Tifton, and 20 October at Marianna. In 2011, stems were collected 26 October at Marianna, 25 October at Tifton, and 26 October at Attapulgus. Lesions were counted as described by Culbreath et al. (1992) except counts were made for the distal 30 cm of the stem. Representative lesions from all trials were examined with a hand lens to determine which pathogen was present. In 2011, representative lesions from stems at trials at Marianna and Attapulgus were examined using the dissecting microscope, and conidia produced on the stems were evaluated with a compound microscope to confirm diagnosis. All stem lesions examined were late leaf spot.

In 2010, plots were dug and 14 October at Tifton, and 20 October at Marianna. In 2011 plots were inverted 2 November at Marianna, 28 October at Tifton, and 26 October at Attapulgus. Plots were harvested mechanically, and yield was determined for each plot as pod weight and adjusted to 10% moisture (wt/wt).

The individual plot data collected each year was transferred to statistical discovery software (JMP; SAS Institute Inc., Cary NC) and was subjected to analysis variance to evaluate cultivar and treatment effects on leaf spot severity, number of stem lesions, and yield. Cultivar effects were considered fixed effects, and replication was considered a random effect. Fisher's protected least significant difference (LSD) values where used for comparison among the individual treatments, and cultivars.

RESULTS

Late leaf spot was the predominant foliar disease in trials by the time of harvest, but early leaf spot was present in all trials earlier in the season. Only late leaf spot lesions were observed on the stems. Leaf spot epidemics began late in the season in all trials. Epidemics were moderate at Tifton in 2010, but were heavy in all other trials.

In Tifton, in 2010, there were no differences among cultivars for incidence of stem lesions, leaf spot severity ratings, or pod yield (Table 4.1). Results were similar at Tifton in 2011 except leaf spot severity ratings and percent defoliation were lower for Tifguard than any other cultivar (Table 4.1).

In 2010, at Marianna, incidence of stem lesions was highest for Florida-07. Incidence of stem lesions was higher for Georgia-07W than for Tifguard and York (Table 4.1). Florida scale leaf spot severity ratings were highest for Florida-07, and Georgia-07W, Tifguard, and York each differed, with severity ratings decreasing in that respective order. Percent defoliation was similar for Florida-07 and Georgia-07W. Percent defoliation was lowest in York (Table 4.1). There were no differences in yield among cultivars. In 2011 at Marianna, incidence of stem lesions was highest in Florida-07W, and there were no differences among the other cultivars (Table 4.1). Florida scale ratings and percent defoliation were similar for Florida-07 and Georgia-07W, and higher than for Tifguard and York. Yield of Florida-07 was higher than that of York (Table 4.1). Yields of Georgia-07W and Tifguard were intermediate and did not differ from either Florida-07 or York.

At Attapulgus, incidence of stem lesions was low, but there were differences among cultivars (Table 4.1). Incidence of stem lesions was higher for Florida-07 than for Tifguard or Georgia-06G. Incidence was intermediate for Georgia-07W. Leaf spot ratings and percent defoliation were lowest in Tifguard, and there were no differences among the other cultivars. Yield was higher in Florida-07 than for Georgia-07W (Table 4.1). Yields of Georgia-06G and Tifguard were intermediate (Table 4.1).

DISCUSSION

Results from this study corroborate the previous report by Culbreath et al. (1992) that peanut cultivar can affect the incidence of stem lesions caused by *C. personatum.* Incidence of stem lesions caused by *C. personatum* was higher in Florida-07 than in Tifguard at Attapulgus, and higher than in Tifguard, York, and Georgia-07W in both experiments at Mariana. Lower incidence of stem lesions in Tifguard and York than in Florida-07 or Georgia-07W correspond with lower levels of defoliation in those cultivars. Tifguard and York have moderate levels of field resistance to *C. personatum*, compared to Florida-07 as was the case with Southern Runner compared to Florunner (Culbreath et al., 1992). However, incidence of stem lesions in Georgia-07W was lower than in Florida-07 in two years at Marianna in which the percent defoliation caused by leaf spot was very high and did not differ for those cultivars.

Although Georgia-06 was included in three of the trials, stem lesion incidence in those trials was too low to determine conclusively the relative susceptibility of that cultivar. At Attapulgus, however, although Georgia-06G had higher Florida scale leaf spot ratings, and similar levels of defoliation as Florida-07, stem lesion incidence in Georgia-06G was lower than that of Florida-07. These results suggest that relative susceptibility to foliar infection and defoliation by *C. personatum* may not be completely indicative of susceptibility to stem infections by this pathogen.

Although peanut cultivar affects incidence of stem lesions incidence, other factors that affect stem lesion development have not been characterized. Variability among trials for stem lesion incidence in Florida-07 was substantial, despite levels of defoliation of 70% or more in all trials. Components of the apparent resistance to stem lesion infection such as incubation and latent periods, lesion size, and capability to completely girdle the peanut stem need characterization. Similarly, it is not known whether the same environmental conditions are optimal for leaf infection and stem infection. The occurrence of stem lesions typically only after high levels of leaf let infection and defoliation are present suggests that the time at which high levels of defoliation is reached should be examined as a factor affecting stem susceptibility to infection.

Yield losses to leaf spot often are associated with breaking of the gynophores during the inversion process (Knauft, 1988). However, comparisons of strength of gynophores with leaf spot lesions and those without, have not been reported. Lesions on gynophores themselves were not evaluated in this study, but these and stem lesions likely should be examined for characterizing the relationship between leaf spot severity and yield.

Nuesry (1981), reported that infected stem tissue was suitable for survival of *C. arachidicola* and *C. personatum*. Culbreath et al. (1991) hypothesized that cultivar differences in incidence of stem lesions on peanut crop debris might also affect survival of the leaf spot pathogens, especially in fields not planted to peanut the next year, since woody stem tissue should be more resilient. However, that hypothesis has not been tested.

This study indicates that there are differences in susceptibility to stem lesion development among new runner-type cultivars. As observed in the previous investigation (Culbreath, 1991), cultivars with moderate levels of resistance to *C. personatum* based on foliar disease assessment also had lower incidence of stem lesions. However, results from this study also indicate that there may be variability in susceptibility to stem lesion formation among cultivars that are similar in their susceptibility to foliar infection and defoliation.

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Table 4.1 Effect of cultivar on incidence of stem lesions, defoliation, and pod yield.

Experimental fields	**Stem lesions**[1]	**Florida Scale**[2]	**Percent defoliation**[2]	**yield (kg/ha)**
Tifton 2010				
Florida-07	3.60a	6.85a	70.0a	6046a
Georgia-06G	3.30a	6.90a	69.2a	5891a
Georgia-07W	1.94a	6.05a	48.7a	6127a
Tifguard	2.33a	6.65a	64.2a	6437a
Marianna FL, 2010				
Florida-07	22.02a	9.00a	97.6a	5446a
Georgia-07W	7.88b	7.66b	86.8a	5652a
Tifguard	1.97c	5.16c	29.1b	5880a
York	0.24c	4.00d	6.7c	5182a
Marianna FL, 2011[3]				
Florida-07	8.73a	8.3a	94.4a	6230a
Georgia-07W	2.04b	8.5a	95.0a	5815ab
Tifguard	0.95b	7.0b	76.5b	5771ab
York	0.31b	6.6b	66.9b	5056bc
Tifton, 2011 [3]				
Florida-07	1.45a	7.4a	80.82a	5119a
Georgia-06G	0.38a	8.1a	92.26a	4947a
Georgia-07W	0.92a	7.1a	73.95a	5119a
Tifguard	0.42a	5.3b	27.89b	5213a
Attapulgus, 2011[3]				
Florida-07	2.50a	7.1b	78.9a	6519a
Georgia-06G	0.70b	7.8a	89.5a	5827ab
Georgia-07W	1.38ab	7.5a	86.0a	5713b
Tifguard	0.55b	5.8b	45.0b	6167ab

Disease severity evaluated using the Florida 1-10 scale, where 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spot.

Means within the same column followed by the same letter are not significantly different ($P \leq 0.05$) using LSMeans Student's t-test comparisons.

[1] Average : 30 cm of lateral stem stem

[2] Final rating

[3] Only non-treated replications

CHAPTER 5

CONCLUSIONS

The main objective of this research was to provide information on the relationship between severity of leaf spot caused by *Cercospora arachidicola* or *Cercosporidium personatum* (measured by defoliation and canopy reflectance) and yield that will be useful in making decisions on what management inputs are necessary to prevent losses to leaf spot diseases on new runner type-cultivars. Additional objectives were to determine the effect of new runner-type cultivars on incidence stem lesions caused by *C. arachidicola* or *C. personatum* and to relate those responses to the respective effects of those cultivars on severity of foliar symptoms caused by those pathogens, and to evaluate field response to *C. arachidicola* and *C. personatum* of new breeding lines developed as part of a USAID-CRSP project for developing peanut cultivars with multiple pathogen resistance for use in the U.S. and in developing countries. The primary disease investigated in these studies is *Cercosporidium personatum*

There was a reduction in yield and crop value with increasing defoliation in one or more trials for all the cultivars evaluated except Tifguard. Georgia-06G had a linear reduction in yield and crop value with increasing defoliation in all trials except Plains in 2011. Results from Tifton and Attapulgus trials in 2011 corroborated previous reports that Tifguard has a moderate level of resistance to *C. personatum*, and indicate that also is less prone to reduction in yield by leaf spot. However, since the ranges of defoliation levels in Tifguard were considerably narrower, it cannot be concluded that higher levels of defoliation would not result in similar losses to leaf spot. There were no consistent differences in leaf spot severity among the other three cultivars.

Results indicate that canopy reflectance measurements (NDVI) can provide useful assessments of relative levels of defoliation within cultivars, that relate to yield as well as do visual assessments of defoliation. Canopy reflectance assessments are more objective, and should be less prone to inter-rater variability than visual assessments. Our results corroborated previous reports that canopy reflectance was correlated with levels of defoliation caused by leaf spot. There were indications of differences in NDVI among cultivars in plots with little leaf spot.

Onsets of the epidemics in this study were relatively late in all experiments, so how yields of these cultivars would be maintained in situations with defoliation incurred earlier is not known. However, results from this study indicate that high levels of defoliation by late leaf spot do not necessarily result in high levels of yield loss in these cultivars.

Our results corroborated previous reports of field resistance in Georganic, and in York, and more moderate/intermediate resistance in C-99R and Tifguard. Under conditions of severe leaf spot disease pressure University of Florida breeding lines (98x64-2-2-1-2b4-B, 97x45-HO1-2-B2G-1-2-1-2, and 96x72-HO1-10-2-1-2-b4-B) and one CRSP breeding line (CRSP 192T) had disease ratings that were not significantly different than resistant cultivars Georganic and York in 2010. In 2011 York and Georganic significantly less defoliation than these lines, but breeding lines still had lower levels of defoliation than standard susceptible cultivars. The same year in Marianna two Florida breeding lines (98x64-2-2-1-2b4-B and 96x72-HO1-10-2-1-2-b4-B) had similar levels of defoliation as moderately resistant cultivars Tifguard and C-99R. The breeding lines from Florida have moderate field resistance to *C. personatum* and potential for use in production. None of the CRSP lines showed a high level of resistance to *C. personatum* , but CRSP 1048-192T showed low to moderate field resistance across two years in Tifton. One of the most promising breeding lines was 96x72-HO1-10-2-1-b4-B. That genotype was among the best yielding lines in Marianna both years, along with lower levels of leaf spot. One or more of hese breeding lines had better yields than the resistant cultivars Georganic and York.

This study corroborates a previous report that peanut cultivar can affect the incidence of stem lesions caused by *C. personatum.* Incidence of stem lesions caused by *C. personatum* was higher in Florida-07 than in Tifguard at Attapulgus, and higher than in Tifguard, York, and Georgia-07W in both experiments at Mariana. Lower incidence of stem lesions in Tifguard and York than in Florida-07 or Georgia-07W correspond with lower levels of defoliation in those cultivars that have moderate levels of field resistance to *C. personatum*. However, incidence of stem lesions in Georgia-07W was lower than in Florida-07 in two years at Marianna in which the percent defoliation by leaf spot did not differ for those cultivars. Although Georgia-06 was included in three of the trials, stem lesion incidence in those trials was too low to determine conclusively the relative susceptibility of that cultivar.