

INFLUENCE OF ROW PATTERN AND PLANT POPULATION ON THE
EPIDEMIOLOGY OF SOUTHERN STEM ROT (*SCLEROTIUM ROLFSII*) ON
PEANUT, *ARACHIS HYPOGAEA* L.

by

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ABSTRACT

Several field studies were conducted to determine the effects of row pattern, plant population, and cultivar growth habit on the development of southern stem rot (*Sclerotium rolfsii* .) and tomato spotted wilt disease of peanut (*Arachis hypogaea* L.). A microplot and grid study were set up in order to determine the development of stem rot in seed spacings ranging from 5.1 cm to 30.5 cm. Two conventional field studies were also designed in order to assess disease development in either single (91.4 cm) or twin (20.3 cm) rows and at three seeding rates (single rows: 12.5, 17.4 or 22.6 seed/m; twin rows: 6.2, 8.9 or 11.5 seed/m). In one of these field studies, fungicide (azoxystrobin, 1.35 L/ha at 60 and 90 DAP) efficacy was also assessed. From these studies, it is apparent that stem rot severity and incidence is greater when plants are spaced closely together (5.1 - 10.2 cm). Further, severity, incidence and spread were also reduced when planted in a twin row pattern versus single row pattern, especially in single rows planted at a high seeding rate (22.6 seed/m). Incidence of tomato spotted wilt symptoms and actual virus incidence were also assessed, and symptoms were significantly greater in single rows planted at low seeding rates (12.5 seed/m) than twin rows at any seeding rate. However, actual virus incidence was approximately the same, regardless of seeding rate or row pattern. These results do not change the tomato spotted wilt index, however they do indicate that sometimes disease symptoms are not always a good predictor of actual virus infection. Hopefully with this information, producers will be better able to plan their inputs properly and assess their disease risk.

INDEX WORDS: Stem rot, Row pattern, Seeding rate, Tomato spotted wilt

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DEDICATION

To My Grandparents

‘Let us not become weary in doing good,
for at the proper time we will reap a harvest
if we do not give up.’ - Galatians 6:9

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

The peanut *Arachis hypogaea* L. is a member of the plant family Leguminosae and has been an important component of civilization since about 950 B.C. From its origins in South America, in Paraguay, it was carried west to Africa (Hammons 1982, Johnson 1987), and presumably from there to North America. In the 1920s, peanut was promoted as an alternative crop to cotton, which was destroyed by the infamous boll weevil at this time (Woodroof 1966). Since this period, peanuts have become an important cash crop for Georgia and other southern states, bringing in millions of dollars annually. Georgia accounts for approximately 40 percent of peanuts produced in the United States (Beasley 1997). The crop is prized for its myriad of uses in cooking, while the foliage used for fodder of cattle in Asia and Africa (Sturkie and Buchanan 1973).

Peanuts are generally grown in light-colored, well drained, friable sandy loamy soils with no stones or pebbles (Woodroof 1966). This unique nitrogen-fixing plant produces inflorescences with up to five flowers in each. Fertilized flowers form gynophores that grow toward and into the soil, where pods develop below the soil surface (Beasley 1997). Peanuts do not grow well in strongly acidic or alkaline soil. If they are planted in acidic soil, then lime is needed to neutralize the acidity (Harris 1997). Peanuts are most productive if conditions

are warm and moist during the growing season, and dry during harvest (Beasley 1997). Unfortunately, conditions that are optimal for peanut growth are also conducive for many pests including diseases, insects, and weeds.

As with most crops, peanuts should not be planted year after year, but rather should be incorporated into a crop rotation system (Woodroof 1966). Brenneman, *et al.* (1995) found that both soilborne and foliar peanut diseases could be significantly reduced when peanut was grown in rotation with Bahiagrass (*Paspalum notatum*) as compared to a continuous peanut program. One such pest is *Sclerotium rolfsii* Sacc., a fungal pathogen that has plagued peanut farmers since they began growing peanuts. In Georgia alone, this pathogen cost farmers an average of \$24.8 million in damages and \$13.4 million in control costs for each of the last 12 years (1990-2001 Georgia Plant Disease Loss Estimates).

This fungus was first observed by Peter Henry Rolfs on tomato in Florida. *Sclerotium rolfsii* is considered to be a severe pathogen causing root and stem rot on peanut, tomato, eggplant, and over 200 hundred other species of plants (Kokalis-Burelle and Rodriguez-Kabana 1997). Typically, this fungus is found in its asexual stage or anamorph. The teleomorph, *Athelia rolfsii* (Curzi) Tu Kimbrough, has been found in nature, but the basidiospores have not been shown to have a significant role in disease development (Punja 1988).

This disease of peanut has many common names including white mold, southern blight, southern stem blight, and stem rot, and often the common name

is confused with other 'white mold' diseases caused by *Sclerotinia minor* or *Sclerotinia sclerotiorum* (Aycock 1966, Kokalis-Burelle and Rodriguez-Kabana 1997). 'White mold' is the name often given for the disease due to the fluffy, white, mycelial growth of the fungus typically found at the crown of its host (Aycock 1966). *Sclerotium rolfsii* is distributed throughout tropical and subtropical areas, and thrives in warm temperatures and moist conditions (Aycock 1966, Bennett 1899, Punja, 1985).

The optimal temperature for the growth of this fungus varies. Hyphal growth range has been shown to be 8- 40° (Punja 1985). The linear hyphal growth rate on Potato Dextrose Agar (its optimum media for growth) ranges from 0.85 - 0.97 mm/hr, at 27°, and optimal temperatures for growth are similar for sterile soil and culture inoculation (Punja 1985).

Sclerotium rolfsii is an aerobic, necrotrophic fungus, which also depends on high oxygen concentrations (Garren 1963, Punja 1985). Mycelial extension is more restricted by low oxygen concentrations on nonsterile soil than on agar, and the mechanism behind this is unknown (Punja 1985). Some studies show that mycelial growth is only slightly inhibited when there is an increase in moisture content (Punja 1985). Other studies have shown disease incidence was greater in well-drained, sandy soils (Bennett 1899, Punja 1985). This may mean that the fungus needs some free moisture to initiate mycelial growth and disease development. Although different environmental factors may influence

each stage of stem rot development, Rideout, *et al.* (2002) determined that relative humidity and canopy temperature, seem to be the most critical.

Sclerotium rolfsii produces hard round resting structures known as sclerotia. Sclerotia range from 0.5-2 mm in diameter, and they form laterally from main hyphal strands (Alexopoulos *et al.* 1996, Punja 1985). Sclerotia have an outer melanin rind that varies in thickness depending on the environment (Punja 1985), and they germinate by either hyphal or eruptive germination between 27-30°. Hyphal germination occurs when one mycelial strand grows from the sclerotium surface, while eruptive germination occurs when many mycelia literally burst through the outer sclerotial layer (Punja 1985). The amount of disease initiated is related to sclerotial germination. When more mycelia are formed, more growth and energy are available for infection (Punja 1985). Since colonies of this fungus can multiply rather quickly, large scale field epidemics can occur over a relatively short period of time if conditions are conducive (Johnson and Joham 1954, Punja 1985). In one study, stem rot incidence was found to be greater when relative humidity and canopy temperature increased as the peanut canopy became more dense (Rideout *et al.* 2002).

According to several sources, *S. rolfsii* has an optimum germination pH of 2-5, but can also germinate at a higher pH. Also, deeper burial of sclerotia and more physical pressure on them can inhibit germination (Johnson and Joham 1954, Punja 1985). Since peanuts are typically grown in friable soils at a slightly

acidic pH, *S. rolfii* growth and disease development can occur quickly and can be devastating if proper management is not practiced.

Some of the earlier studies demonstrated that conventional tillage including pre-plant moldboard plowing and fungicide application resulted in improved pod yields and less loss to stem rot (Boyle 1956, Garren and Duke 1957, Sholar *et al.* 1995). However, there has been a growing trend toward conservation tillage practices, in an effort to help conserve soil and decrease the amount of fuel and equipment costs (Sholar *et al.* 1995). Although this form of cultivation has many benefits, conservation tillage does not always produce high peanut yields when compared to conventional tillage (Sholar *et al.* 1995). This is the case especially with no-tillage, which often has lower peanut yields due to shallow planting and increased weed competition (Sholar *et al.* 1995). It has also been suggested that increased organic matter would create optimum conditions for stem rot. However, Minton *et al.* (1991) reported that conservation tillage did not increase the incidence of stem rot. Other researchers have since found similar results (Sholar *et al.* 1995). Johnson *et al.* (2001) also found that stem rot and Rhizoctonia Limb Rot were not affected by tillage, and that flutolanil (Moncut) controlled peanut stem rot effectively in all tillage systems studied. Of course, poor weed management can cause complications in any production system. For example, tall weeds such as Florida beggarweed can produce a canopy which can interfere with spray interception and also hold in moisture, creating an optimal environment for insects and other diseases (Vencill 2002). If

conservation tillage is used, preventative weed control is critical (Boyle 1956, Garren 1963).

In recent years, there has been increasing interest in inter-row and intra-row spacing of peanut seed for agronomic purposes, as well as an additional option for disease management. Most of the early studies were concerned with the management of weeds between narrow and wide rows. Later, researchers began to evaluate cultivars with different growth habits and found that pod yield increased more for erect cultivars where the rows were planted closer than with cultivars with prostrate growth habits (Bennett 1899, Sholar *et al.* 1995, Sturkie and Buchanan 1973).

Another study showed that when peanut plant populations were increased by reducing inter-row or intra-row spacing, the result was greater pod yields if disease did not limit growth (Hauser and Buchanan 1981). Kvien and Bergmark (1987) found that twin rows gave faster canopy closure at high plant populations (212,000 plants ha⁻¹), but there were no yield differences due to row pattern. Further, increasing plant population increased competition for light, resulting in greater plant height (Kvien and Bergmark 1987). Mozingo and Steele (1989) found that seed spacing had little effect on crop value and grade characteristics of the cultivars, but pod yield increased significantly when seeds were spaced at 5.1 cm. Knauff *et al.* (1981) found that 'Florunner' and 'Florigiant' had the same yields for intra-row spacings of 10.2 and 15.2 cm; however, there was a significant yield reduction at the 30.5 cm spacing. Igbokwe and Nkongolo (1996)

also found that peanut yield was greater for an intra-row spacing of 15.2 cm when compared to spacings of 10.2 and 20.3 cm. Chin Choy *et al.* (1982) found that the 0.25-m row spacing gave the highest yield of Spanish peanuts in both irrigated and non-irrigated plots as compared to row spacings of 0.5, 0.75, and 1.0 m. They suggested that the narrow rows hold more soil moisture, and that the reduced evapotranspiration would enhance conditions for pegging (Chin Choy *et al.* 1982).

Colvin *et al.* (1985) conducted a test in which conventional 91-cm single rows and dual twin 18-cm rows were used to compare weediness and pod yield. Fewer weeds and higher pod yields resulted in the dual twin rows, and these studies agree with earlier findings that narrow rows gave a 15% yield advantage compared to the conventional 91-cm spacing (Hauser and Buchanan 1981). The mechanism behind these results is unclear. Perhaps the twin row pattern provides a more rapid row closure and shading, and thus fewer weeds develop. It has also been proposed that there is an inherent ability to yield more when peanuts are planted in this pattern (Colvin *et al.* 1985, Hauser and Buchanan 1981). Mozingo and Coffelt (1984) found that peanut productivity could be increased if cv. VA81 bunch was planted at a high seeding rate and twin row pattern. Mozingo (1984) also examined the skip row planting pattern and found that there was a significant increase in yield when compared to 'solid' planting of peanuts. However, the greatest yield increase was found in bunch type peanut. The same results occurred when two similar studies were performed by Kirby

and Kitbamroong (1986) using runner-type and Spanish-type peanuts to study the effects of inter-row spacing and seeding rates on pod yield and peanut quality. For all cultivars, yield was greatest when row spacing was decreased from 91.4 to 45.7- cm and when seeding rate was increased from 2 to 4 plants/30.5-cm. Further increases in plant density did not result in higher yield or quality (Kirby and Kitbamroong 1996, Sholar *et al.* 1995). For runner type peanuts, there have been some conflicting results. While Duke and Alexander (1964), Mixon (1969), and Wynne *et al.* (1974) found no significant increase in yield for closer row spacings, Hauser and Buchanan (1981) found that close row patterns reduced weeds and increased yield by 14%. Most recently, Baldwin *et al.* (1997) found that when peanuts were planted in 17.8 - 25.4-cm twin rows at higher seeding rates, there was an increase in yield and grade, as well as a two-fold decrease in Tomato Spotted Wilt incidence.

Other research on plant spacing effects on disease has been conducted in other field crops. Ottman and Welch (1989) found that when corn was planted at wider row spacings, radiation was redistributed from the upper canopy to the lower canopy, with more radiation hitting the soil surface, resulting in decreased corn yield. In Oklahoma, Kahn and Nelson (1991) found that when snow peas were planted in a twin row pattern with a 10 cm within-row spacing there was an increase in yield and branching compared to a single row pattern with a 5 cm within-row spacing. Pea pods were more widely distributed on the twin row plants and made harvest easier (Kahn and Nelson 1991).

Soybean research in Japan has also provided information on row pattern effects. One study examined the effects of wide rows (70-80 cm), square patterns, and twin row pattern with two narrow rows 10 or 20 cm apart and 50 or 60 cm apart between twin rows (Ikeda 1992). They found decreased yields with wider row spacings and narrower within-row spacings, and the greatest yield was produced with 70-cm twin rows planted with plants offset rather than being planted directly across from each other. The exact reason for the yield increase was not mentioned, but the different row spacings possibly had an effect on canopy microclimate, radiation interception, disease development, and/or plant architecture and competition (Ikeda 1992).

Row spacing and pattern studies have also been conducted in cotton. Although inconsistent results have been found concerning yield, there has been some consistency among studies concerning effects of row pattern on seasonal fruiting patterns. Buxton *et al.* (1979) found that two rows with equivalent plant densities per bed gave 11% more seed cotton, and greater boll production than one row per bed. With greater plant density, the quality and strength of the cotton fiber decreased (Buxton *et al.* 1979). For cotton, it seems that the row spacing effects primarily fruiting pattern and yield, while plant density effects primarily fiber properties.

In recent years there has been an interest in ultra-narrow row cotton (UNRC). Cotton planted at a row spacing < 25.4-cm is considered UNRC (Atwell and Jost 1996). Jost and Cothren (2001) found that the narrower row spacings

and higher plant densities had greater leaf area index and light perception than the conventional row spacings of 76 and 101-cm rows. For the first year of this study, plots were planted on a heavy clay soil, and the narrow rows planted at higher seeding rates had greater yield (Jost and Cothren 2001). However, the following year, the experiment was conducted on a silty clay loam soil and there was no significant difference between row spacing. Results are inconsistent, but it seems that UNRC could be beneficial if grown on heavier clay soils (Jost and Cothren 2001).

Much research has been conducted on the effects of seeding rate and/or row spacing on the development of many plant diseases including some fungal soilborne diseases. In one study, Brede (1991) examined the effect of seeding rate on the severity of dollar spot, caused by *Sclerotinia homeocarpa*, and found that disease severity tended to be less at a lower fescue seeding rate of 2100 seeds m⁻². Cook *et al.* (2000) found that take-all of wheat, caused by *Gaeumannomyces graminis* var. *tritici* and Rhizoctonia root rot caused *Rhizoctonia solani*, could be reduced when rows were planted in close paired rows rather than spacing them uniformly. The exact mechanism is unknown, but perhaps this type of row spacing provided a more open canopy, which could have warmed and dried the top soil where these pathogens were active (Cook *et al.* 2000). A study on barley examined the effect of planting rows at either 10-cm or 20-cm apart found that the narrower row spacing resulted in an 11-13.5% increase in grain yields and a reduction in leaf disease (Leibovitch *et al.* 1992).

For the most part, it seems that diseases which develop in the above-ground plant parts of wheat and barley can be managed with row spacing. However, Bailey *et al.* (1998) found that higher seeding rates decreased root rot only slightly and wider row spacings showed a 6% decrease in root rot severity and *Fusarium* incidence. They concluded that keeping the row spacing between 10 to 20-cm could effect both the below-ground and above-ground microclimate, and as a result can maintain pathogens and disease at a minimum level.

Research conducted on potato examined the effects of both within-row and between row spacings (Cappaert and Powelson 1990). Plant densities of 13, 26, and 52 7×10^3 plants ha^{-1} , and between-row spacings of 86-cm and 173-cm were compared. Between-row spacings had a greater effect on aerial stem rot onset (*Erwinia carotovora* subsp. *carotovora*) and AUDPC than within-row spacing, and dense plantings provided an optimal microclimate in which periods of leaf wetness lasted longer, thus inciting more disease and earlier disease onset (Cappaert and Powelson 1990).

Minton (1980) found cotton planted 4 rows/bed spaced 100-cm apart, had less foliar symptoms of *Verticillium* wilt and higher yield when compared to plots with 1 or 2 rows/bed with the same spacing of 100-cm. In another cotton study, Koch *et al.* (1987) found that between-row spacing had no effect on *Phymatotrichum* root rot development, but disease progress could be reduced at a plant density of ≤ 5 plants m^{-1} .

Numerous studies have been conducted on other members of the Legume family including snap bean, dry bean, and soybean. A study in Wisconsin found that planting snap bean in wide row spacing (which was the strategy for managing white mold) could be improved with addition of an alternative fungicide, Intercept WG (*Coniothyrium minitans*) (Stevenson *et al.* 2002). This combination provided an alternative to using the usual regime of thiophanate methyl, vinclozolin, or iprodione, in narrower row spacings (Stevenson *et al.* 2002).

In a dry bean study in Canada, Saindon *et al.* (1993) found that white mold caused by *Sclerotinia sclerotiorum* was not significantly effected by the between-row and within row spacings. Rather, the upright growth habit of some cultivars was more beneficial in reducing disease regardless of row spacing used (Saindon *et al.* 1993).

Some row spacing work has also been conducted in nematological studies. Chen *et al.* (2001) observed no effect of row spacing on soybean cyst nematode population density. Again, it seems that some pathogens and/or diseases are not affected by row spacing modifications. In soybean, studies concerning other diseases have shown the benefit of modifying row spacing. Joye *et al.* (1990) found that the within-row plant population did not have a significant effect on *Rhizoctonia* aerial blight or yield. However, row spacings 50-cm or greater resulted in less disease. This decrease in disease

development may be attributed to quicker canopy drying associated with wider row spacings (Joye *et al.* 1990).

Some research has been conducted concerning row spacing effects on fungal disease on peanut. One study in India found that root rot incidence (*Macrophomina phaseolina*) was reduced at 30-cm row spacings when compared to 45 cm or 60 cm (Bhowmik *et al.* 1985). Minton and Csinos (1986) examined the effect of planting single and twin rows (1.0X seeding rate for single rows and 0.5X and 1.0X seeding rates for twin rows) on nematode damage and stem rot incidence, and found no consistent advantage for any of the treatments in managing these soilborne pests. Wells *et al.* (1992) found that stem rot incidence increased at higher seeding rates, but that TSWV incidence increased at lower seeding rates in runner type peanuts planted in conventional single rows. In Georgia, peanuts planted in twin row patterns had significantly less TSWV symptoms than peanuts planted in single rows (Culbreath *et al.* 1999). There was also an increase in yield in the twin versus single rows. The same seeding rate per hectare was used with both patterns. The exact mechanism for these effects is unknown, but it may have something to do with plant canopy environmental differences, or the fact that thrips, which vector TSWV, prefer an open canopy, and twin rows provide less of an open canopy (Brown *et al.* 1996, Culbreath *et al.* 1999, Sholar *et al.* 1995, Wells *et al.* 1992). Regardless of the mechanism, the consistent reduction in TSWV symptoms in twin versus single rows has lead more producers in Georgia to plant more twin rows at seeding

rates greater than 13.12 seed m⁻¹. In 2001 in Georgia, over 30% of the acreage was planted in a twin row pattern at a higher seeding rate (Smith 2001).

With the current shift toward planting higher seeding rates in twin rows, there is growing interest in the effects of these practices on the development of other diseases such as stem rot, which is the most damaging soilborne pest in Georgia (Plant Disease Loss Estimates - 1990-2001). Recent observations by Brenneman (1999) reveal that there may also be a decrease in stem rot in twin row pattern peanuts. The mechanisms influencing disease development of *S. rolfii* in different planting patterns is largely unknown. There have been numerous studies conducted on other crops concerning row spacing, seeding rate, disease, and yield/quality, but no extensive research has been conducted concerning the mechanism of stem rot development in twin row and single row patterns at different population densities.

Until 1994, *S. rolfii* was treated with PCNB (Terraclor) and chloropyrifos (Lorsban) with moderate success (Hagan *et al.* 1991). Today there are many different and more effective fungicides used for stem rot control such as azoxystrobin (Abound), tebuconazole (Folicur), and flutolanil (Moncut). These new fungicides are sprayed on the foliage and then redistributed to the lower stems and pods where stem rot infects the plants. The effect of changing row patterns and plant canopy traits on fungicide deposition and redistribution are not known.

There were four research objectives for this particular study 1) examine the effects of peanut plant population, row spacing and peanut growth habit on development of stem rot, 2) determine the relative efficacy of azoxystrobin for stem rot in peanut plantings of different density, 3) determine the effects of peanut plant populations and row spacings on the true incidence of TSWV infection, 4) quantify relative humidity and air temperature in peanut canopies with different plant populations and row spacings.

This study should provide researchers with information on the development of stem rot at different row spacings and seeding rates, and it should also help farmers choose the most beneficial row pattern and seeding rate for managing stem rot when planting peanut.

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CHAPTER 2
EFFECTS OF SEED SPACING, INOCULATION DATE AND PEANUT
CULTIVAR ON EPIDEMICS OF PEANUT STEM ROT¹

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Abstract

Two microplot studies were conducted with peanut (*Arachis hypogaea* L.) in 2000, 2001 and 2002 to determine the effects of seed spacing, inoculation date and cultivar on stem rot development (*Sclerotium rolfsii* Sacc.) and microclimate (temperature and relative humidity). Stem rot severity and incidence was significantly greater ($P < 0.05$) in plots with close seed spacings (5.1 cm). Two cultivars with similar susceptibility but different growth habits were compared, and the highly vegetative 'Florida MDR-98' had greater stem rot incidence than the upright 'Georgia Browne'. Plants inoculated later in the year (90 DAP) consistently developed more severe symptoms within the first week, and the pathogen spread further. This may have been due to more available host tissue or possibly just to a more favorable environment. Canopy temperature and relative humidity were different than ambient temperature and humidity for all treatments. However, canopy microclimate differences among treatments were difficult to discern due to missing data. The available data suggests that the physical spacing between plants was the critical factor in disease development, since stem rot was greater at close seed spacings and in highly vegetative 'Florida MDR-98', where plant-to-plant contact was greater than in wide seed spacings and in plots planted with a cultivar with an upright growth habit, 'Georgia Browne'.

Key Words: *Arachis hypogaea*, microclimate, plant spacing, severity

Introduction

Peanut is a major cash crop in Georgia, but growers have experienced major losses to tomato spotted wilt virus (TSWV) since the early 1990s. In recent years, producers are planting peanuts at higher seeding rates to help manage tomato spotted wilt (TSW) (Smith 2001). According to Wehtje *et al.* (1994) and Culbreath *et al.* (1999), there is a significant reduction in TSWV, an increase in quality, and an increase in yield when twin rows are planted at seeding rates greater than 13.12 seed m⁻¹. Although this cultural practice helps reduce TSWV, the effect of high plant density on the development of soilborne fungal diseases in peanut is not as well characterized. There have been indications that higher plant populations are more conducive to development of stem rot (Black *et al.* 2001, Wehtje *et al.* 1994), but this relationship has not been examined fully.

Some research has been conducted to determine the effects of seeding rate and/or row pattern on peanut disease development. Minton and Csinos (1986) examined the effect of planting single and twin rows (1.0X seeding rate for single rows and 0.5X and 1.0X seeding rates for twin rows) on stem rot incidence, and found no consistent advantage for any of the treatments in managing this disease. Wehtje *et al.* (1994) found that stem rot incidence increased and that spotted wilt incidence decreased at higher seeding rates in runner type peanuts planted in conventional single rows. A linear relationship was found with the 34 kg ha⁻¹ seeding rate, having fewer stem rot loci/plot (5.0),

and the 123 kg ha⁻¹ seeding rate having more stem rot loci/plot (6.7). In another study, reduced seeding rate (8-12 seed m⁻²) in irrigated peanuts did not increase the risk of TSWV and may also help manage stem rot and rust in 'GK-7' and 'Southern Runner' which have partial resistance (Black *et al.* 2001). The mechanism for the decrease in stem rot in these studies was not defined, but presumably could be due to reduced plant-to-plant spread and/or environmental conditions within the peanut canopy.

There are other factors that could alter the effects of row spacing and plant density, including genetically resistant varieties and varieties with different growth habits. The partial resistance of peanut cultivars to stem rot has been well documented (Branch and Csinos 1987, Branch and Brenneman 1993, Brenneman *et al.* 1990, Grichar and Smith 1992, Shokes *et al.* 1996), and one suggested mechanism of resistance is a more open and/or upright plant canopy (Shew *et al.* 1987). However, the interactive effect of plant canopy and plant spacing on the development of stem rot in peanut has not been examined. The relative effects of stem rot epidemics starting early in the season versus later, after plant canopies have developed, have also not been quantified.

The main objective of this study was to quantify the effect of a range of plant densities on development of peanut stem rot from controlled inoculations at different times during the growing season. The interactive effects of plant growth habit and plant spacing were also evaluated for a range of plant densities

and cultivars of similar susceptibility to stem rot but having different growth habits.

Materials and Methods

Microplot study. In 2000, 2001, and 2002, certified 'Georgia Green' peanut seed treated with Vitavax PC (2.49 g/kg seed) were germinated in nursery flats in moist vermiculite. Germinated seeds were planted in 0.9-m diameter field microplots (cylindrical aluminum ring, 0.9-m diam. x 0.3-m high, buried 15 cm in the soil). The soil was a Fuquay sand and had been treated previously with metam sodium (Vapam 32%, Amvac Chemical Coop., Newport Beach, CA) at 1429 L/ha several weeks prior to planting. Seeds were planted in two intersecting perpendicular rows centered in the plot at spacings of either 5.1 (equivalent to current recommendation of 19.7 seed/m), 10.2, 15.2, 20.3, 25.4, or 30.5-cm apart, for a total plant population of 27, 13, 9, 5, 5 and 5 plants/plot, respectively. Plots were irrigated via solid-set sprinklers as needed. Chlorothalonil (Bravo 720, Syngenta Crop Protection, Greensboro, NC) was applied at a rate of 1.3 kg/ha on a 14-day schedule to control leaf spot diseases according to conventional management practices (Compendium of Peanut Diseases).

Isolate SR-8 of *S. rolfsii*, known to be virulent on peanut, was grown and maintained on potato dextrose agar (PDA) at approximately 24°C. At 50, 70, and 90 days after planting (DAP), 1-cm-diameter hyphal plugs were taken from the edge of actively growing colonies and placed with the mycelium against the base of the main stem of the center plant of each plot at the soil line. Plots were

then treated with acephate insecticide (Orthene 75S, Valent Agricultural Products, Germantown, TN) at a rate of 1.1 kg/ha a.i. to prevent imported fire ants (*Solenopsis invicta*) from eating the agar plugs. Microplots were irrigated for 3 consecutive days following each inoculation at approximately 1.27 cm/day to promote the growth of the fungus and to initiate disease development. At 57, 77, and 97 DAP, disease severity on the inoculated plant was measured using the Shokes 0-5 severity scale (Shokes *et al.* 1996). Disease incidence was also measured by counting all plants showing signs or symptoms of stem rot and then dividing by the total plant count per plot. Disease spread was assessed by measuring the length of visible signs or symptoms along both rows and then averaging the two. Disease severity on the center plant and terminal plants of each row was assessed, again at harvest. Yield was not assessed in this study.

Data were analyzed by analysis of variance with SAS PROC GLM procedure to determine the effect of main factors of seed spacing and inoculation date on disease severity, incidence or total plant disease count, and spread. For disease severity ratings from the Shokes 0 -5 scale, the midpoint of each disease severity range of the scale was used for all analyses. AUDPC (Area Under Disease Progress Curve) values were determined for center plant severity, disease incidence, and spread for all 3 years and all six spacings. Initial ratings taken 7 days after each inoculation date were compared for all three years of the study. Means were separated using Tukey's Multiple Comparison Test. Linear regression analysis was also used to determine the

quantitative relationship between seed spacing or plant density and mean stem rot development.

Grid study. This test was conducted in 2001 and 2002 with peanut seed of cultivars 'Florida MDR-98' and 'Georgia Browne' germinated as described previously. Germinated seeds were planted by hand in 0.3-m² plots using a 0.3-m² grid as a guide for planting seeds at 7.6, 15.2, 22.9, or 30.5 cm apart. Plots with the 7.6-cm spacing had 121 seeds/plot and the 30.5-cm plots had five seeds/plot. The test site was tarped and fumigated with a methyl bromide/chloropicrin mixture (450 kg/ha, 67% methyl bromide and 33% chloropicrin) prior to planting to minimize existing soilborne pathogen inoculum. The soil was a Tifton loamy sand (2-5% slope). Chlorothalonil (Bravo 720, 1.3 kg/ha) was applied to all plots on a 14-day schedule to reduce leaf spot disease. Host plants were irrigated as needed via solid set sprinklers and insects and weeds managed by practices currently recommended by University of Georgia.

Onset Data Loggers (Onset Computer Corporation, Bourne, MA) were placed beside the crown of plants under the peanut canopy to record air temperature and relative humidity in plots that represented each of the cultivars and seed spacing treatment combinations. At 50 or 90 DAP, the center plant of each plot was inoculated with *S. rolfsii* as described previously. Stem rot severity was assessed at 57, 77, and 97 DAP using the Shokes 0 - 5 severity scale. After determining disease severity from the Shokes 0 - 5 scale, the midpoint of each disease severity range of the scale was used for all analyses.

A total stem rot disease count was also obtained by counting all plants showing signs or symptoms. Disease spread was assessed by measuring the greatest diameter of the disease focus. Mainstem heights (cm) were obtained prior to end of growing season for the center plant of each plot by measuring from the base of the mainstem to the tip of the terminal leaf.

AUDPC values were calculated for each year, seed spacing and cultivar for center plant severity. Data were analyzed by analysis of variance with SAS PROC GLM procedure to determine the effects of main factors seed spacing, inoculation date, cultivar, and year on severity, number of symptomatic plants, severity AUDPC, and mainstem height. Treatment means were compared using Tukey's Multiple Comparison Test. Linear regression analysis was also used to determine the quantitative relationship between seed spacing or plant density and mean disease development. Weather data were analyzed by analysis of variance using SAS PROC MIXED procedure (see chapters 3 and 5 for details), and regression analysis was used to determine the quantitative relationship between seed spacing and canopy environment.

Results

Microplot study. All treatment by year interactions were significant; therefore data for each year were analyzed separately. For disease severity and incidence on the center plants at harvest, there were no significant treatment by inoculation date interactions, therefore, data were combined across inoculation dates (Tables 2.1 and 2.2). Plots with 5.1 cm between seed had greater stem

rot severity (60-80%) than the other seed spacings. Generally, as seed spacing increased, disease severity decreased, but the shape of the curves varied somewhat among years. The relationship between seed spacing and mean disease severity was best described by a cubic polynomial in 2000 and 2001 (Fig. 2.1) and quadratic (Fig. 2.1c) in 2002.

As with disease severity, there was a significant seed spacing by year interaction on disease incidence at harvest (Table 2.2). For 2001 and 2002, there was a cubic relationship between seed spacing and mean disease incidence (Fig. 2.2) with the 5.1-cm spacing having the greatest incidence (93-96%). Disease incidence was lower but more consistent at the intermediate seeding rates, and consistently lowest at the widest seed spacing.

For disease severity on terminal plants there was a significant year x seed spacing interaction and a significant year x inoculation date interaction (Table 2.3). Means were calculated accordingly, and regression analysis was used to describe the relationship between seed spacing and mean terminal plant severity (Figure 2.3). Disease severity on terminal plants was greatest at the 5.1-cm spacing and generally with the 50 DAP inoculations. The effect of seed spacing on severity was not consistent among years or inoculation dates. In 2000, the 50, 70 and 90 DAP severity eventually decreased with seed spacing but the relationships were cubic, linear, and quadratic, respectively (Fig. 2.3a). In 2001, relationships for 50, 70 and 90 DAP were all cubic, and in 2002, the trend for each of the inoculation dates were quadratic (Figure 2.3b-c).

AUDPC values were determined for center plant severity, disease incidence, and spread for all three years and all six spacings (Table 2.4). For all three years, AUDPC values for all disease measures were greatest in rows with the 5.1-cm spacing. In general, as spacing increased, AUDPC values decreased.

In all three years, the later in the season that plants were inoculated, the more rapidly disease developed (Figures 2.4, 2.5 and 2.6). When inoculated at 50 DAP, only 7 to 10% of plants were symptomatic the next week, versus 17 to 23% when inoculated at 90 DAP. The same trend was observed for all disease variables including severity, incidence, and spread. Similar trends were observed at harvest for incidence and disease severity of terminal plants, but there were no differences in disease severities at harvest of the central inoculated plants.

Grid study. Due to significant year x treatment interactions, data were analyzed by year (Table 2.5). For disease severity of the inoculated center plant at harvest, there was also a significant inoculation date interaction, so data were also analyzed separately by inoculation date. There were no significant main or interactive effects of cultivar on severity of disease on inoculated plants at harvest (Table 2.5). In 2001, severity of disease on plants inoculated 50 or 90 DAP decreased linearly with increasing seed spacing (Figure 2.7a), whereas in 2002 they decreased following a quadratic trend (Figure 2.7b). The disease

severities in the closer plantings were approximately twice as high as those in the widest plant spacing in 2001 and about three times as high in 2002.

There were significant interactive effects of seed spacing, cultivar and year on number of symptomatic plants at harvest (Table 2.6). As seed spacing increased, the number of plants showing signs or symptoms decreased quadratically with 'Florida MDR-98' having more symptoms than 'Georgia Browne' (Figure 2.8). AUDPC values were calculated for each year, seed spacing and cultivar for center plant severity (Table 2.8). In general, disease severity decreased with an increase in seed spacing, and tended to be greater for 'Florida MDR-98' than 'Georgia Browne'.

There was a significant year x seed spacing x cultivar interaction on the height of the mainstem of the central inoculated plant (Table 2.7). In 2001, mainstem height of 'Georgia Browne' decreased linearly and mainstem height of 'Florida MDR-98' decreased quadratically with increasing seed spacing (Fig. 2.9a). In 2002, mainstem height of 'Georgia Browne' and 'Florida MDR-98' decreased quadratically with increasing seed spacing (Fig. 2.9b). In 2002, main stem height was greater for 'Florida MDR-98' than 'Georgia Browne'.

There was little or no difference in disease severity or incidence for initial stem rot ratings taken 7 days after inoculation between the early and later inoculations in 2001 and 2002 (Figure 2.10-2.11). Initial disease incidence was greater on 'Florida MDR-98' than on 'Georgia Browne' in 2001, but early disease severity was similar for the two cultivars in both years (Fig. 2.11).

For treatment means of temperature and relative humidity (RH) within the peanut canopy, there was a significant quadratic relationship for 'Georgia Browne' and a significant cubic relationship for 'Florida MDR-98' when the ambient air temperature for Tifton, Georgia was used as a covariant in the SAS MIXED analysis (Figure 2.12a). Again, there was a significant quadratic relationship for 'Georgia Browne' and a significant cubic relationship for 'Florida MDR-98' when the ambient humidity for Tifton, Georgia was used as a covariant in the SAS Mixed analysis (Figure 2.12b). At high and low seeding rates, microclimates of the two cultivars were similar, but at intermediate rates 'Georgia Browne' tended to be cooler and have higher relative humidity. Microclimate data was also analyzed across the entire growing season each year. Although some seed spacing treatments did create a unique canopy microclimate (when compared to ambient conditions), differences among treatments were relatively small. Missing data also made it difficult to discern differences between treatments. Additional data are presented in Appendix A.

Discussion

Based on these results, peanuts planted closer together are subject to greater severity, incidence, and spread of stem rot. Above-ground plant to plant contact is greater, and a plant bridge may permit the fungus to spread and affect more plants. Apparently, it is more likely the hyphae extending from an infected plant will have the energy needed to infect an adjacent plant if it is not as far away. This was reflected in the severity ratings of terminal plants in the

microplots, the length of individual disease foci in both studies, and the higher numbers of infected plants in plots with closer plantings. In the microplot study, disease decreased in a quadratic or cubic fashion with increasing seed spacing. This suggests that after a certain spacing between plants is obtained, the effect of increased spacing is less. The limits of this mechanism have not been defined, but data from the microplots suggests that disease spread was negligible at 30 cm, intermediate at 10-20 cm, and extensive at 5 cm. Unfortunately, the 5.1-cm spacing is equivalent to the current recommendation of 19.7 seed/m for improved stands and TSWV management (Culbreath *et al.* 1999). At this time, plant density is a critical component of TSWV management, so reduced seeding rates are not an option with current cultivars. However, cultivars with greatly improved levels of resistance to TSWV are being introduced (Culbreath *et al.* 1999). These cultivars may be grown at lower seeding rates, thus reducing costs of seed as well as the potential for stem rot development. In the meantime, fungicides such as tebuconazole, azoxystrobin, and flutolanil are critical for management of stem rot in stands planted at higher seeding rates.

Numerous studies have been conducted concerning the effect of plant density on other diseases and hosts. In a recent study of downy mildew on container-grown roses, it was found that reducing the plant density significantly reduced downy mildew development (O'Neill *et al.* 2002). Some evidence has shown that density modification can also help reduce diseases in small grains.

Garrett and Mundt (2000) found that stripe rust of wheat, caused by *Puccinia striiformis*, was less severe when the planting densities were reduced to 250 seeds m⁻². In strawberry, plants grown at narrower spacings (38 and 46-cm) had higher incidence of Botrytis fruit rot than wider plant spacings (23 and 30-cm) (Legard *et al.* 2000). Research has been conducted on other legumes including *Kemmerowia stipulacea*. Mihail *et al.* (1998) found that reducing plant density significantly reduced disease caused by *R. solani* and *P. irregulare*. Littlely and Rahe (1987) found that high density plantings had approximately twice the level of white rot, caused by *Sclerotium cepivorum* as onions planted at a low density.

The effects of plant density may have been due to changes in other factors such as environmental conditions within the canopy or even susceptibility of individual plants to infection. It is not known if peanut plant density affects susceptibility to *S. rolfisii*, but the environmental data showed only subtle changes in temperature and humidity with change in plant spacing. Clearly something was involved that consistently resulted in the inoculated center plant having more severe disease than non-inoculated plants in both studies. One option is that a “critical mass” of fungal growth is obtained by having several infected plants in close proximity. Whatever the mechanism, it is a very real effect.

Based on results of the grid study, disease incidence was significantly greater in ‘Florida MDR-98’ than in ‘Georgia Browne’, at least at the closer seed spacings (Fig. 2.8). The was also true of the earliest disease assessments 7

days after inoculation, presumably due to the more prolific vine growth of 'Florida MDR-98'. In contrast, there was a higher initial severity on 'Georgia Browne', possibly due to its more compact growth habit. These two cultivars were selected for this experiment since in previous studies they exhibited different growth habits but similar susceptibility to stem rot and to spotted wilt. Unfortunately, the frequent watering regime in this study caused extensive foliar growth with both cultivars. Greater differences in plant growth may have lead to greater differences in disease development.

Modification of spatial arrangements of cultivars with different growth habits have been examined in other studies. Saindon *et al.* (1993) found that white mold of bean caused by *Sclerotinia sclerotiorum* was not significantly affected by the between-row and within row spacings. Rather, the upright growth habit of some cultivars was more beneficial in reducing disease, regardless of row spacing used. Mozingo and Wright (1994) found taller main stems and longer cotyledonary lateral branches in the 15.2 x 15.2-cm diamond-shape seed configuration compared to the 30.5 x 30.5 and 45.7 x 45.7-cm seed configurations. Yield was also greater in the 15.2 x 15.2-cm seed configuration, and cultivars with a bunch type growth habit responded better to the closer seed configurations. Those cultivars with a runner- type growth habit responded better to more distant seed configurations (Mozingo and Wright 1994). Sternitzke *et al.* (2000) found as total emergence and population decreased,

yield also decreased, but pod mass per plant increased due to a reduction in plant competition.

Another interesting result of these experiments is the influence of inoculation date, regardless of seed spacing, on the speed of disease establishment. Plants inoculated later in the year consistently developed more severe symptoms within the first week, and the pathogen spread further. This may have been due to more available host tissue or possibly just to a more favorable environment. Previous work has shown that older plants are less susceptible to stem rot (Rideout *et al.* 2002) when environment is not a factor, so increased host plant susceptibility is probably not responsible for the increased initial rate of stem rot development following inoculations later in the season. These data verify how rapidly stem rot can develop, especially late in the year.

Based on this study, stem rot becomes a significant problem in stands planted at closer spacings, especially with indeterminant cultivars such as 'MDR-98'. However, closer plant spacings are needed to reduce losses to TSWV with the partially resistant cultivars currently grown (Culbreath *et al.* 1999). As cultivars with greater levels of resistance to TSWV are released, thresholds are needed to define seeding rates that will minimize both TSWV and stem rot.

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Table 2.1. Effect of seed spacing and inoculation date in 2000, 2001 and 2002 on severity of peanut stem rot at harvest for peanuts planted in two intersecting perpendicular rows in field microplots (2000-2002)

Source	df	Mean Square Error	<i>P</i> > <i>F</i>
Year	2	6415.80	< 0.0001
Rep (Year)	24	436.75	0.6149
Seed spacing	5	23124.24	< 0.0001
Date	2	1514.71	0.0465
Seedsp x Date	10	467.71	0.4832
Year x Seedsp	10	2279.90	< 0.0001
Year x Date	4	949.27	0.1036
Year x Seedsp x Date	20	369.31	0.7692
Error	388	490.14	-

Table 2.2. Effect of seed spacing and inoculation date in 2001 and 2002 on incidence of peanut stem rot at harvest for peanuts planted in two intersecting perpendicular rows in field microplots (2000-2002)

Source	df	Mean Square Error	<i>P</i> > <i>F</i>
Year	1	1948.79	< 0.0001
Rep (Year)	16	492.88	0.8236
Seed spacing	5	18599.23	< 0.0001
Date	2	2580.95	0.0316
Seedsp x Date	10	511.36	0.7299
Year x Seedsp	5	1706.47	0.0442
Year x Date	2	369.71	0.6061
Year x Seedsp x Date	10	928.93	0.2532
Error	258	736.95	-

Table 2.3. Effect of seed spacing and inoculation date in 2000, 2001 and 2002 on average severity of peanut stem rot on terminal peanut plants at harvest for peanuts planted in two intersecting perpendicular rows in field microplots (2000-2002)

Source	df	Mean Square Error	<i>P</i> > <i>F</i>
Year	2	1969.99	0.0006
Rep (Year)	24	426.23	0.0325
Seed spacing	5	19931.14	< 0.0001
Date	2	4657.57	< 0.0001
Seedsp x Date	10	627.01	0.0091
Year x Seedsp	10	851.44	0.0005
Year x Date	4	1729.12	< 0.0001
Year x Seedsp x Date	20	195.53	0.7765
Error	388	261.74	-

Table 2.4. Calculated AUDPC values for peanut stem rot severity, incidence, and total spread length (cm) for peanuts planted in two intersecting perpendicular rows in field microplots (2000-2002)

Seed Spacing (cm)	AUDPC ¹ values for severity			AUDPC values for incidence			AUDPC values for total spread length ²		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
5.08	3766.1a ³	2758.2 a	3831.9 a	1424.8 a	5064.8 a	5193.9 a	2032.0 a	2977.4 a	2703.7 a
10.16	2411.1 b	2087.9 ab	2186.5 b	1380.6 a	3797.9 b	3773.9 b	1611.5 a	1903.6 b	1625.4 b
15.24	1737.4 bc	1714.9 bc	1729.0 c	775.3 b	3210.0 b	3101.2 c	714.0 b	1041.4 c	1185.3 c
20.32	885.0 c	1322.9 bcd	1210.3 d	533.3 b	2918.5 bc	2368.3 d	293.5 b	818.4 c	547.5 d
25.4	1475.3 bc	964.4 cd	866.4 de	511.1 b	2067.8 c	1605.6 e	183.4 b	660.4 c	471.3 c
30.48	897.2 c	762.8 d	761.7 e	372.2 b	1957.8 c	1546.9 e	158.0 b	568.7 c	443.1 d

¹Area under the disease progress curve

²Total spread of signs or symptoms determined by measuring length (cm) of spread for both perpendicular rows

³Values followed by different letters are significantly different ($P \leq 0.05$), based on Tukey's Multiple Comparison Test

Table 2.5. Effect of seed spacing, inoculation date, and cultivar in 2001 and 2002 on severity of peanut stem rot at harvest in peanuts planted in a 0.27-m² grid pattern

Source	df	MS	<i>P</i> > <i>F</i>
Year	1	8850.29	< 0.0001
Rep (Year)	20	170.02	0.2603
Seed spacing	3	19867.54	< 0.000
Date	1	302.07	0.1468
Seedsp x Date	3	337.87	0.0710
Cultivar	1	25.49	0.6729
Seedsp x Cultivar	3	84.17	0.6222
Date Cultivar	1	281.21	0.1615
Seedsp x Date x Cultivar	3	98.80	0.5575
Year x Seedsp	3	2465.72	< 0.0001
Year x Date	1	509.11	0.0599
Year x Cultivar	1	4.60	0.8577
Year x Seedsp x Date	3	618.70	0.0052
Year x Date x Cultivar	1	214.74	0.2210
Year x Seedsp x Cultivar	3	117.68	0.4813
Year x Seedsp x Date x Cultivar	3	31.19	0.8835
Error	298	142.7518	-

Table 2.6. Effect of seed spacing, inoculation date, and cultivar in 2001 and 2002 on number of diseased plants with peanut stem rot at harvest in peanuts planted in a 0.27-m² grid pattern

Source	df	MS	<i>P</i> > <i>F</i>
Year	1	37.13	< 0.0001
Rep (Year)	20	2.61	0.3130
Seed spacing	3	672.07	<0.0001
Date	1	0.08	0.8568
Seedsp x Date	3	2.24	0.4061
Cultivar	1	29.18	0.0004
Seedsp x Cultivar	3	10.98	0.0029
Date x Cultivar	1	0.85	0.5447
Seedsp x Date x Cultivar	3	1.03	0.7187
Year x Seedsp	3	24.12	<0.0001
Year x Date	1	0.30	0.7201
Year x Cultivar	1	1.64	0.3997
Year x Seedsp x Date	3	0.39	0.9166
Year x Date x Cultivar	1	10.18	0.0363
Year x Seedsp x Cultivar	3	0.75	0.8049
Year x Seedsp x Date x Cultivar	3	1.93	0.4732
Error	298	2.30	-

Table 2.7. Effect of seed spacing, inoculation date, and cultivar in 2001 and 2002 on height of peanut mainstem prior to harvest in peanuts planted in a 0.27-m² grid pattern

Source	df	MS	<i>P</i> > <i>F</i>
Year	1	2431.64	< 0.0001
Rep (Year)	20	60.15	0.0153
Seed spacing	3	6537.62	< 0.0001
Date	1	59.04	0.1781
Seedsp x Date	3	17.44	0.6566
Cultivar	1	764.68	< 0.0001
Seedsp x Cultivar	3	56.96	0.1553
Date x Cultivar	1	43.61	0.2469
Seedsp x Date x Cultivar	3	0.53	0.9971
Year x Seedsp	3	191.48	0.0006
Year x Date	1	9.99	0.5792
Year x Cultivar	1	220.96	0.0095
Year x Seedsp x Date	3	28.58	0.4508
Year x Date x Cultivar	1	5.21	0.6888
Year x Seedsp x Cultivar	3	83.35	0.0543
Year x Seedsp x Date x Cultivar	3	92.38	0.0376
Error	299	32.41	-

Table 2.8. Calculated AUDPC¹ values for stem rot severity on center, inoculated plant of 'Florida MDR-98' and 'Georgia Browne' planted at different seed spacings in 2001 and 2002

Seed Spacing (cm)	2001		2002	
	MDR-98	Georgia Browne	MDR-98	Georgia Browne
7.62	1192.5 a ²	926.3 a	2212.8 a	1682.5 a
15.24	948.8 ab	776.3 ab	1388.5 b	1103.6 b
22.86	1091.3 a	562.5 b	1046.5 bc	1016.6 b
30.48	641.3 b	652.5 ab	727.4 c	837.0 b

¹ Area under the disease progress curve

² Values followed by different letters are significantly different ($P \leq 0.05$), based on Tukey's Multiple Comparison Test

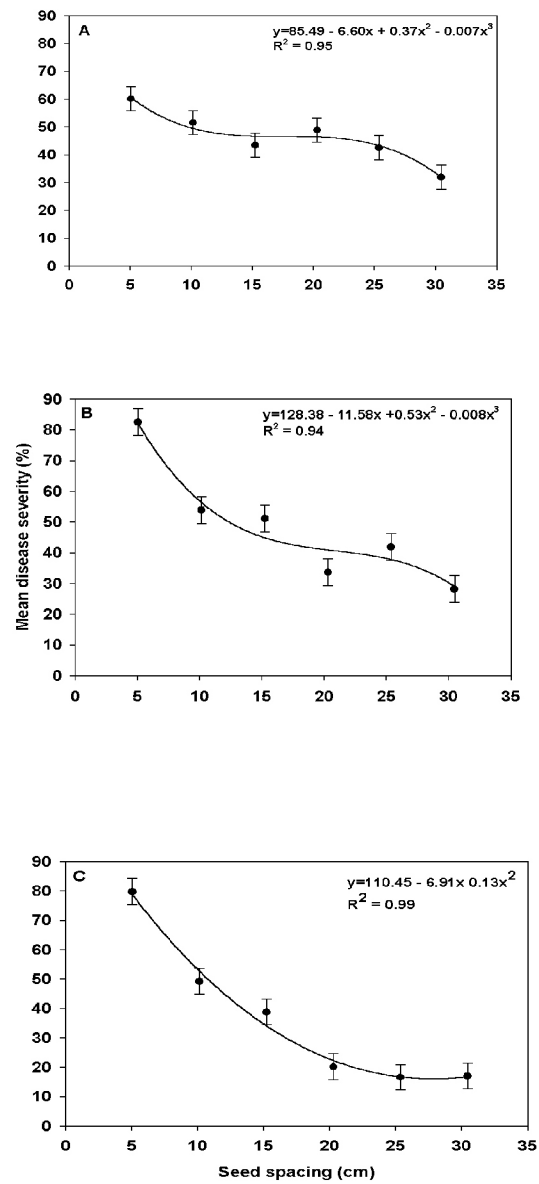


Figure 2.1. Severity of stem rot on the central inoculated peanut plant at harvest in a microplot study in 2000 (A), 2001 (B) and 2002 (C). ‘Georgia Green’ seeds were planted in two intersecting perpendicular rows.

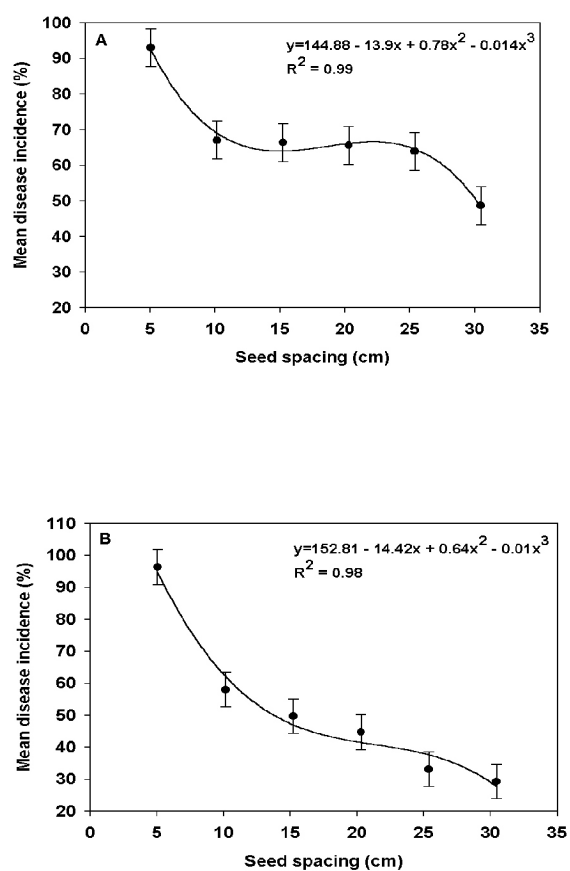


Figure 2.2. Incidence of peanut stem rot on total plant population at harvest in microplots in 2001 (A) and 2002 (B). 'Georgia Green' seeds were planted in two intersecting perpendicular rows.

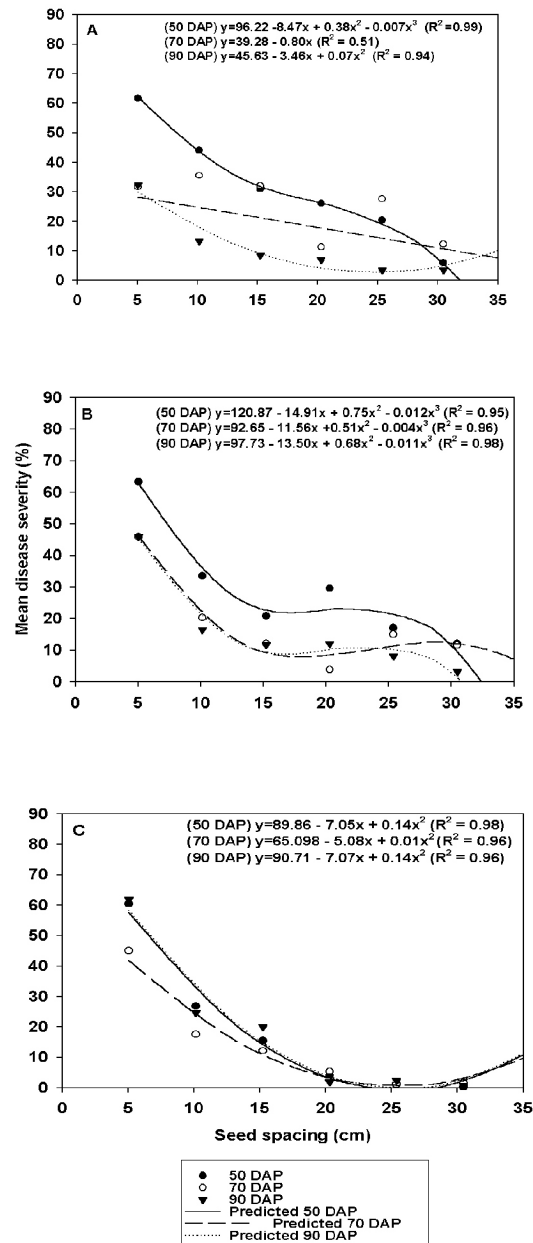


Figure 2.3. Average stem rot severity of terminal plants (ie. the most distant from the inoculated plant) in microplot study at harvest in 2000 (A), 2001 (B) and 2002 (C). 'Georgia Green' seeds were planted in two intersecting perpendicular rows.

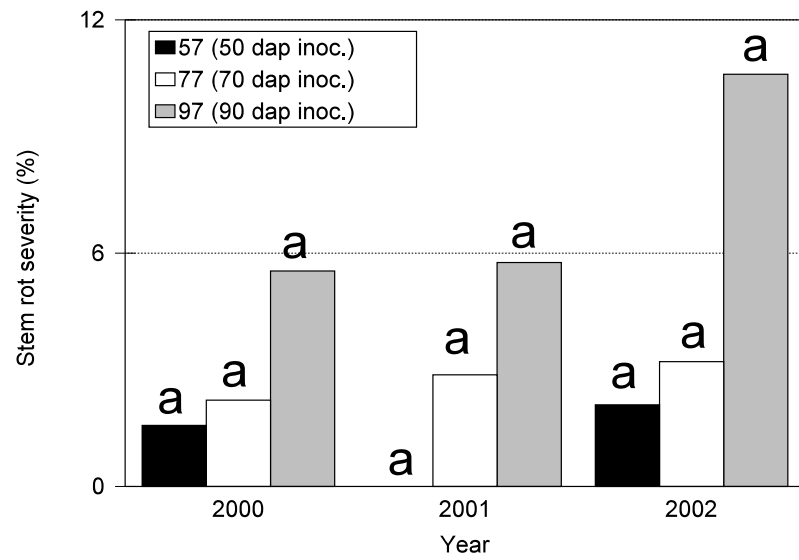


Figure 2.4. Initial peanut stem rot severity ratings taken 7 days after each inoculation date in microplot study in 2000, 2001 and 2002. 'Georgia Green' seeds were planted in two intersecting perpendicular rows.

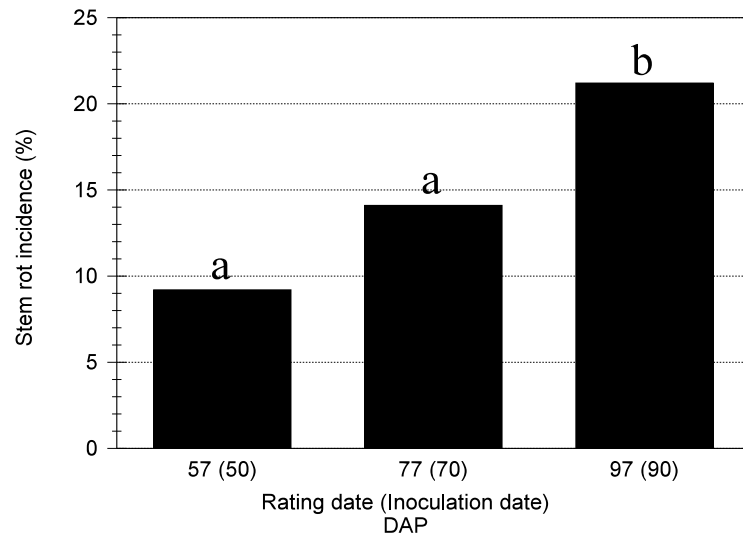


Figure 2.5. Initial peanut stem rot incidence ratings taken 7 days after each inoculation date in microplot study in 2000, 2001 and 2002. ‘Georgia Green’ seeds were planted in two intersecting perpendicular rows.

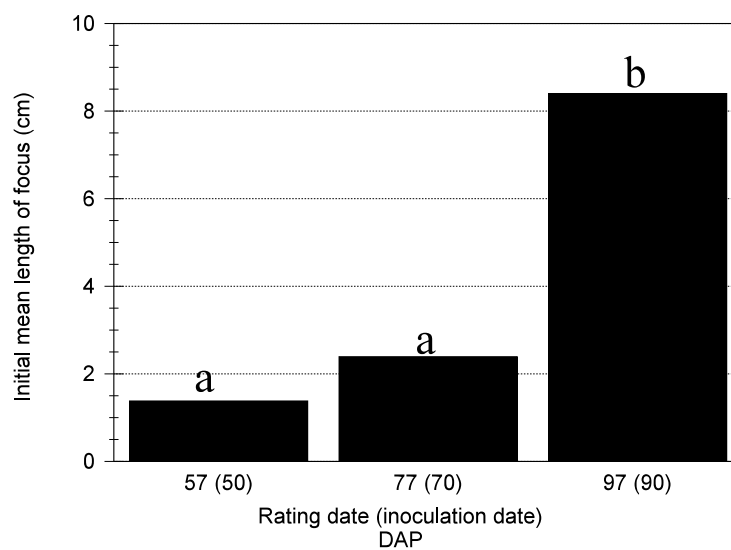


Figure 2.6. Initial peanut stem rot spread length (cm) taken 7 days after each inoculation in 2000, 2001 and 2002.

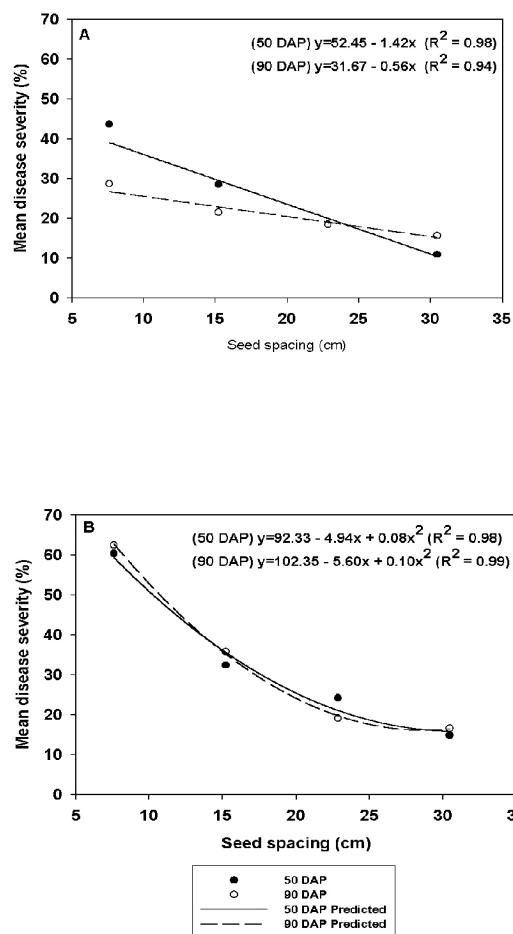


Figure 2.7. Severity of peanut stem rot on central inoculated plant at harvest in grid study in 2001 (A) and 2002 (B).

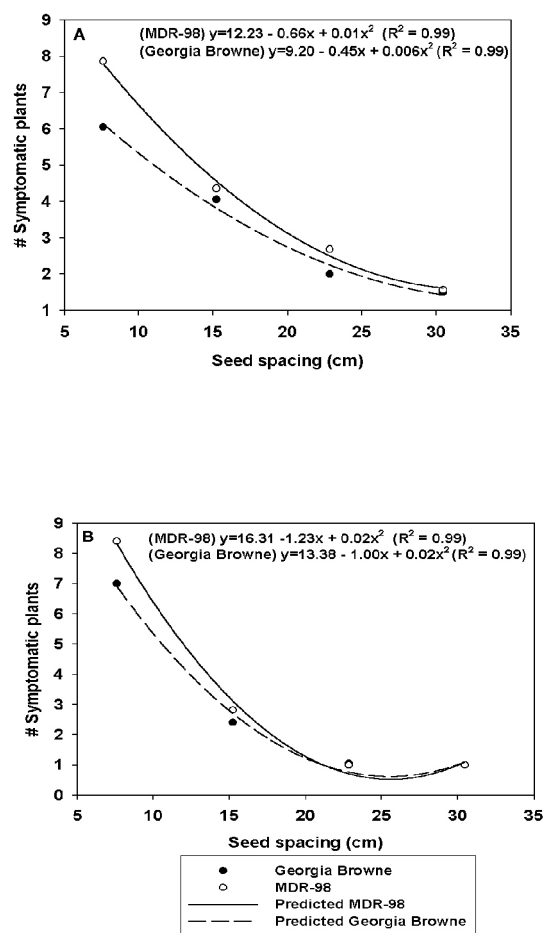


Figure 2.8. Influence of seed spacing and cultivar on number of peanut plants infected with stem rot in grid study for 2001 (A) and 2002 (B).

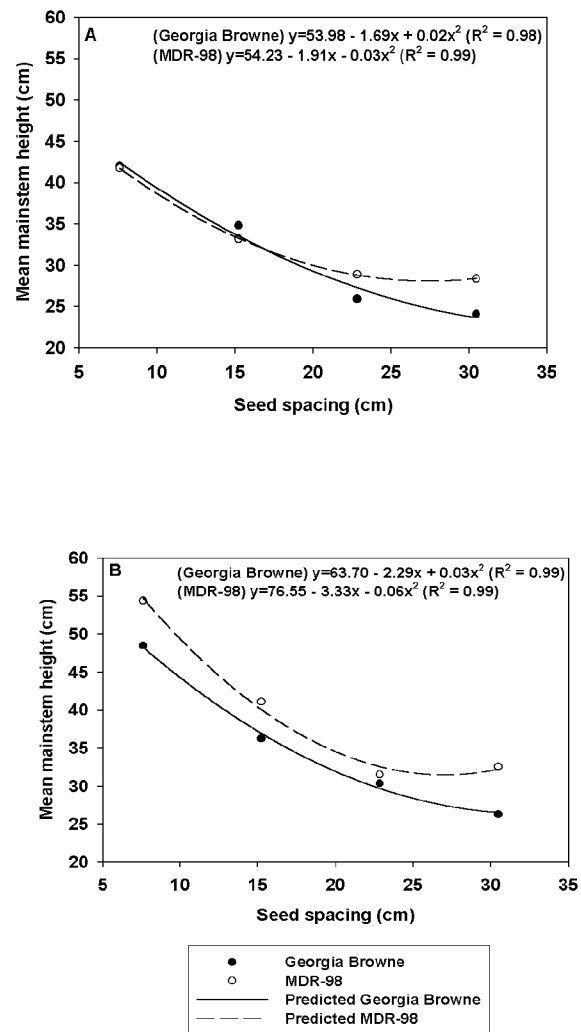


Figure 2.9. Height of mainstems of two peanut cultivars at harvest in 2001 (A) and 2002 (B).

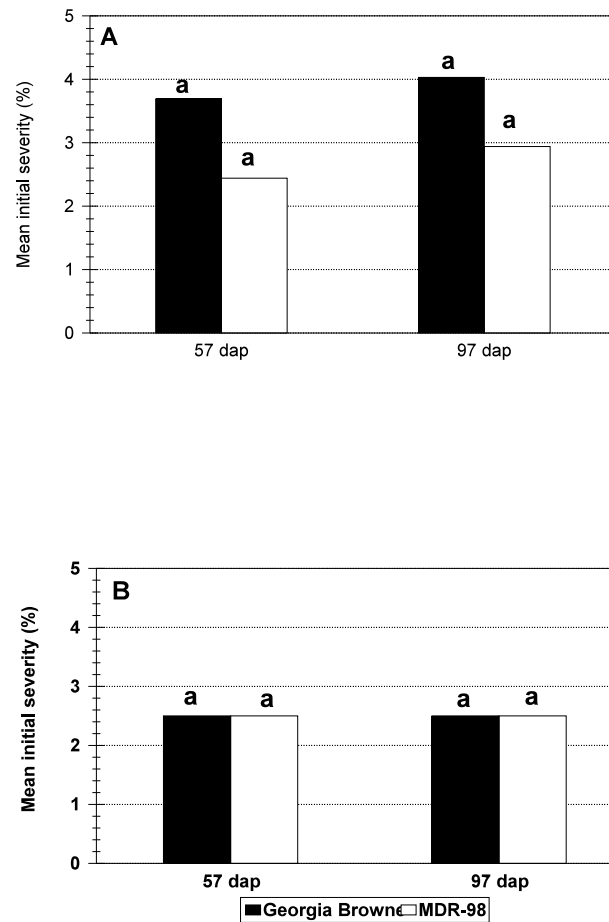


Figure 2.10. Initial peanut stem rot severity ratings taken 7 days after each inoculation in 2001 (A) and 2002 (B). Same letter above bars indicate no significant differences between cultivars for each of the rating dates based on Grid test ($P > 0.05$).

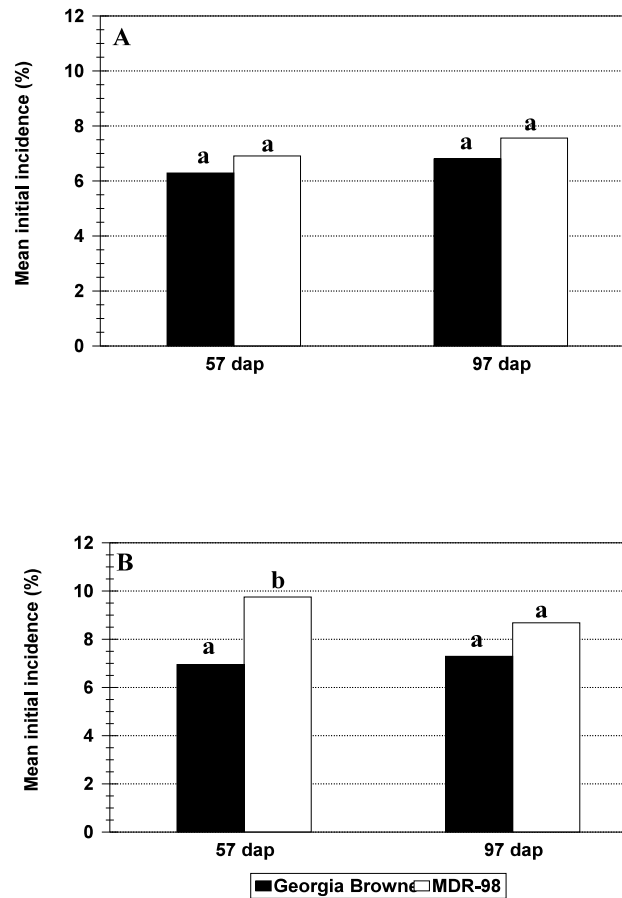


Figure 2.11. Initial incidence of peanut stem rot 7 days after each inoculation date in 2001 (A) and 2002 (B). Same letter above bars indicate no significant differences between cultivars for each of the rating dates based on Grid test ($P > 0.05$).

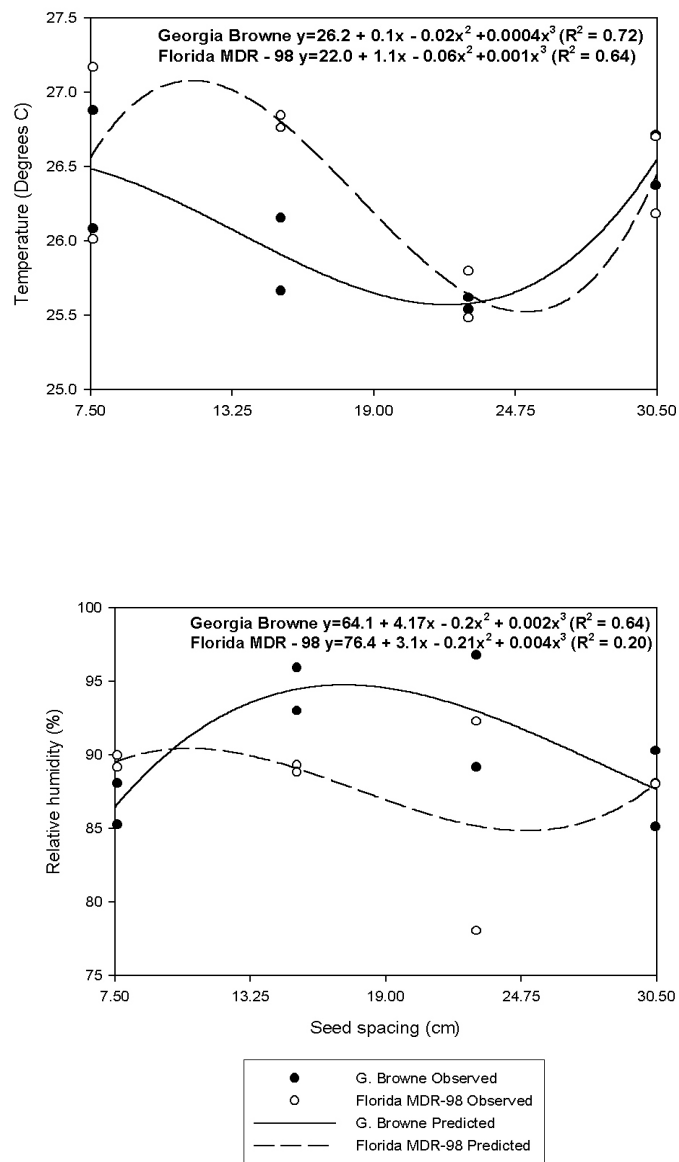


Figure 2.12. Relationship between seed spacing and predicted canopy temperature (A) and humidity (B) for two peanut cultivars in 2001 and 2002.

CHAPTER 3
EFFECTS OF PEANUT ROW PATTERN AND SEEDING RATE ON STEM ROT
DEVELOPMENT AND FUNGICIDE EFFICACY¹

¹Sconyers, L.E., T.B. Brenneman and K.L. Stevenson. 2003. To be submitted to *Peanut Science*.

Abstract

Two conventional field studies were conducted with peanut (*Arachis hypogaea* L.) in 2000, 2001 and 2002 to determine the effects of row pattern (91.4-cm single or 20.3-cm twin) and seeding rate (single-12.5, 17.4 or 22.6 seed/m or twin-6.2, 8.9 or 11.5 seed/m) on stem rot(*Sclerotium rolfsii* Sacc.) development, canopy microclimate (temperature and relative humidity), and azoxystrobin (Abound 2.08 F, applied at a rate of 1.35 liters/ha at 60 and 90 DAP) efficacy. Stem rot was significantly greater ($P < 0.05$) in single rows planted at high seeding rates than in twin rows planted at any of the seeding rates in this study. Row pattern did not affect azoxystrobin efficacy, and disease was reduced by nearly half in twin rows treated with fungicide as compared to single rows treated with fungicide. In the second trial, plots were inoculated with *S. rolfsii* on one of three dates (50, 70 or 90 DAP), and plots inoculated at 50 DAP had greater stem rot at harvest than the 70 or 90 DAP inoculations. Canopy temperature and relative humidity were different than ambient temperature and humidity for all planting patterns but differences between planting patterns were minor. The available data suggests that the physical spacing between plants was the critical factor in disease development, since stem rot was greater at high seeding rates and in single rows, where plant-to-plant contact was greater than in twin rows.

Key Words: *Arachis hypogaea*, azoxystrobin, microclimate, cultural control

Introduction

Since the late 1980s, tomato spotted wilt (TSW), caused by tomato spotted wilt virus (TSWV), has been a significant problem for peanut (*Arachis hypogaea* L.) producers. In Georgia alone, TSW has cost producers an average of \$12.6 million in losses for the last 4 years (Williams-Woodward 1998-2001). In the early 1990s, researchers found that establishing higher populations of plants in conventional single rows could significantly reduce tomato spotted wilt incidence (Wehtje *et al.* 1994). Later, it was found that planting twin rows (17.8 to 25.4-cm apart) and high seeding rates (> 13.3 seed/m) could further reduce TSW and also increase quality and yield (Culbreath *et al.* 1999). There has been a steady increase in the planting of twin row peanuts and use of higher seeding rates (>112 kg/ha) over the last 14 years (Georgia Peanut Extension Surveys 1998-2001), largely for management of tomato spotted wilt.

Soilborne fungal diseases, such as stem rot, caused by *Sclerotium rolfsii* Sacc., are also very damaging to peanut. In Georgia alone, this disease cost farmers an average of \$24.8 million in damages and \$13.4 million in control costs for the last 12 years (Williams-Woodward 1998-2001). Several field studies have been conducted to examine the effect of seeding rate on stem rot incidence, but less is known about the quantitative effect of row pattern on stem rot incidence. Minton and Csinos (1986) examined the effect of planting single and twin rows (1.0x seeding rate for single rows and 0.5x and 1.0x seeding rates for twin rows) on stem rot incidence, and found no consistent advantage for any

of the treatments in managing this disease. Wehtje *et al.* (1994) found that stem rot incidence increased linearly from 5.0 loci/plot at 34 kg ha⁻¹ to 6.7 loci/plot at a seeding rate of 124 kg ha⁻¹ at higher seeding rates in runner type peanuts planted in conventional single rows, but that TSW incidence decreased with increasing seeding rates (Wehtje *et al.* 1994). In another study, a reduced seeding rate (8 to 12 seed m⁻²) in irrigated 'GK-7' and 'Southern Runner' peanuts did not increase the risk of TSW, and also helped manage stem rot and rust (Black *et al.* 2001). The mechanism for the decrease in stem rot with lower seeding rates is unclear, but it may be due to less plant-to-plant spread and/or less favorable environmental conditions within the peanut canopy.

There has been much research conducted on the effects of plant spacing/population and row spacing on the development of several plant diseases, and modification of plant spacing may be useful in disease management. Pande *et al.* (1989) found that there was a similar positive relationship between plant density and incidence of charcoal rot in sorghum. Littlely and Rahe (1987) also found a significant positive effect on the rate of white rot development (*Sclerotium cepivorum*) on onion, with high density plantings having about twice the disease levels as low density plantings.

Research has also been conducted on the effect of row spacing on the management of numerous diseases on many hosts. In one study of Botrytis fruit rot in annual strawberry, Legard *et al.* (2000) found that narrower spacing (23 cm) resulted in higher incidence of Botrytis than wider spacing (46 cm), but that

yield was still higher with denser plant populations. In snap bean, it has been found that planting wider rows promotes foliage drying and significantly reduces white mold, caused by *Sclerotinia sclerotiorum* (Stevenson *et al.* 2002). In wheat, take all, caused by *Gaeumannomyces graminis*, and root rot, caused by *Rhizoctonia solani* were both found to be significantly reduced in paired rows (Cook *et al.* 2000). The decrease in disease was attributed to a more open canopy which is associated with the paired rows.

Although modification of row spacing has often been shown to reduce disease, some studies have demonstrated that changing row spacing has no effect on disease development. For example, three between-row (BR) and within-row (WR) spacings of bean cultivars with different growth habits were compared to determine if these factors affected the development of white mold caused by *Sclerotinia sclerotiorum* (Saindon *et al.* 1993). They found that neither BR or WR spacing had a significant effect on disease development, but that the least amount of disease was observed in the cultivar with an upright growth. From these studies, it is apparent that many factors effect disease development besides row spacing.

Although planting pattern of peanut has shown some effects on stem rot, the primary means of control has been with fungicides. Until 1994, stem rot of peanut was treated with granular products including pentachloronitrobenzene (PCNB) and chloropyrifos (Lorsban) (Hagan *et al.* 1991). However, these pesticides only offer about 20-60% control of stem rot (Thompson 1978, Csinos

et al. 1983) and growers found the return on investment to be marginal (Csinos *et al.* 1983). Today there are many different and more effective fungicides used for stem rot control, such as azoxystrobin (Abound), tebuconazole (Folicur), and flutolanil (Moncut) (Brenneman *et al.* 1991, Csinos 1987).

These products are all applied by spraying on the foliage of the plants, an application strategy generally thought best-suited for foliar diseases. Studies with dye have since shown foliar applications to be very effective at delivering fungicides to key targets where fungicide protection is most needed, such as the crown and pegs of peanut plants (Csinos, unpublished data), where *S. rolfsii* generally infects peanut. Changing row pattern and seeding rate can alter peanut growth (Kvien and Bergmark 1987), but it is not known if these changes affect fungicide deposition or subsequent redistribution, and thus efficacy. Deposition within the peanut canopy may be influenced by the volume of water used during application, with lower volumes giving a more layered effect of very high concentrations on the upper leaves and very low concentrations near the soil (Brenneman *et al.* 1990). Studies evaluating the interactive effects of plant growth and fungicide efficacy in turf have been inconsistent (Fidanza and Dernoeden 1996). The objectives of this study were to 1) examine the effects of seeding rate and row pattern on stem rot progression in the field using either natural inoculum or single plant inoculations, 2) document the effects of seeding rate and row pattern on the microclimate within the plant canopy, and 3) determine if these planting patterns affect fungicide efficacy.

Materials and Methods

Two field experiments were conducted in 2000, 2001, and 2002, all planted with certified 'Georgia Green' peanut (*Arachis hypogaea* L.) seed were treated with 2.49 g/kg of seed of a captan (45%), pentachloronitrobenzene (15%), and carboxin (10%) mixture (Vitavax PC, Gustafson LLC, Plano, TX). Both experiments were planted May 17, May 20 and May 22 in 2000, 2001 and 2002, respectively. 7.5-m long plots were planted in either single rows (91.4 cm apart) or twin rows (91.4 cm between outer rows, 20.3 cm between twins) with Monosem Vacuum Planters (ATI. Inc., Lenexa, KS) at a low, medium, or high seeding rates of 12.5, 17.4 or 22.6 seed/m for single rows, and 6.2, 8.9 and 11.5 seed/m for each twin row. Seeding rates were chosen to obtain similar plant populations in plots at each seeding rate level (low, medium, high), regardless of row pattern. The experiment was designed as a randomized complete block factorial experiment with four replicates. Fallow alleys (2.4 m long) between plots were included to reduce positive inter-plot interference. Phorate (Thimet 20 G, BASF Ag Products, Research Triangle Park, NC) was applied at a rate of 4.5 kg a.i./ha in-furrow at planting to reduce TSW.

First field experiment. The first experiment was planted in a Fuquay sand (2-5% slope) in a field that had a history of stem rot and continuous peanut production for 3 to 4 years prior to this study. Chlorothalonil (Bravo Ultrex, Syngenta Crop Protection, Greensboro, NC) was applied to all plots at a rate of 1.57 kg/ha on a 14-day schedule to reduce leaf spot diseases that may interfere

with stem rot development. Plots were either treated with azoxystrobin (Abound 2.08 F, Syngenta Crop Protection, Greensboro, NC) at a rate of 1.35 liters/ha at 60 and 90 DAP with a CO₂ pressurized belt-pack sprayer (using a 2-liter bottle and a 20- GPA broadcast boom with three Conjet TX-SS6 hollow cone nozzles per row at 40 PSI) or were not treated with fungicide.

Second field experiment. The second experiment included the same planting patterns as the first trial but was planted in a Tifton loamy sand (2-5% slope) that was tarped and fumigated with a methyl bromide/chloropicrin mixture (applied at a rate of 450 kg/ha, 67% methyl bromide and 33% chloropicrin) prior to planting each year to reduce populations of *S. rolfsii*. This experiment was conducted to monitor stem rot development initiated at known times during the season, and to compare results of a controlled inoculation test with those from a naturally infested field (Experiment 1). In the second experiment, chlorothalonil (Bravo Ultrex, Syngenta Crop Protection, Greensboro, NC) was applied on a 14-day schedule at a rate of 1.57 kg/ha. Individual plants at 1.5-m intervals within the rows of each plot were flagged for a total of 8 flagged plants per plot. Each flagged plant was inoculated once at either 50, 70 or 90 DAP with 1-cm-diameter hyphal plugs taken from the edge of actively growing colonies of *S. rolfsii* (isolate SR8 from peanut) on Potato Dextrose Agar (PDA). Plots were then irrigated for three consecutive days at 1.3-cm of water per day to promote the growth of the fungus and to initiate disease development.

In each experiment, the total number of plants in each plot was counted (stand count) approximately 10 days after emergence, and the approximate date of canopy closure in each plot was recorded. Six Hobo Pro Series 8 sensors (Onset Computer Corporation, Bourne, MA) were attached to a white plot sign holder (Collier Metal Specialties, Inc., Austell, GA) and were placed in both field trials to record air temperature and relative humidity near the soil surface at the crown of the plants at 30 minute intervals. The sensors were placed in the canopy of six plots, each representing a particular row pattern (Single or Twin) and seeding rate (Low, Medium, or High) treatment combination in each field test. Microclimate data was downloaded from the sensors using a HOBO shuttle (Onset Computer Corporation, Bourne, MA) and transferred to a computer using Boxcar Pro Version 3.51 (Onset Computer Corporation, Bourne, MA). Data were analyzed using the SAS Mixed procedure to determine significant factor effects ($P < 0.05$), and regression analysis was used to evaluate the relationship between weather and the independent factors (SAS Institute, Cary, NC) (Draper and Smith 1981). All analyses included a covariance adjustment for ambient temperature and humidity (Box, Hunter and Hunter 1978) using the State of Georgia Weather Data for Tifton in 2000, 2001 and 2002 (Hoogenboom 2000 - 2002 State of Georgia Weather Service).

In the first experiment, stem rot incidence was assessed at 57 days after planting (DAP) and at harvest by counting the number of 30.5-cm row lengths per plot showing signs or symptoms, and then dividing that number by the total

number of 30.5-cm row lengths per plot. In the second experiment, disease was assessed at 57, 77, 97 DAP and at harvest. Disease severity of each inoculated plant was obtained by using the Shokes 0-5 severity scale (Shokes *et al.* 1998). After determining disease severity from the Shokes 0-5 scale, the midpoint of each disease severity range of the scale was used for all analyses. A total diseased plant count was also obtained by counting all plants per plot showing signs or symptoms. Disease incidence was expressed as the total diseased plant count divided by the total plant count/plot. Disease spread along rows was assessed by measuring the length (cm) of each disease focus. Cumulative spread was then obtained by summing the lengths of all 8 foci per plot. The incidence of disease spread across rows was also determined based on the percentage of the 8 inoculated foci per plot that spread to the adjacent twin row. All plots in both tests were mechanically dug and inverted (KMC digger/inverter) at 149, 137 and 160 DAP in 2000, 2001 and 2002, respectively. Windrows were then mechanically harvested (Lilliston 1580 combine) in 2000, 2001 and 2002 at 154, 149 and 179 DAP, respectively. Pods were dried to about 10% moisture and graded according to standard USDA procedures. For both experiments, crop value was calculated based on grade and current market price for peanut.

Analysis of variance, using SAS PROC GLM (SAS Institute, Cary, NC) was performed on the data from each experiment across all years to determine the significance of row pattern, seed spacing, inoculation date and year on stem rot severity, incidence and spread. Least square treatment means were

calculated and separated by the Tukey's Multiple Comparison Test (SAS Institute, Cary, NC)(Ott 1993). Simple linear regression (Draper and Smith 1981) was also used to determine any relationship between plant count and stem rot incidence. PROC CORR was used to determine any correlation between yield, stem rot and spotted wilt. The level of significance for all comparisons was $P \leq 0.05$.

Results

Although all three years were somewhat dry, rainfall plus irrigation during the growing season were over 50 cm each year. Some insecticide/herbicide injury did occur, particularly in the first field experiment, which delayed maturity and lowered grades.

First field experiment. Due to significant interactions with year, data for stem rot incidence at 57 DAP are presented separately by year (Figures 3.1 and 3.2). In 2000, stem rot incidence was greater for the non-treated, high seeding rate plots than the non-treated medium or low seeding rate plots. There was no significant difference in stem rot incidence among seeding rates when treated with a azoxystrobin. Non-treated plots had significantly greater stem rot than treated plots except at the low seeding rate (Fig. 3.1a). In 2001 and 2002, stem rot incidence was much lower. There were no significant differences among the three seeding rates or between Abound-treated and untreated plots in either year (Fig. 3.1b,c).

There was a significant year x row pattern x fungicide interaction effect on the incidence of stem rot assessed at 57 DAP (Fig. 3.2 a-c). In 2000, there was a significant difference between single and twin non-treated plots (Fig. 3.2a). However, there was no difference between single and twin plots treated with fungicide. The Abound treatment reduced stem rot incidence with both single and twin rows. In 2001 and 2002, there were no significant differences between row patterns or fungicide treatments (Fig. 3.2b,c).

At harvest, there was a significant row pattern x seeding rate interaction (Fig. 3.3), a year x row pattern interaction (Fig. 3.4), and a year x seeding rate interaction (Fig. 3.5) on stem rot incidence. Stem rot was significantly greater at the single, high seeding rate compared to the single, medium or low seeding rates (Fig. 3.3). Disease incidence was also significantly greater in the single row pattern compared to the twin row pattern regardless of seeding rate. There was no significant difference between seeding rates planted in a twin row pattern. For all three years, there was significantly greater disease in the single row pattern compared to the twin row pattern (Fig.3.4 a-c). In 2000 and 2001, seeding rate did not have a significant effect on stem rot incidence (Fig. 3.5a - b). However, in 2002, the high seeding rate had a higher incidence than the low seeding rate (Fig. 3.5c). Neither 2000, 2001, or 2002 data produced a good linear fit between plant count and stem rot incidence. R^2 values for 2000, 2001, and 2002 were 0.0008, 0.0685, and 0.053, respectively.

There were significant row pattern, seeding rate, and fungicide treatment main effects. Yield was significantly greater in twin rows (3113 kg/ha) than single rows (2540 kg/ha). Yield was also significantly greater in plots planted at the high seeding rate than in those planted at the low, but not the medium, seeding rate (Fig. 3.6). Yield was significantly greater in plots treated with Abound (3054 kg/ha) than non-treated plots (2599 kg/ha).

Evaluation of peanut grade data showed there was a significant year x row pattern x seeding rate interaction effect on % foreign material, but differences were small and no plot had more than 0.7%. The mean percentage of immature kernels was significantly higher in single rows (10.6%) than in twin rows (9.8%). There were more immature kernels in 2001 than 2002, and in 2001, the low seeding rate had more immature kernels than the medium rate only (Fig. 3.7). There were no significant differences among seeding rates in 2002. The percentage of sound mature kernels and sound splits (SMKSS) across all years was significantly greater in the medium seeding rate than the low seeding rate (Fig. 3.8). The mean percentage of damaged kernels was 1.2% and 2.9% in 2001 and 2002, respectively, and was not significantly affected by row pattern or seeding rate.

Second field experiment. There was significant seeding rate effects on stem rot severity at harvest (Fig 3.9). The high seeding rate had the greatest severity of about 42% while the lowest seeding rate had a severity of 31%.

There was a year x row pattern interaction effect on stem rot severity of inoculated plants at harvest (Table 3.1). In 2002, disease severity was greater in the single row pattern rather than the twin row pattern (Fig. 3.10).

There was a significant ($P < 0.05$) row pattern x seeding rate interaction effect on the total number of diseased plants at harvest (Fig. 3.11). Stem rot incidence was significantly greater in single rows compared to twin rows at all seeding rates. There was no significant difference among twin rows planted at different seeding rates, but more diseased plants were observed in single rows planted at high seeding rates than in those planted at a low seeding rate (Fig. 3.11). There were also significant effects of inoculation date and year x row pattern interaction effects on plant disease count per plot (Table 3.2). The number of diseased plants was significantly greater in plots inoculated at 50 DAP than 90 DAP (Fig. 3.12). In 2001 and 2002, the number of diseased plants was significantly higher in single rows than in twin rows (Fig. 3.13).

There was a year x row pattern interaction and a seeding rate x row pattern interaction effect on disease spread (Table 3.3). In two of three years, spread was significantly greater in single rows than twin rows (Fig. 3.14). Spread was also significantly greater in single rows planted at a high seeding rate than in those planted at a low seeding rate (Fig. 3.15). There was no significant difference in disease spread among twin rows planted at any of the seeding rates.

There was an inoculation date x row pattern interaction as well as a year x seeding rate x row pattern interaction effect on percentage of foci per plot that spread across rows (Table 3.4). Spread in twin rows was greater in plots inoculated at 50 DAP than in those inoculated at 90 DAP (Fig. 3.16). There was no spread across single rows for any year. Spread within twin rows was greatest at a high seeding rate compared to the medium or low seeding rate in 2000 (Fig. 3.17a). In 2001, no spread between twin rows was observed (Fig. 3.17b). In 2002, spread occurred between twin rows, but it was not significantly different among the three seeding rates (Fig. 3.17c).

The only factor with a significant effect on yield was row pattern in both 2001 and 2002. The mean pod yield in twin rows was 5469 kg/ha versus 5159 kg/ha in single rows. These findings are consistent with previous studies (Baldwin *et al.* 1997). There was a significant year x row pattern interaction for % foreign material, but all values were very low ($< 0.6\%$) and therefore of no economic significance. Only seeding rate had a significant effect on the percentage of immature kernels, and the percentage of immatures was significantly greater in the low seeding than the in high seeding rate plots (Fig. 3.18). There was a significant year x row pattern interaction and a significant seeding rate effect on the percent sound mature kernels and sound splits (SMKSS) (Table 3.5). SMKSS was significantly greater in twin rows than in single rows in 2002, but there was no difference in SMKSS between row patterns in 2001 (Fig. 3.19). The high seeding rate had significantly greater

SMKSS than the low seeding rate (Fig. 3.20). In field 1, there was a significant negative correlation between yield and stem rot incidence (-0.43), as well as a significant negative correlation between yield and 2001 TSWV incidence.

However, in field 2, there was no significant correlation between yield, stem rot or TSWV (Table 3.6). In field 1, crop value was significantly greater in twin rows (\$921/ha) than in single rows (\$758/ha). High seeding rates gave the greater crop value of \$895/ha compared to the low seeding rates (\$754/ha), and plots treated with azoxystrobin had a crop value of \$915/ha compared to \$766/ha for non-treated plots (Table 3.7). For field 2, there was an interaction between year and row pattern. There was no difference in crop value between single and twin rows in 2001; however, in 2002, twin rows had a higher crop value (\$1423/ha) than single rows (\$1219/ha). There was no difference in crop value among seeding rates (Table 3.7).

Microclimate. Canopy closure for most twin row plots occurred at approximately 35 DAP, 42 DAP and 50 DAP, in 2000, 2001, and 2002, respectively. Single row closure occurred later in the season or did not occur at all. Based on mean values for all three years in the first experiment, there were no significant differences between seeding rates or row spacings for temperature or relative humidity (Figs. 3.21 and 3.22). Regression analysis of weather data across each growing season revealed some differences, but differences were not consistent and some data was compromised by logger failures. Based on mean values, calculated by treatment for the second field experiment, there were

no significant differences between treatments for temperature (Fig. 3.23), but there were differences between the high seeding rate (twin row only) and low seeding rate (both row patterns) for relative humidity (Fig. 3.24). Additional data are presented in Appendix B.

Discussion

When disease pressure was more severe, higher seeding rates and single rows were both associated with greater incidence of stem rot in non-treated plots early in the growing season (57 DAP). This effect was not seen in years of lower disease incidence, or in plots treated with azoxystrobin. Late in the season, stem rot was greater in single rows compared to twin rows, particularly with high seeding rates. This was observed in naturally infested plots as well as artificially inoculated plots, and was evident in both disease severity and degree of spread to other plants. In a year of high disease pressure, disease spread across rows occurred in twin row plots planted at high seeding rates and/or early inoculation dates; however, the overall incidence of disease was still lower in twin rows than single rows. In the controlled inoculation study, it was evident that disease incidence at harvest was greater in plots inoculated at 50 DAP than 70 or 90 DAP. Although inoculations later in the season can develop more rapidly (see chapter 2), plots inoculated earlier had a longer period of time to develop greater disease, and illustrates the greater danger from very early season stem rot infections.

Based on these results, stem rot can be reduced by planting lower seeding rates in twin rows and applying fungicide. This was verified by the significantly higher yields (and higher crop value) in twin versus single rows and also by the disease and yield results in the controlled inoculation study. Despite the higher stem rot incidence at the high seeding rate, yield was still greater at the high than the low seeding rate in the first experiment, perhaps due to the confounding effects of TSWV infections. As mentioned earlier, concern about losses to TSWV have been largely responsible for the shift to twin rows and higher seeding rates. The availability of new cultivars with much better resistance to TSWV should enable growers to lower seeding rates, thus reducing input costs and the severity of stem rot. Further cost savings may be possible by reducing fungicide inputs in fields with lower levels of soilborne disease when combining lower seeding rates with twin row plantings.

Analysis of environmental data showed that temperature and relative humidity within the peanut canopy were consistently different than ambient conditions. However, based on the mean values for each treatment, modifying row pattern or seeding rate did not have a significant effect on either canopy temperature or relative humidity within the canopy in the first trial, and there was a difference only in mean relative humidity between the low and high seeding rates in the second trial. Examination of the predicted curves for the canopy conditions and corresponding analyses did not reveal large differences between treatments, at least not of a magnitude to biologically explain the obvious

significant disease differences between treatments. Unfortunately data gaps with some sensors made it more difficult to distinguish differences due to planting pattern. In general, most of the mean canopy temperatures were within the large temperature range for fungal growth (8-40°C and maximum growth at 27-30°C)(Aycock 1966, Punja 1985). Perhaps space between plants was the critical factor in *S. rolfsii* growth and subsequent stem rot development. High seeding rates, and single row plantings both create greater plant-to-plant contact making it easier for the fungus to grow from one plant to the next.

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Table 3.1. Effect of row pattern, seeding rate and inoculation date in 2000, 2001 and 2002 on severity of peanut stem rot foci at harvest in 'Georgia Green' peanuts planted in field 2

Source	df	MS	<i>P</i> > <i>F</i>
Year	2	18897.39	<0.0001
Rep (Year)	9	203.59	0.2049
Row Pattern	1	3546.21	<0.0001
Seeding Rate	2	1293.02	0.0003
RP x SR	2	56.44	0.6885
Inoculation Date	2	3241.69	<0.0001
RP x ID	2	96.78	0.5221
SR x ID	4	54.54	0.8312
RP x ID x SR	4	153.73	0.3902
Year x RP	2	3123.95	<0.0001
Year x SR	4	305.70	0.0886
Year x ID	4	522.32	0.0088
Year x RP x SR	4	244.12	0.1655
Year x SR x ID	8	167.65	0.3458
Year x RP x ID	4	30.76	0.9340
Year x RP x SR x ID	8	32.70	0.9868
Error	152	148.27	-

Table 3.2. Effect of row pattern, seeding rate and inoculation date in 2000, 2001 and 2002 on total number of plants per plot with peanut stem rot at harvest in 'Georgia Green' peanuts planted in field 2

Source	df	MS	<i>P</i> > <i>F</i>
Year	1	1066.59	<0.0001
Rep (Year)	6	32.82	0.5151
Row Pattern	1	3451.07	<0.0001
Seeding Rate	2	517.34	<0.0001
RP x SR	2	134.23	0.0313
Inoculation Date	2	309.55	0.0005
RP x ID	2	65.06	0.1812
SR x ID	4	41.77	0.3535
RP x ID x SR	4	75.75	0.0969
Year x RP	1	597.68	0.0001
Year x SR	2	89.73	0.0962
Year x ID	2	75.55	0.1383
Year x RP x SR	2	18.30	0.6149
Year x SR x ID	4	39.76	0.3795
Year x RP x ID	2	0.23	0.9940
Year x RP x SR x ID	4	35.01	0.4469
Error	101	37.45	-

Table 3.3. Effect of row pattern, seeding rate and inoculation date in 2000, 2001 and 2002 on average focus length (cm) of peanut stem rot foci at harvest in 'Georgia Green' peanuts planted in field 2

Source	df	MS	<i>P</i> > <i>F</i>
Year	2	24493.11	<0.0001
Rep (Year)	9	143.09	0.9501
Row Pattern	1	33033.89	<0.0001
Seeding Rate	2	4155.39	<0.0001
RP x SR	2	1769.93	0.0125
Inoculation Date	2	10933.98	<0.0001
RP x ID	2	2318.20	0.0034
SR x ID	4	176.01	0.7732
RP x ID x SR	4	694.25	0.1378
Year x RP	2	5776.48	<0.0001
Year x SR	4	826.70	0.0826
Year x ID	4	1259.18	0.0146
Year x RP x SR	4	175.91	0.7734
Year x SR x ID	8	570.66	0.1784
Year x RP x ID	4	147.14	0.8261
Year x RP x SR x ID	8	301.39	0.6312
Error	152	392.28	-

Table 3.4. Effect of row pattern, seeding rate and inoculation date in 2000, 2001 and 2002 on percentage of inoculated peanut stem rot foci that spread to adjacent row at harvest in 'Georgia Green peanuts planted in field 2

Source	df	MS	<i>P</i> > <i>F</i>
Year	2	5440.87	<0.0001
Rep (Year)	9	144.43	0.0335
Row Pattern	1	6956.44	<0.0001
Seeding Rate	2	316.38	0.0117
RP x SR	2	367.08	0.0059
Inoculation Date	2	257.75	0.0262
RP x ID	2	321.59	0.0109
SR x ID	4	42.44	0.6528
RP x ID x SR	4	32.71	0.7551
Year x RP	2	5201.23	<0.0001
Year x SR	4	445.56	<0.0001
Year x ID	4	100.58	0.2183
Year x RP x SR	4	510.85	<0.0001
Year x SR x ID	8	52.49	0.6385
Year x RP x ID	4	133.01	0.1089
Year x RP x SR x ID	8	39.02	0.8053
Error	152	69.07	-

Table 3.5. Effect of row pattern, seeding rate and inoculation date in 2001 and 2002 on % SMKSS¹ in 'Georgia Green' peanuts in field 2

Source	df	MS	<i>P</i> > <i>F</i>
Year	1	910.53	<0.0001
Rep (Year)	6	10.56	0.0120
Row Pattern	1	22.17	0.0154
Seeding Rate	2	8.19	0.1110
RP x SR	2	0.01	0.9975
Inoculation Date	2	2.32	0.5314
RP x ID	2	0.00	0.9999
SR x ID	4	0.60	0.9560
RP x ID x SR	4	3.21	0.4784
Year x RP	1	14.38	0.0498
Year x SR	2	2.24	0.5437
Year x ID	2	8.95	0.0910
Year x RP x SR	2	2.36	0.5261
Year x SR x ID	4	0.43	0.9754
Year x RP x ID	2	2.64	0.4878
Year x RP x SR x ID	4	6.30	0.1499
Error	102	3.65	-

¹ percentage of sound mature kernels and sound splits

Table 3.6. Correlation coefficients for yield, stem rot and TSWV in 'Georgia Green' peanuts in field 1 and 2

	Field Experiment 1-Yield		Field Experiment 2-Yield	
	Correlation Coefficient ¹	p ²	Correlation Coefficient	p
Stem rot incidence	-0.43	<0.0001	-0.13	0.1326
TSWV 2001	-0.41	0.0438	-0.26	0.2263
TSWV 2002	-0.41	0.0532	-0.22	0.3071

¹ Correlation coefficients obtained from Pearson Correlation Test

² Probabilities for rejecting null hypothesis of having no correlation.
Significance level for all comparisons was $p \leq 0.05$

Table 3.7. Crop value for row pattern, seeding rate and fungicide treatments in 2001 and 2002 in 'Georgia Green' peanuts in fields 1 and 2. Values represent dollars per hectare

Field Experiment 1		Field Experiment 2	
Row Pattern			
		Year 2001	Year 2002
Single	758 a ¹	1869 a	1219 a
Twin	921 b	1859 a	1423 b
Seeding Rate			
Low	754 a	1524 a	
Medium	871 ab	1639 a	
High	895 b	1615 a	
Fungicide Treatment			
Non-treated	766 a	not evaluated	
Azoxystrobin	915 b	not evaluated	

¹ Mean comparisons by Tukey's Multiple Comparison test. Level of significance for all comparisons was $p \leq 0.05$

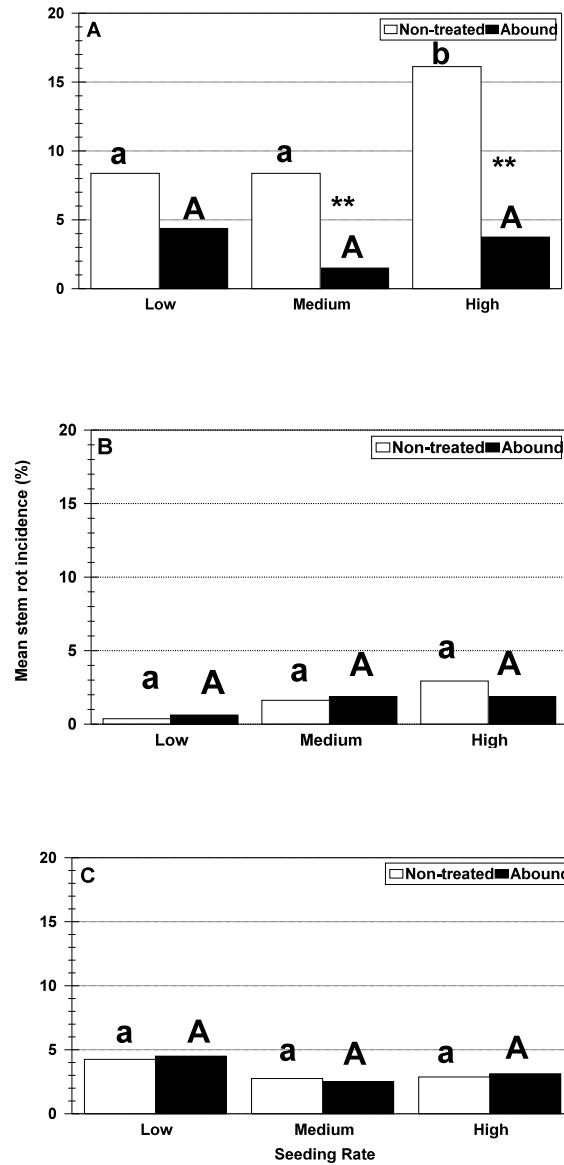


Figure 3.1. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) and fungicide treatment (Abound 2.08 F 1.35 L/ha at 60 and 90 DAP) on peanut stem rot incidence at 57 DAP in 2000 (A), 2001 (B) and 2002 (C) in field 1. Values for non-treated plots represented by the same lowercase letters are not significantly different, and values for Abound-treated plots represented by the same upper case letters are not significantly different. **indicates a significant difference between fungicide treatments for that particular seeding rate. $P \leq 0.05$ for all comparisons.

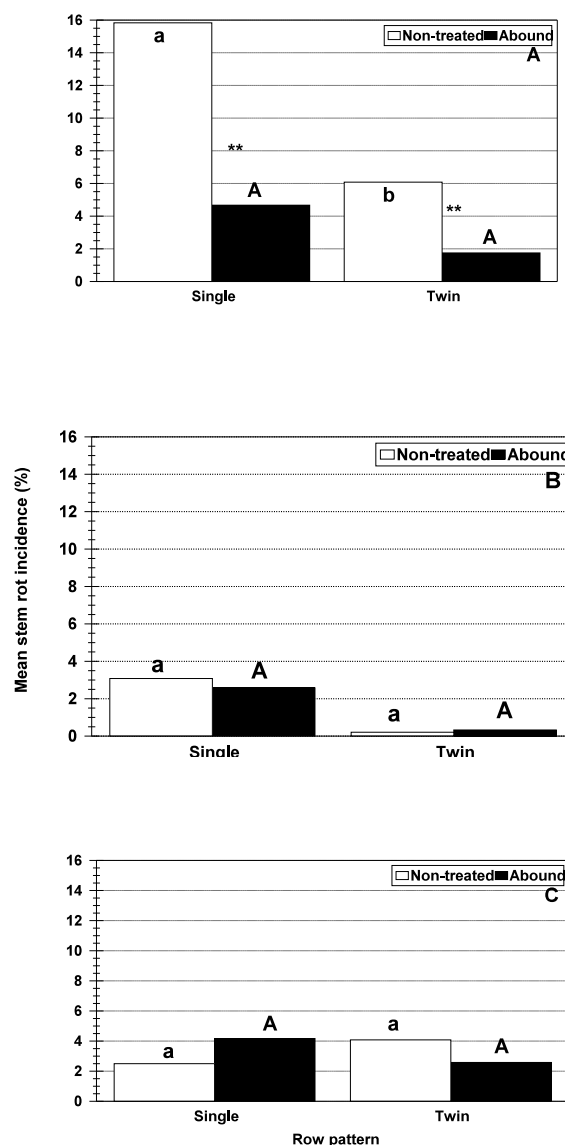


Figure 3.2. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) and fungicide treatment (Abound 2.08 F 1.35 L/ha at 60 and 90 DAP) on peanut stem rot incidence at 57 DAP in 2000 (A), 2001(B) and 2002 (C) in field 1. **Indicates significant difference between single and twins for non-treated plots only. Values for non-treated plots represented by the same lowercase letters are not significantly different, and values for Abound-treated plots represented by the same upper case letters are not significantly different. **indicates a significant difference between fungicide treatments for that particular row pattern. $P \leq 0.05$ for all comparisons.

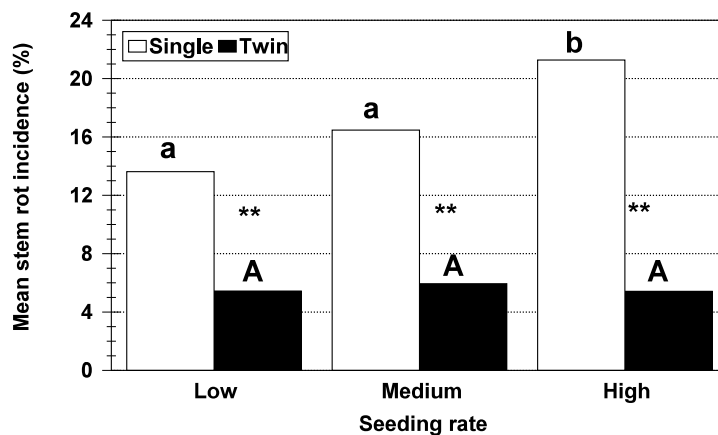


Figure 3.3. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) and row pattern (91.4-cm single rows or 20.3-cm twin rows) on peanut stem rot incidence in 2000-2002 at harvest in field 1. Values for single rows represented by the same lowercase letters are not significantly different, and values for twin rows represented by the same upper case letters are not significantly different. **indicates a significant difference between row pattern for that particular seeding rate. $P \leq 0.05$ for all comparisons.

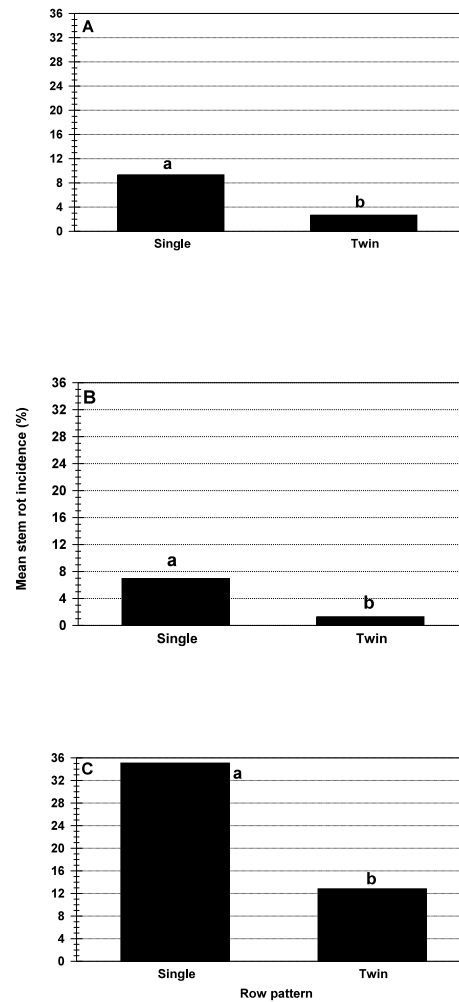


Figure 3.4. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) on peanut stem rot incidence at harvest in 2000 (A), 2001 (B) and 2002 (C) in field 1. Values followed by different letters are significantly different at the 5% level of significance.

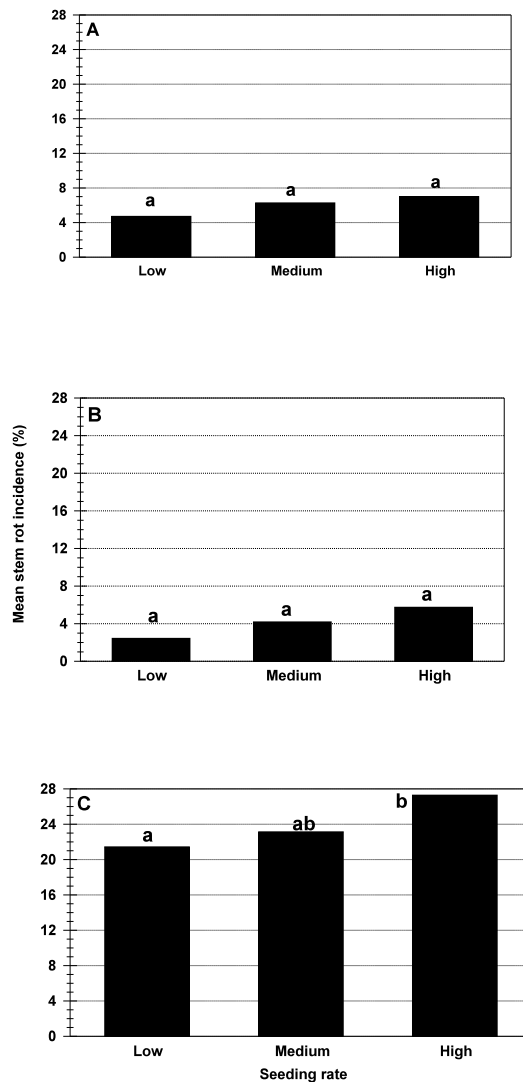


Figure 3.5. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on peanut stem incidence at harvest in field 1 in 2000 (A), 2001 (B) and 2002 (C). Values represented by the same letter are not significantly different at the 5% level of significance.

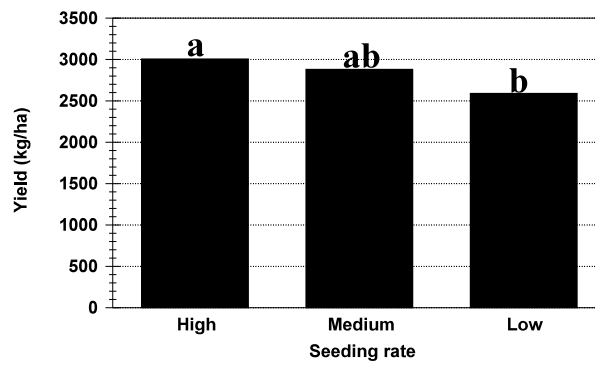


Figure 3.6. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on mean yield in field 1 in 2000, 2001 and 2002. Values represented by the same letter are not significantly different at the 5% level of significance.

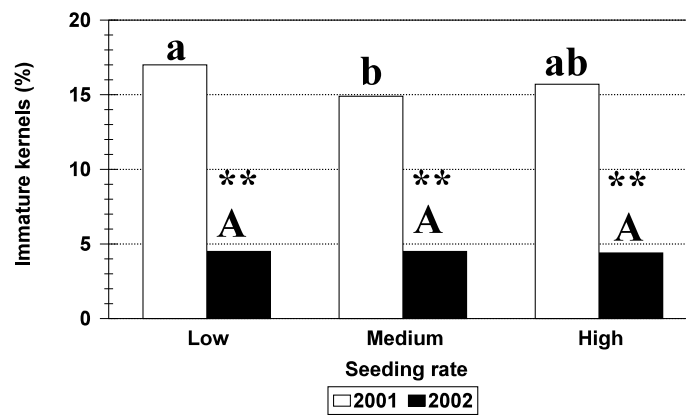


Figure 3.7. Influence of year and seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on the percent of immature kernels in field 1. Values for 2001 only represented by the same lowercase-letter are not significantly different at the 5% level of significance. Values for 2002 only represented by the same uppercase-letter are not significantly different at the 5% level of significance.

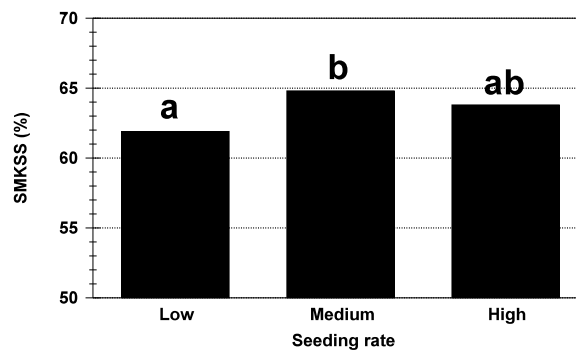


Figure 3.8. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on the percent % of sound mature kernels and sound splits in peanut grade samples (SMKSS) in field 1 in 2001 and 2002. Values followed by the same letter are not significantly different at the 5% level of significance.

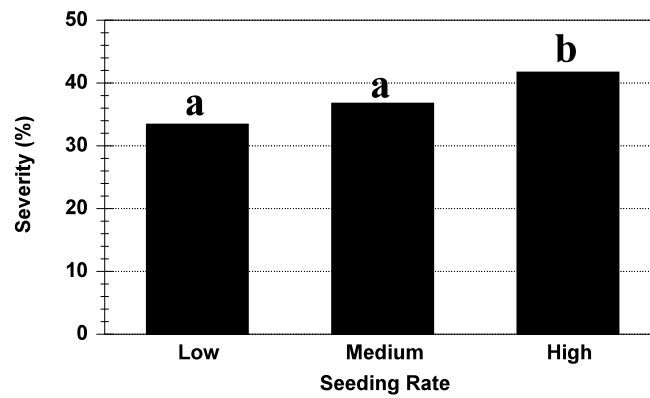


Figure 3.9. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on peanut stem rot severity of inoculated foci at harvest in Field 2 for 2000, 2001 and 2002. Values followed by the same letter are not significant at the 5% level of significance.

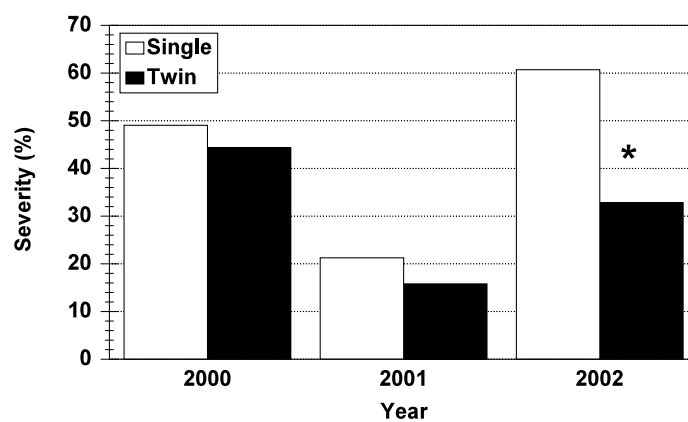


Figure 3.10. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) on peanut stem rot severity of inoculated plants at harvest in Field 2 for 2000, 2001 and 2002. *indicates significant difference between row pattern at 5%.

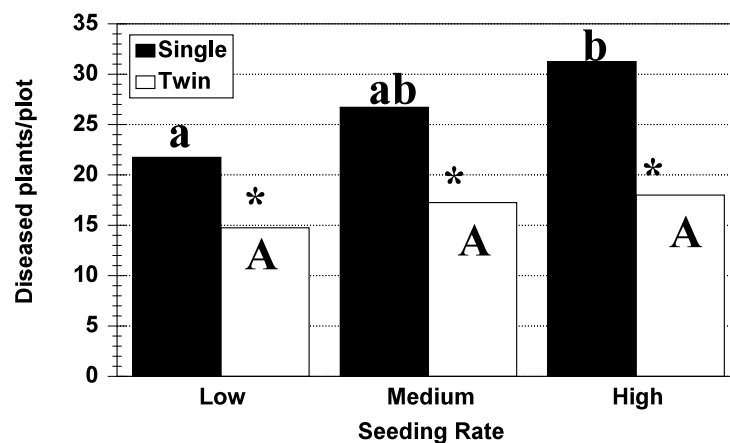


Figure 3.11. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) and seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on the number of plants per plot with peanut stem rot at harvest in Field 2 for 2000, 2001 and 2002. Values for single rows represented by the same lower case letters are not significantly different, and values for twin rows represented by the same upper case letters are not significantly different. *Indicates a significant difference between single and twin row patterns for the given seeding rate. ($P \leq 0.05$ for all comparisons).

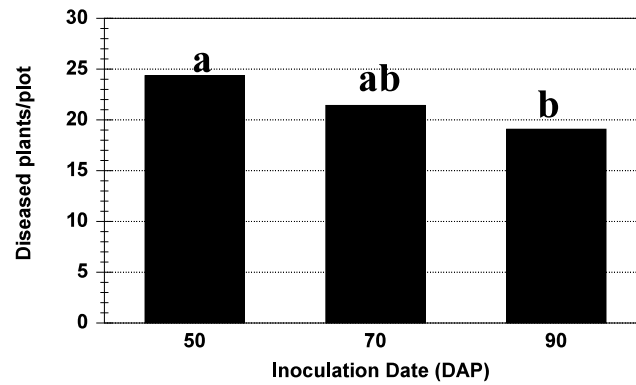


Figure 3.12. Influence of inoculation date on the number of plants per plot with peanut stem rot at harvest in Field 2 for 2000, 2001 and 2002. Values followed by the same letter are not significant at the 5% level of significance.

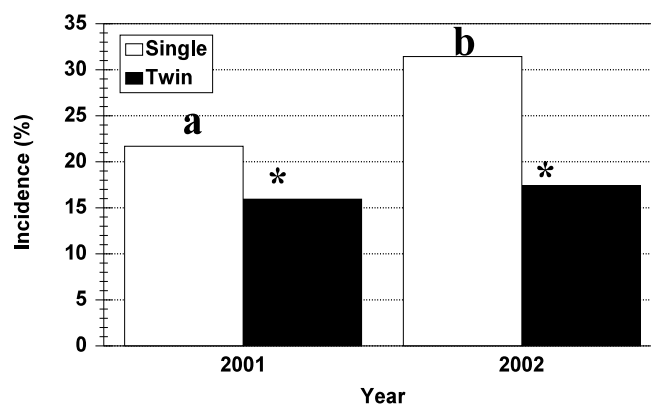


Figure 3.13. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) in 2001 and 2002 on the number of plants per plot with peanut stem rot at harvest in Field 2. Values for single rows represented by lower case letters are not significantly different, and values for twin rows represented by upper case letters are not significantly different. *indicates a significant difference between single and twin rows for the given year. ($P \leq 0.05$ for all comparisons)

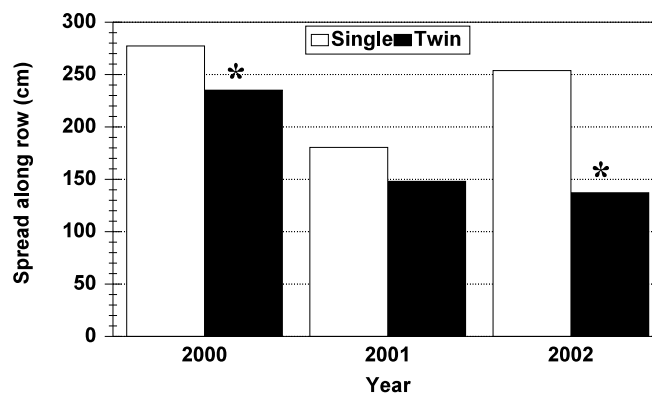


Figure 3.14. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) on peanut stem rot spread along rows (cm) at harvest in Field 2. *Indicates a significant difference between row patterns within year at the 5% level of significance.

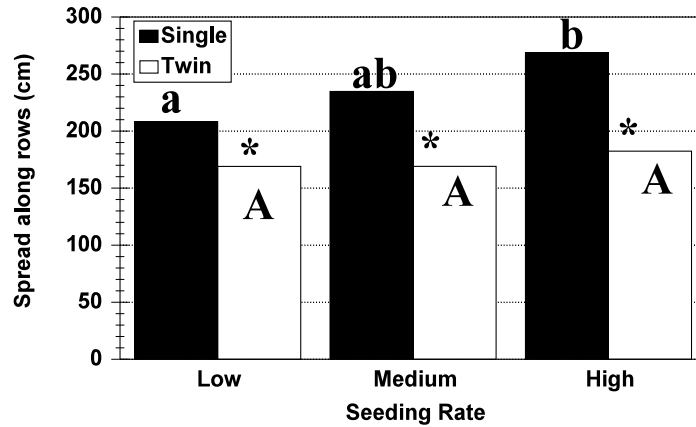


Figure 3.15. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) and seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on peanut stem rot spread along rows (cm) at harvest in Field 2 in 2000, 2001 and 2002. Spread values represented by the same letter above single row value bars are not significantly different at the 5% level of significance. Spread values represented by the same letter above twin row value bars are not significantly different at the 5% level of significance. *Indicates a significant difference between single and twin row patterns for the given seeding rate.

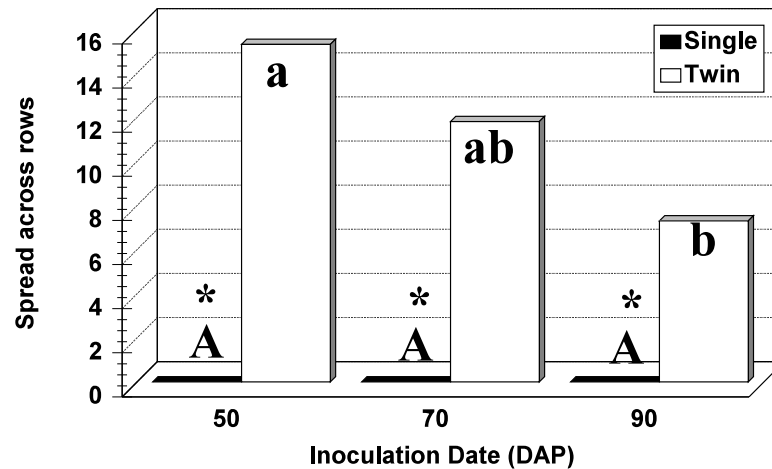


Figure 3.16. Influence of inoculation date and row pattern (91.4-cm single rows or 20.3-cm twin rows) on peanut stem rot spread across rows at harvest in Field 2. Spread values followed by the same letter above single row value bars are not significantly different at the 5% level of significance. Spread values followed by the same letter above twin row value bars are not significantly different at the 5% level of significance. Spread was calculated by determining the percentage of inoculated foci that spread to adjacent row. *Indicates a significant difference between single and twin row patterns for the given inoculation date.

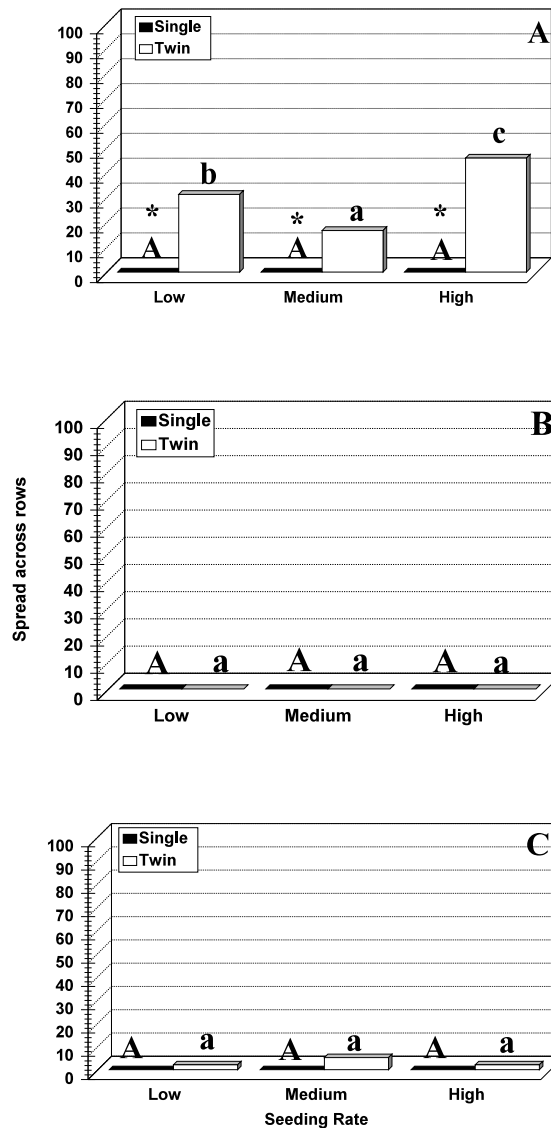


Figure 3.17. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) and seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on stem rot spread across rows for harvest rating in Field 2 in 2000 (A), 2001 (B), and 2002 (C). Spread values followed by the same letter above single row value bars are not significantly different at the 5% level of significance. Spread values followed by the same letter above twin row value bars are not significantly different at the 5% level of significance. *Indicates a significant difference between single and twin row patterns for the given seeding rate.

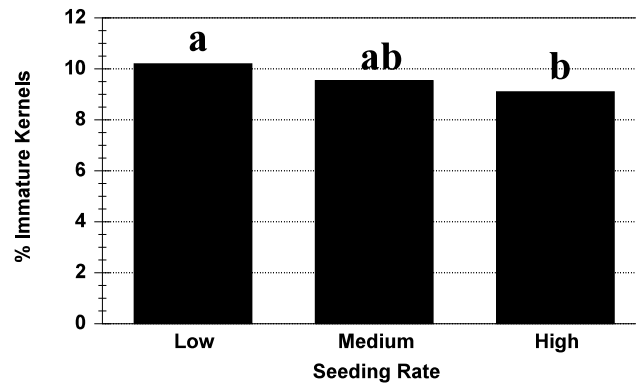


Figure 3.18. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on % immature kernels in 2001 and 2002 for field trial 2. Values followed by the same letter are not significantly different at the 5% level of significance.

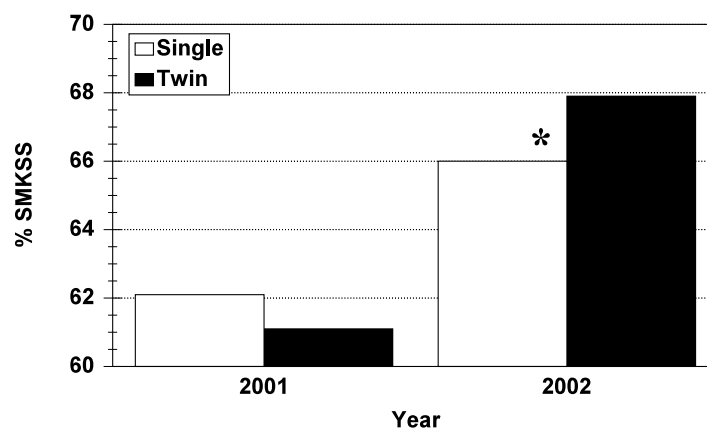


Figure 3.19. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) in 2001 and 2002 on % sound mature kernels and sound splits (SMKSS). *Indicates a significant difference between row pattern for the given year at the 5% level of significance.

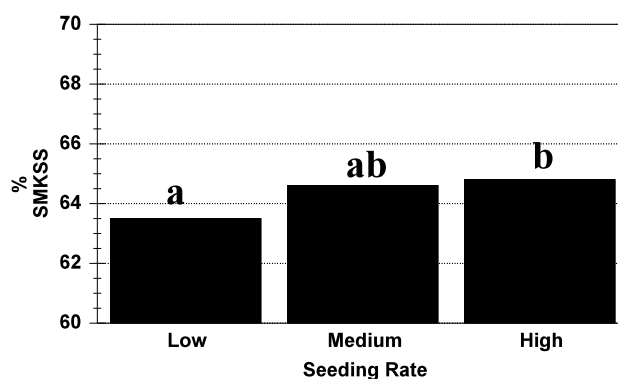


Figure 3.20. Influence of seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on % sound mature kernels and sound splits (SMKSS) across both years, 2001 and 2002. Values followed by the same letter are not significantly different at the 5% level of significance.

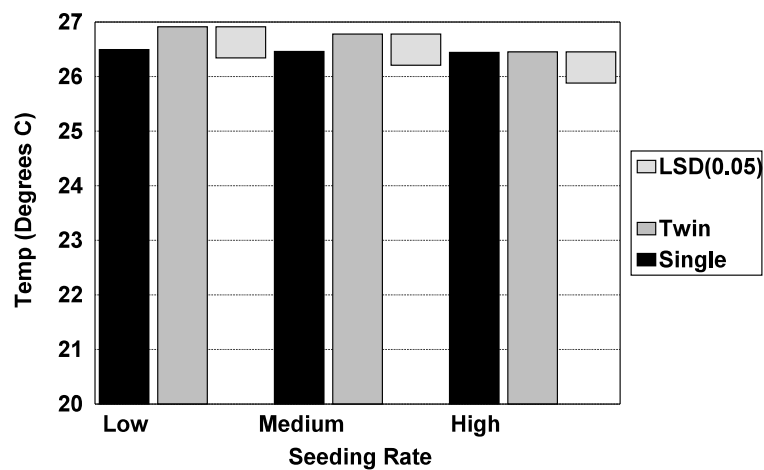


Figure 3.21. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) and seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on mean temperature (C) within the peanut canopy in field 1 for 2000-2002 .

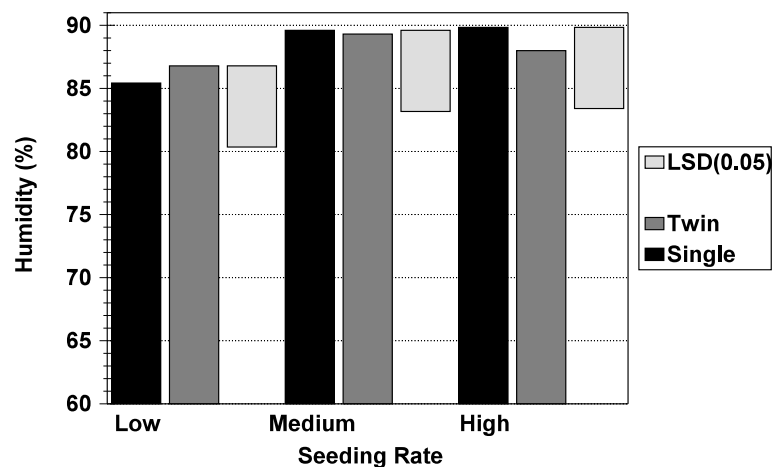


Figure 3.22. Influence of row pattern (91.4-cm single rows or 20.3-cm twin rows) and seeding rate (Low: 12.5 seed/m for single rows, 6.2 seed/m for twin rows; Medium: 17.4 seed/m for single rows, 8.9 seed/m for twin rows; High: 22.6 seed/m for single rows, 11.5 seed/m for twin rows) on mean humidity within the peanut canopy in field 1 for 2000-2002.

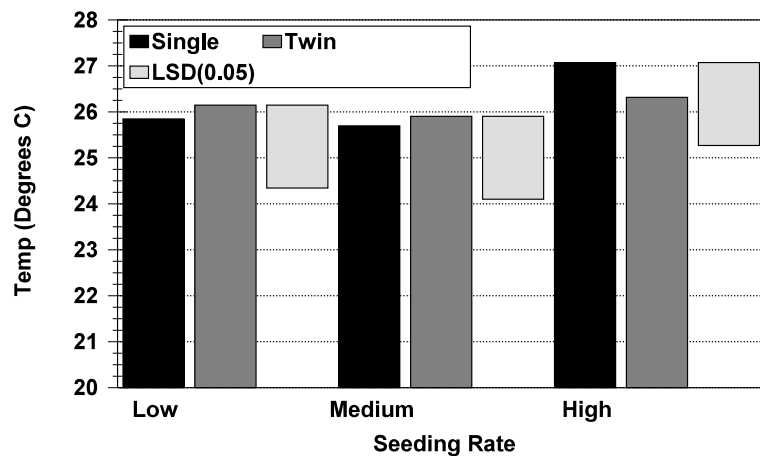


Figure 3.23. Comparison of mean temperatures (C) within the plant canopy for twin versus single rows, each at 3 seed spacings, for 2000, 2001, and 2002 in field 2.

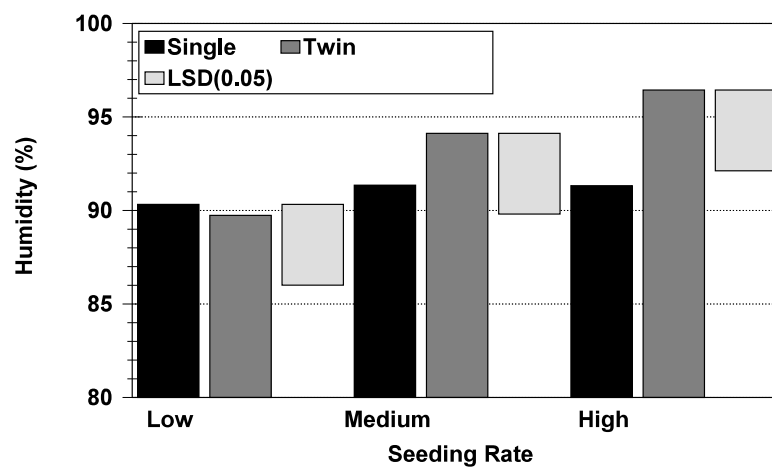


Figure 3.24. Comparison of mean humidity (%) within the plant canopy for twin versus single rows, each at 3 seed spacings, in 2000, 2001, and 2002 in field 2.

CHAPTER 4
EFFECTS OF ROW PATTERN AND SEEDING RATE ON THE INCIDENCE OF
TOMATO SPOTTED WILT IN PEANUTS¹

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Abstract

The influence of plant population and row pattern on the incidence of both spotted wilt symptoms and tomato spotted wilt virus in peanut (*Arachis hypogaea* L.) tissues was assessed and compared in two field experiments in 2001 and 2002. The relationship between plant population and spotted wilt symptoms was also assessed in two microplot studies for three years. In the microplot studies, there was a significant reduction in spotted wilt symptoms with an increase in plant density. In both field experiments, incidences of symptoms and actual viral infection were assessed at 30 and 90 days after planting (DAP) and harvest. At harvest, there were significant differences between row patterns and seeding rates for symptom incidence, based on counts of 30.5-cm sections of row showing symptoms. Single rows consistently had more symptoms than twin rows, and single row plots planted at a low seeding rate (12.5 seed/m) had greater symptom incidence (8%) than plots with higher plant populations. However, the incidence of virus infection (assessed by DAS-ELISA) was uniformly high (50-100%) in all treatments, and there was no significant effect of row pattern or seeding rate on incidence of virus infection. Results from correlation analysis showed very poor correlation between symptom and viral incidence, which indicate that assessment of symptomatic plants is a poor predictor of actual virus infection. Apparently plant spacing can influence the

expression of virus symptoms, even when incidence of virus infection is not affected.

Key Words: ELISA, symptom expression, epidemiology

Introduction

Since the mid-late 1980s, tomato spotted wilt virus (TSWV) has been a significant economic problem for peanut producers in Georgia. TSWV has cost producers an average of \$12.6 million in losses for the last 4 years (Williams-Woodward 1998-2001). In the early 1990s, in their search for cultural practices to reduce TSWV, researchers found that in-row plant spacings of 7.6 cm, 15.2 cm, 30.5 cm, 45.7 cm, and 61.0 cm resulted in 9%, 22%, 55%, 67%, and 70% infection rates for the cultivar 'Sunrunner' and 5%, 10%, 22%, 36%, and 45% infection rates for 'Southern Runner' (Gorbet and Shokes 1994). Further, seeding rates of 34 kg/ha, 56 kg/ha, 78 kg/ha, 101 kg/ha, and 123 kg/ha were found to have 6.0, 3.5, 2.9, 2.4, and 2.6 symptomatic plants per plot, respectively (Wehtje *et al.* 1994). Later, it was also found that planting twin rows (17.8 - 25.4-cm apart) and high seeding rates (rates >13.1 seed m^{-1}) could significantly reduce TSWV and also increase grade and yield (Culbreath *et al.* 1999). The mechanism for these findings is not known, but may be due to plant population differences or change in behavior of the thrips vector, created by the different row patterns and plant populations (Brown *et al.* 1996). These findings, along with the TSWV Risk Index Assessment (Culbreath *et al.* 2003), have been significant contributions in the reduction of losses due to this disease.

There has been a great deal of research conducted on the effects of row spacing and seeding rate on many different diseases and crops and the results have varied widely. However, there have been few studies concerning the

effects of plant spacing on virus diseases. In one study of sugar beets, researchers found that reducing row spacing reduced the incidence of beet yellows (Blencowe and Tinsley 1951), with wider rows having greater incidence of beet yellows (20 - 83%) than narrow rows (12 - 63%). One possible mechanism for reduction in disease could be attributed to the reduction in the size of plants due to competition, and as a result, a smaller surface for aphids (*Aphis fabae*) to feed and infect (Blencowe and Tinsley 1951). Reduction of plant spacing has also been shown to reduce the incidence of groundnut rosette virus in peanut (Harper 1927). One possible mechanism suggests that wide-spaced plants are more spreading than close-spaced plants, and apical buds and leaves in close-spaced plants are hidden from the vector (*Aphis craccivora*) under a canopy of mature leaves (Hull 1964). A reduction in rice tungro disease due to closer plant spacings have also found, and this reduction may be due to the same mechanisms from previous studies (Shukla and Anjaneyulu 1981).

Tomato spotted wilt assessment in the field is based on visual symptoms of the host, rather than detecting virus infection by using a serological assay such as Enzyme Linked Immunosorbant Assay (ELISA). ELISA is often not used except for confirmation because of cost of assay materials since a large number of samples is required (Bwye *et al.* 1999). Also, visual assessment of symptomatic plants has been very accurate, based on large numbers of symptomatic plants assayed by ELISA (Culbreath *et al.* 1992). However, assessments based on visible symptoms may not be adequate for determining

number of plants actually infected with the virus. Assessments of disease incidence based on visible symptoms may underestimate the actual incidence of infected symptoms, since a plant can be infected and not show symptoms. Since the previous studies of effects of cultural practices on tomato spotted wilt (TSW) of peanut were based solely on visual symptoms, the objectives of this study were to 1) verify the effects of seeding rates and row patterns on incidence of spotted wilt symptoms, TSWV infection, and yield and 2) determine the correlation between incidence of symptoms and incidence and incidence of virus infection in peanut.

Materials and Methods

Microplot experiment. In 2000, 2001, and 2002, certified 'Georgia Green' peanut seed treated with 2.49 g/kg of seed of a captan (45%), pentachloronitrobenzene (15%), and carboxin (10%) mixture (Vitavax PC, Gustafson LLC, Plano, TX) were germinated in nursery flats with moist vermiculite covering the seed. Germinated seeds were planted in 0.9-m diameter Fuquay sand field microplots which had been treated previously with metam sodium (Vapam 32%, 1429 L/ha, AMVAC Chemical Corp., Newport Beach, CA). Two perpendicular intersecting rows of seeds were planted centered in the plot at spacings of either 5.1, 10.2, 15.2, 20.3, 25.4, or 30.5 cm apart, corresponding to total plant populations of 27, 13, 9, 5, 5, and 5 respectively. Plots were irrigated via solid-set sprinklers as needed. Chlorothalonil (Bravo 720, 1.3 kg/ha, Syngenta Crop Protection, Greensboro,

NC) was applied on a 14-day schedule to control leaf spot diseases, and the crop was managed according to conventional practices (Georgia Peanut Production Guide). The central plant in each plot was inoculated on one of three inoculation dates (50, 70 or 90 days after planting [DAP]) with a 1-cm agar disk taken from the outer edge of actively growing colonies of *Sclerotium rolfsii* Sacc. (isolate SR8) grown on potato dextrose agar (PDA). At harvest, tomato spotted wilt (TSW) incidence was determined by counting all plants showing symptoms and then dividing by the total plant count/plot. Data were analyzed by analysis of variance with PROC GLM to determine significant effects of seed spacing and stem rot inoculation date on TSW incidence (SAS Institute, Cary, NC). Regression analysis was used to determine the quantitative relationship between seed spacing and spotted wilt incidence.

Grid plot experiment. Two cultivars of peanut, 'Florida MDR 98' and 'Georgia Browne', were germinated as described previously. Germinated seeds were planted by hand in 0.27-m² plots using a 0.27-m² grid frame as a guide for planting seeds either 7.6, 15.2, 22.9, or 30.5 cm apart, corresponding to total plant populations of 121, 25, 5, and 5 respectively. In 2001 and 2002, the test site was fumigated with a methyl bromide/chloropicrin mixture (applied at a rate of 450 kg/ha, 67% methyl bromide and 33% chloropicrin) prior to planting to reduce populations of soilborne pathogens. Chlorothalonil (Bravo 720, 1.3 kg/ha, Syngenta Crop Protection, Greensboro, NC) was applied to all plots on a 14-day schedule to reduce leaf spot diseases. Host plants were irrigated as

needed via solid set sprinklers and insects and weeds managed by practices currently accepted by the University of Georgia . The central plant in each plot was inoculated on one of two inoculation dates (50 or 90 DAP) with *S.rolfsii* as described previously. Tomato spotted wilt incidence was determined at 97 DAP by counting the total number of plants showing symptoms and dividing by the plot stand count. Data were analyzed by analysis of variance using PROC GLM to determine the significance of seed spacing, cultivar, stem rot inoculation date and year on tomato spotted wilt incidence. Regression analysis was used to determine the quantitative relationship between seed spacing and disease development.

Conventional field experiment. An experiment was conducted in two different fields in 2000, 2001, and 2002. The experiment was designed as a randomized complete block factorial experiment. Certified 'Georgia Green' peanut seed were planted in either single rows or twin rows at a low, medium, or high seeding rate. The seeding rates were 12.5, 17.4 or 22.6 seed/m for single rows, and 6.2, 8.9 and 11.5 seed/m for twin rows. Seeding rates were chosen to achieve similar plant populations for the low, medium and high seeding rate regardless of row pattern. Plot tiers were separated by 2.4-m fallow alleys to reduce inter-plot interference. Phorate (Thimet 20 G, BASF Ag Products, Research Triangle Park, NC) was applied at a rate of 4.5 kg/ha in-furrow at planting to reduce TSWV. Chlorothalonil (Bravo Ultrex, 1.57 kg/ha, Syngenta

Crop Protection, Greensboro, NC) was applied on a 14-day schedule to reduce leaf spot diseases.

In 2000, disease incidence was determined only at harvest by counting the number of 30.5-cm lengths of row per plot showing signs or symptoms of TSW, and then dividing that number by the total number of 30.5-cm lengths of row per plot. In 2001 and 2002, disease incidence was determined at 30 DAP, 90 DAP and harvest as described above, and DAS-ELISA was used to determine the incidence of plants infected with TSWV. At 30 and 90 DAP, 15 terminal leaves from central stems were sampled systematically from each plot at intervals of 0.3 to 0.6 m. Leaf samples were ground with a plant sap extractor (Ravenel Specialites Co., Seneca, SC), and the presence of TSWV in each sample was determined based on standard protocols for DAS-ELISA (Agdia, Inc., Elkhart, IN). Negative controls for the ELISA consisted of healthy tobacco leaves obtained from greenhouse-grown plants, and positive controls were symptomatic tobacco leaves from field-infected field-grown plants that previously tested positive for TSWV presence by ELISA. Both controls were processed in the same manner as the samples. After determining the incidence of samples testing positive for TSWV per plot, that incidence was multiplied by the plant stand count (corresponding to the plot in which the samples were collected) in order to estimate the total number of possible plants infected per plot.

At harvest, plants were mechanically dug and inverted (KMC digger/inverter) at 149, 137 and 160 DAP, in 2000, 2001 and 2002, respectively.

Windrows were mechanically harvested (Lilliston 1580 combine) at 154, 149 and 179 DAP in 2000, 2001 and 2002, respectively. Pods were dried to approximately 10% moisture, weighed and mechanically graded according to standard USDA procedures. Immediately after inversion, 15 whole root samples per plot were collected in the same sampling method as described previously for leaf samples. Roots were washed with tap water to remove soil, and assayed for presence of TSWV by ELISA as described previously. Field experiment two was also inoculated with *S. rolfsii* as described in chapter 3. Data were analyzed by analysis of variance with SAS PROC GLM to determine the effects of row pattern and seeding rate on TSW symptoms and TSWV infection for all assessment dates (SAS Institute, Cary, NC). The effect of stem rot inoculation date was not examined in this study as in the microplot and grid experiments. Pearson correlation coefficients were calculated using SAS PROC CORR for correlations between the percentages of symptomatic and virus-infected plants per plot.

Results

All experiments were irrigated and received approximately 50 cm of water from rain or irrigation annually during the growing season.

Microplot study. Analysis of TSW incidence at harvest indicated that the year by seed spacing interaction was significant ($P = 0.0070$), therefore years were analyzed separately. The relationship between seed spacing and incidence for each year can be described as cubic, with incidence increasing with seed spacing up to a spacing of 20.32 cm, then leveling off (or decreasing,

as in year 2001) (Fig. 4.1). Stem rot inoculation date had no effect on TSWV incidence.

Grid study. There were no significant interactions between independent variables, and only seed spacing had a significant effect ($p < 0.05$) on incidence of TSW. Disease incidence was greater at the 30.5-cm than at the 7.6-cm spacing, and there was a gradual decrease in incidence with a decrease in seed spacing (Fig. 4.2). Incidence of TSW was not significantly affected by stem rot inoculation date or cultivar.

Conventional field one. In 2001 and 2002, there was no significant difference at any sampling date between row pattern or seeding rate on incidence of virus infection as determined by ELISA (Table 4.1). Mean virus incidence for all treatments are shown in Table 4.2. In field one, the total estimated number of peanut plants infected with TSWV was significantly greater in twin rows (46 to 210 plants per plot) than in single rows (20 - 141 plants per plot) in 2001 and 2002 (Table 4.3). In 2002, the high seeding rate had a greater estimate (215 plants) of infected plants than the low (142 plants) or medium (178 plants) seeding rates (Table 4.3). In 2001, there were no significant interactions between seeding rate and row pattern for symptoms. Row pattern only had a significant effect ($P = 0.0140$) on TSW symptoms at harvest (Table 4.1). Incidence of disease in peanuts planted in twin rows was significantly lower (0.5%) than in single rows (2.6%). In 2002 at harvest, there was a highly significant row pattern effect ($P = 0.0003$), with twin rows having significantly

lower TSW (2.3%) than single rows (6.5%) (Fig. 4.3). At the 90 DAP assessment in 2002, there was a significant seeding rate x row pattern effect, and at 30 DAP, there were also significant seeding rate and row pattern effects on disease incidence (Table 4.1). None of the samples collected showed signs or symptoms of *S. rolfsii*.

Conventional field two. There were some significant effects of row pattern and seeding rate on the percentages of symptomatic and virus infected plants at 30 and 90 DAP in both years (Table 4.1). In 2001, virus incidence at 90 DAP was significantly greater in plots planted at the low seeding rate (10.8%) than those planted at the medium (0.8%) or high (0.8%) seeding rates (Table 4.2). In 2002, virus incidence was significantly greater in single rows (18.9%) than in twin rows (6.1%) (Table 4.2). In field two, the total estimated number of peanut plants infected with TSWV was significantly greater in twin rows (117 to 182 plants per plot) than in single rows (82 - 114 plants per plot) in 2001 and 2002 (Table 4.3). The percentage of symptomatic plants was greatest in single rows planted at a low seeding rate, while twin rows had very few symptoms (Fig. 4.4a). At harvest in 2002, there was a highly significant row pattern effect with twin rows having fewer symptoms (0.7%) than single rows (4.2%) (Fig. 4.4b). There was no significant correlation between the percentage of symptomatic plants and the percentage of virus-infected plants for field 1 in either year. The only significant positive correlations were found in field 2, between the 90 DAP

ELISA data (Fig. 4.5). None of the samples collected showed signs or symptoms of *S. rolfsii*.

Discussion

Based on the incidence of visual symptoms at harvest (the method used in previous studies), there are differences in symptom expression among the seeding rates and row patterns. Stem rot inoculation date did not have any effect on TSW incidence (in the microplot and grid studies), which shows that this disease can progress regardless of stem rot development. Single rows planted at low seeding rates had the greatest percent of spotted wilt and twin rows had the lowest, which verifies previous findings (Gorbet and Shokes 1994; Wehtje et al. 1994; Culbreath et al. 1999). However, based on incidence of samples per plot testing positive for TSWV, there were no differences between row pattern or seeding rates. Yet, when the estimated number of infected plants per plot was determined (based on incidence of samples per plot testing positive multiplied by stand count per plot), there were supposedly more plants infected with TSWV in twin rows in both tests in both years than in single rows. The same result was found in 2002 in field 1 for seeding rate. The high seeding rate actually had the higher number of estimated infected plants based on plant stand count.

There was also a rather large discrepancy in incidence between visual symptoms and viral incidence. This may be due in part to the different assessment methods for incidence of visible symptoms and the presence of the

virus. For symptom assessment, the total number of 30.5-cm sections of row (50 for single rows and 100 for twin rows) was used as the divisor in determining the incidence. However, for virus incidence, '15' was used as the divisor since there were 15 total samples per plot. These different methods of calculating disease incidence help explain the difference in magnitude between them, but it is still surprising that symptom incidence was also low when over 80% of all plants tested positive for TSWV in 2002. Martinez *et al.* 2002 also found that over 80% of their root samples, whether symptomatic or not, tested positive for TSWV, INSV, or both.

Overall, the incidence of virus infection was quite high, and for the most part, not influenced by row spacing or seeding rates (with the exception of 90 DAP ELISA data in field 2) based only on the percentage of samples testing positive for TSWV. The estimation of total infected plants/plot (based on plot stand and percentage of samples testing positive for TSWV/plot) may suggest that twin rows can become infected just as easily as single rows, and fields planted in high seeding rates could also become infected as easily as low or medium seeding rates. Further studies (over several years) should be conducted to determine the validity of these estimates.

Apparently the primary effect of the planting pattern was to influence symptom expression by infected plants. For unknown reason(s), peanuts planted in a twin row pattern express fewer symptoms. Perhaps infected plants are just more visible since they are more widely spaced. Whatever the reason,

symptom assessment was a poor method of determining virus incidence. This was true for both foliar samples and root samples, which generally are the most reliable tissues for TSWV detection (Culbreath *et al.* 1991, Mitchell *et al.* 1995). The virus is not distributed uniformly throughout individual plants but is concentrated in developing terminal tissue, and as the virus becomes systemic, symptoms appear in the leaves (Mitchell *et al.* 1995). It is assumed that if the virus is detected in the roots, then the virus is systemic.

Despite the fact that the virus was at high frequencies in all treatments, there were still significant yield differences among treatments (see Chapter 3). Yields were greatest for peanuts planted in at high seeding rates (22.6 seed/m for single rows or 11.5 seed/m for twin rows). It is interesting that with an increase in seeding rate, there is an increase in peanut stem rot (*S. rolfsii*), but there is also a decrease in TSW. The net effect appears to be that the virus causes greater yield loss. These findings do not necessarily change the management practices for TSW, however, it does shed some light on the actual occurrence of the virus itself in relation to the visible symptoms.

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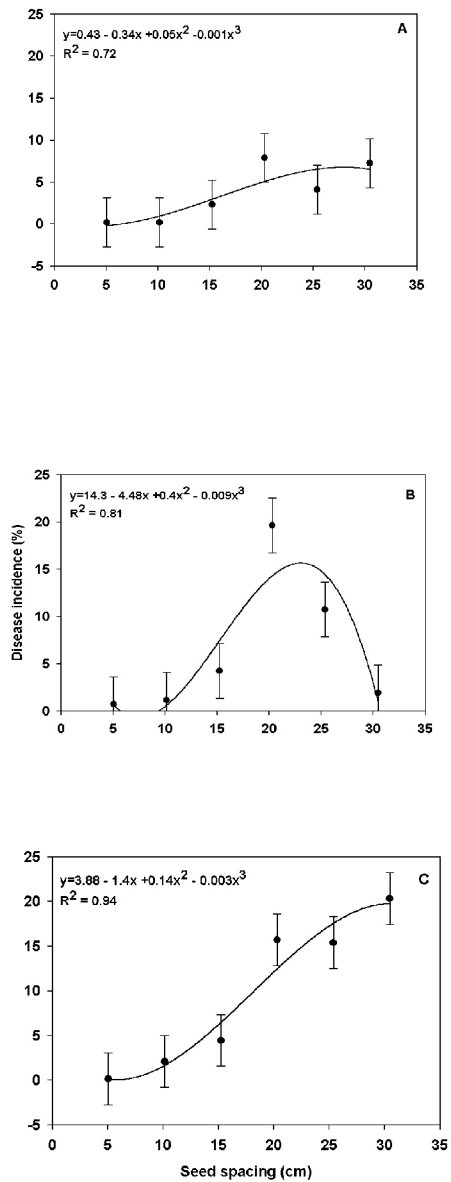


Figure 4.1. Regressions of TSW incidence at harvest on seed spacing in peanuts planted in field microplots in 2000 (A), 2001 (B) and 2002 (C) in microplot study at harvest. Incidence was determined by dividing the total number of plants showing symptoms by the plot stand and then multiplying by 100. Data points are means of incidence values.

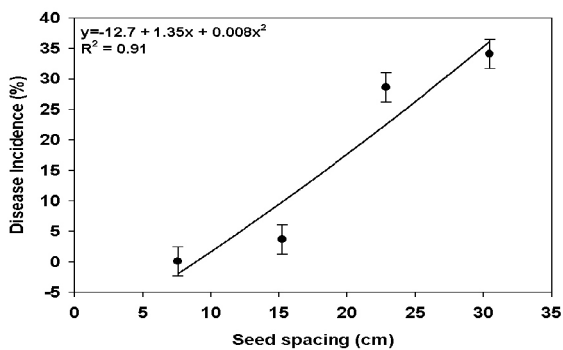


Figure 4.2. Regression of TSW incidence on seed spacing in field-grown peanuts planted in a grid pattern. Incidence was determined at 97 days after planting by dividing the total number of plants showing symptoms by the plot stand and then multiplying by 100. Values represent means over 3 years and two peanut cultivars ('Georgia Browne' and 'MDR-98').

Table 4.1. ANOVA* table for determining significance of treatment factors on rating method and testing date for fields 1 and 2 in 2001 and 2002

Year	Source	Field 1						Field 2					
		30 ¹	90	Harvest	Visual 30 ²	Visual 90	Visual Harvest	30	90	Harvest	Visual 30	Visual 90	Visual Harvest
2001	Rep	.5686	.4199	.0878	.6098	.4354	.0808	.1892	.1886	.0037	.1073	.2473	.5234
	Seed Rate	.5775	.3911	.9009	.5191	.3492	.3555	.8825	.0005	.3924	.6697	.2559	.0006
	Row Pattern	.2108	.3332	.1716	.7094	1.000	.0140	.3037	.0508	.1721	.4781	.1204	<.0001
	SR*RP	.5775	.3911	.1113	.7802	.6730	.5133	.3477	.0247	.3397	.0492	.2133	.0006
2002	Rep	.0299	.5124	.4117	.6449	.2786	.8472	.0505	.8873	.9438	.3483	.5289	.0592
	Seed Rate	.6535	.5944	.3922	.0457	.0035	.0813	.8502	.3135	.3106	.9791	.3629	.2027
	Row Pattern	.1509	.3423	.3311	.0281	<.0001	.0003	.6912	.0309	.8142	.1011	.0019	.0006
	SR*RP	.3525	.0544	.3562	.5623	.0433	.7253	.3780	.6018	.3390	.8284	.1825	.1285

¹P - values for each of the three ELISA (% virus incidence) testing dates 30 and 90 DAP and at harvest in 2001 and 2002

²P - values for each of the three Visual (% symptomatic plants) rating dates 30 and 90 DAP and at harvest in 2001 and 2002

* Analysis of variance performed using SAS PROC GLM. Significance level was $p \leq 0.05$.

Table 4.2. Effects of row pattern (single rows or twin rows) and seeding rate (low, medium or high) on ELISA results (% virus incidence) for all testing dates (30 and 90 DAP and harvest) in 2001 and 2002 in fields 1 and 2.

	Field Experiment 1						Field Experiment 2					
	2001			2002			2001			2002		
	30	90	Harv	30	90	Harv	30	90	Harv	30	90	Harv
Single	1.7a ¹	0.6a	14.1a	3.3a	22.4a	90.8a	0.6a	6.1a	71.1a	6.7a	18.9a	81.1a
Twin row	0.0a	0.0a	23.0a	6.7a	16.1a	94.4a	2.2a	2.2a	61.1a	5.0a	6.1b	82.8a
Low	0.8a	0.8a	16.7a	4.2a	15.0a	89.2a	0.8a	10.8a	69.2a	5.0a	14.2a	86.7a
Medium	1.7a	0.0a	20.0a	4.2a	21.7a	95.8a	1.7a	0.8b	70.0a	5.0a	16.7a	85.0a
High	0.0a	0.0a	18.9a	6.6a	21.1a	92.9a	1.7a	0.8b	59.2a	7.5a	6.7a	74.2a

¹ Means separated using Tukey's Multiple Comparison test. Values followed by the same letter within each column for each variable group (row pattern and seeding rate analyzed separately) are not significantly different at $p \leq 0.05$.

Table 4.3. Effects of row pattern and seeding rate on total estimated number of peanut plants infected with tomato spotted wilt virus in fields 1 and 2 in 2001 and 2002

	Field Experiment 1		Field Experiment 2	
	2001	2002	2001	2002
Single	20.38a ¹	141.7a	82.3a	114.2a
Twin	46.03b	210.6b	117.2b	182.1b
Low	27.2a	142.2a	97.0a	138.5a
Medium	35.3a	178.1b	102.9a	159.4a
High	37.1a	215.2c	99.4a	146.5a

¹ Means separated using Tukey's Multiple Comparison test. Values followed by the same letter within each column for each variable group (row pattern and seeding rate analyzed separately) are not significantly different at $p \leq 0.05$. Plant estimates based on plot stand multiplied by % ELISA sample that tested positive for TSWV

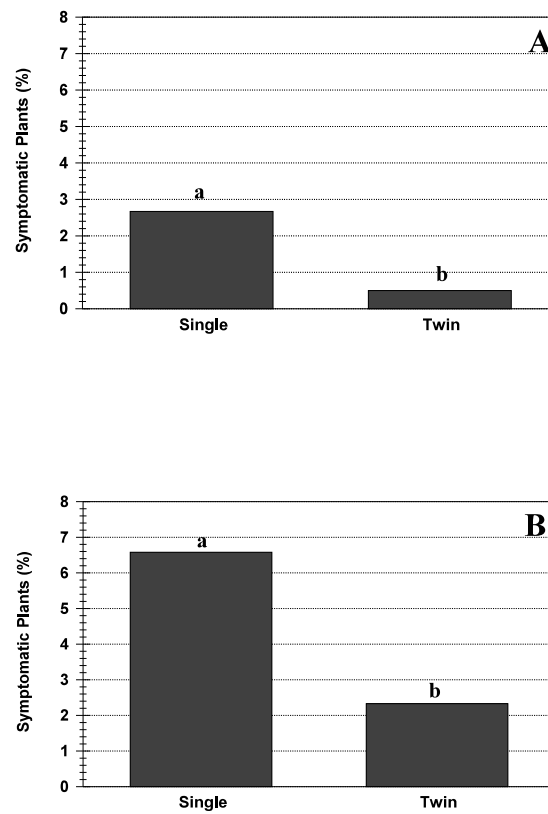


Figure 4.3. Influence of row pattern on incidence of visual symptoms in 2001 (A) and 2002 (B) for field 1 at harvest. Incidence values with the same letter above vertical bars are not significantly different ($P \geq 0.05$).

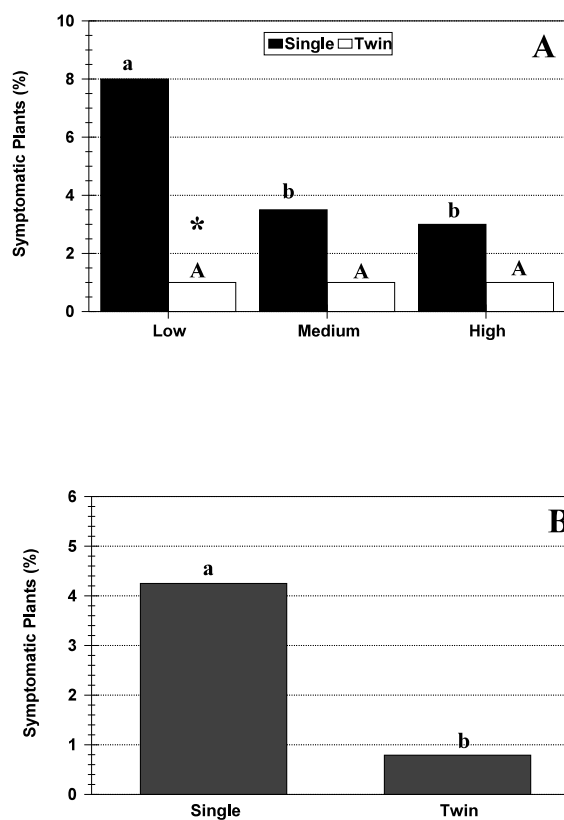


Figure 4.4. Influence of row pattern and seeding rate on incidence of visual symptoms in 2001 (A) and effect of row pattern on incidence of visual symptoms in 2002 (B) for field 2 at harvest. Incidence values for single rows in figure A represented by the same lower case letter and twin rows represented by the same upper case letter are not significantly different ($P \geq 0.05$). Values in figure B represented by the same letter are not significantly different ($P \geq 0.05$).

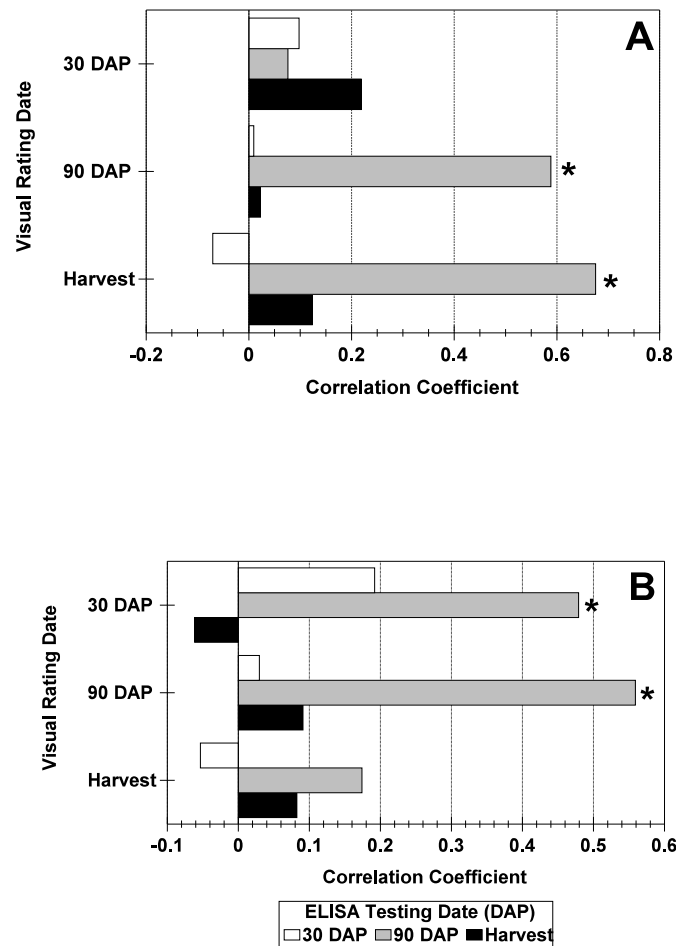


Figure 4.5. Influence of incidence assessment method (and date) on Pearson Correlation Coefficients for Field 2 in 2001 (A) and 2002 (B). * indicates significance ($P \leq 0.05$)

CHAPTER 5

EFFECTS OF TWIN ROW SPACING ON EPIDEMICS OF PEANUT STEM ROT¹

¹Sconyers, L.E., T.B. Brenneman and K.L. Stevenson. 2003. To be submitted to *Peanut Science*.

Abstract

Stem rot (*Sclerotium rolfsii* Sacc.) severity and spread, as well as canopy temperature and humidity, were monitored in peanut (*Arachis hypogaea* L.) field plots containing four row spacings (single, 10.2-cm twin, 20.3-cm twin or 30.5-cm twin) and two inoculation dates (50 DAP or 90 DAP) for three growing seasons to determine the influence of row spacing and disease initiation on stem rot epidemics. In 2000, 2001 and 2002, disease severity at harvest of inoculated foci and spread across rows were greatest in 10.2-cm twin rows, moderate in 20.3-cm twin rows, and low in 30.5-cm twin rows. For all three years, there was no significant difference between row spacings for spread along the inoculated rows. Disease severity of all diseased plants and spread per plot were assessed by destructive sampling at harvest in 2002. There was a significant ($P < 0.05$) inoculation date x planted row (inoculated row or adjacent twin row) x plant number (plant location in relation to inoculation focus) as well as a row spacing x planted row x plant number interaction. Rows inoculated at 50 DAP had greater stem rot severity compared to rows inoculated at 90 DAP. Disease severity in inoculated rows and spread from inoculated to non-inoculated rows was high, medium and low for the 10.2-cm, 20.3-cm, and 30.5-cm twin spacing, respectively. There were some differences between treatments for canopy temperature and humidity, however, plant spacing seems to have a greater role

in disease development. *S. rolfsii* requires a plant bridge for mycelial spread, and twin rows that were planted close together had the greatest severity and spread. Based on these findings, producers can plant twin rows 20.3 cm apart or wider to significantly reduce the spread of peanut stem rot.

Key Words: *Arachis hypogaea*, disease spread, microclimate, severity

Introduction

There have been numerous studies conducted to determine the effect of row spacing of crops on disease development. Open canopies and wider row spacings have been associated with drier foliage and reductions in white mold of snap bean, caused by *Sclerotinia sclerotiorum* (Stevenson *et al.* 2000). Cook *et al.* (2000) found a similar effect in paired-row wheat working with take-all, caused by *Gaeumannomyces graminis* var. *tritici*, and root rot caused by *Rhizoctonia solani*. Other research in legumes shows the beneficial effects of row spacing modification on disease. Distances between soybean rows of 50 cm or more significantly reduced *Rhizoctonia* aerial blight, caused by *Rhizoctonia solani* (Joye *et al.* 1990). Even though wider row spacing often has a beneficial effect of reducing disease, in some cases it has the opposite effect. In India, researchers documented a lower incidence of root rot (*Macrophomina phaseolina*) in peanuts (groundnuts) planted in 30-cm rows than in 45 or 60-cm rows (Bhowmik *et al.* 1985).

For some crops, manipulation of row spacings (either narrower or wider) can provide an effective cultural (non-chemical) means of disease management, or be exploited as one component of an integrated approach to disease management. Culbreath, *et al.* (1999) found that planting peanuts in twin rows, (17.8 - 25.4 cm apart), significantly reduced tomato spotted wilt virus (TSWV), improved grade, and increased yield when compared to conventional 91.4-cm single rows. As a result of these findings, the proportion of peanut producers in

Georgia planting twin rows (17.8 - 25.4 cm apart) has steadily increased over the past few years (Smith, 2001). The effect of row spacing on other peanut diseases is not as well known. One of the most damaging is stem rot, caused by *Sclerotium rolfsii* Sacc., which costs Georgia peanut farmers an average of \$24.8 million in damages and \$13.4 million in control costs for the last 12 years (1990-2001 Georgia Plant Disease Loss Estimates). The objective of this study was to examine the effects of row pattern spacing on microclimate within the peanut canopy, and on development of stem rot epidemics initiated either early or late in the season.

Materials and Methods

Row spacing treatments. In 2000, 2001, and 2002, 1.5-m long by 1.5-m wide plots were established in a field of Tifton loamy sand (2-5% slope) that was tarped and fumigated with a methyl bromide/chloropicrin mixture (applied at a rate of 450 kg/ha, 67% methyl bromide and 33% chloropicrin) prior to planting each year to reduce populations of *S. rolfsii*. Two single rows (91.4-cm centers) of peanut (*Arachis hypogaea* L.) cultivar Agratech 1-1 were planted at a seeding rate of 13.3 seed m⁻¹ using a vacuum planter (Monosem planters, ATI Inc., Lenexa, KS) on 17 May, 20 May and 22 May in 2000, 2001 and 2002, respectively. Two to three days after planting, a precision garden seeder (model 1001-B, Earthway Co., Bristol, IN) was used to plant a second parallel row in designated twin-row plots at a distance of 10.2-cm, 20.3-cm, or 30.5-cm from the first row. Phorate (Thimet 20 G, BASF Ag Products, Research Triangle Park,

NC) was applied at 4.5 kg/ha in-furrow at planting to minimize incidence of TSWV and thrips damage. Chlorothalonil (Bravo Ultrex, Syngenta Crop Protection, Greensboro, NC) was applied at 1.57 kg/ha on a 14-day schedule to prevent leaf spot diseases. Plots were not treated with any other fungicides.

The center plant of the outer row (tractor-planted row) of each plot was inoculated at either 50 or 90 days after planting (DAP), using an isolate of *S. rolfii* from peanut (Fig. 5.1). Acephate (Orthene 97G, Valent Corp., Richardson, TX) was applied at a rate of 0.84 kg/ha prior to inoculation to prevent fire ants (*Solenopsis invicta*) from eating the inoculum. A 1-cm-diam. hyphal plug taken from the edge of an actively growing colony on potato dextrose agar (PDA) was placed at the base of the mainstem. Plots were irrigated for 3 consecutive days at 1.27 cm per day to promote the growth of the fungus and to initiate disease development. Additional irrigation was used to promote plant growth during dry periods.

Disease assessments. At 57, 77 and 97 DAP, stem rot severity was assessed on the center inoculated plant using the Shokes 0-5 scale (Shokes, *et al.* 1998). Disease spread along the inoculated row was assessed by measuring the diseased row length of each inoculated focus. Disease spread from the inoculated row to the adjacent twin row was assessed by assigning a '1' to plots with signs or symptoms of stem rot in the adjacent twin row (hand-planted row), or a '0' to plots with no signs or symptoms of stem rot in the adjacent twin rows. At harvest in 2002, disease severity was mapped to

determine the movement of *S. rolfsii* and the development of stem rot for the different row spacings. Destructive sampling was used to assess all plants showing signs or symptoms. Each plant was assigned a sequential whole number to represent its physical location in relation to the inoculated plant, which was assigned '0'. Negative numbers were assigned to diseased plants west of the inoculated plant, and positive numbers were assigned to diseased plants to the east of the inoculated plant. Disease severity was determined for plants in inoculated rows and adjacent twin rows, again using the Shokes 0-5 (Shokes et al. 1998).

Microclimate monitoring. A temperature and relative humidity (RH) sensor (Hobo Pro Series 8, Onset Computer Corporation, Bourne, MA) was placed in one plot of each row spacing treatment. They were placed within the canopy near the crown of the plants, at 5.1 cm above the soil surface and they recorded air temperature and RH at 30-min. intervals during the experimental period.

Data analysis. After all disease data (excluding stem rot mapping data in 2002) were compiled, PROC GLM was used to analyze the data for each treatment across all three growing seasons (SAS Institute, Cary, NC). Disease severity values on the Shokes scale were converted to percentages using the midpoint of each interval prior to analysis. Means were then calculated and separated by Tukey's Multiple Comparison Test (SAS Institute, Cary, NC). For stem rot mapping data in 2002, PROC MIXED was used to determine

significance of test factors, and regression analysis was used to determine any relationship between disease severity and the test factors (SAS Institute, Cary, NC). The level of significance for all testing was 5%. Microclimate data were analyzed using the SAS Mixed procedure to determine significant effects of row spacing on mean temperature and RH, and regression analysis was used to evaluate the quantitative relationship between microclimate variables and row spacing (SAS Institute, Cary, NC). State of Georgia Ambient Weather Data for Tifton, Georgia were used as a covariance adjustment for recorded weather data (State of Georgia Weather Service, G. Hoogenboom, 2000-2002). All recorded data were compared with ambient conditions for Tifton using t-test comparisons, and treatment comparisons were also examined using t-tests (SAS Institute, Cary, NC).

Results

For disease severity of inoculated plants at harvest, there was a significant year x row spacing interaction (Fig. 5.2). When disease pressure was low in 2001, there were no significant differences among row spacing treatments. However, in 2002, when there was greater disease pressure, severity was significantly greater on inoculated plants in the 10.2-cm twin rows than either the 20.3-cm twin rows or the 30.5-cm twin rows. Disease severity on inoculated plants in 30.5-cm twin rows was significantly lower than any other row spacing treatment.

Since there was no row spacing interaction with year, data for disease spread were combined across years. For disease spread along rows (cm) at harvest, there were no significant differences ($P > 0.05$) among row spacings. However, spread to adjacent rows at harvest was significantly greater in the 10.2- and 20.3-cm twin rows than in the 30.5-cm twin rows (Fig. 5.3). No spread was observed between rows in the 91.4-cm single row plantings.

For the severity mapping data in 2002, there were significant inoculation date x planted row x plant number and row spacing x planted row x plant number interactions (Figures 5.4 and 5.5). For both interactions, there were also significant quadratic trends for each of the factor combinations. Severity data were similar regardless of whether peanut plants were on the left(-) or right(+) side of the inoculation focus(0) (Figures 5.4 and 5.5). For the inoculation date x planted row x plant number interaction, inoculated rows consistently had greater disease severity than adjacent twin rows, but both had a similar pattern with the plants nearest to the inoculation point having the greatest disease severity. In both inoculated and paired twin rows, plots that were inoculated at 50 DAP had greater disease severity than plots inoculated at 90 DAP (Figure 5.4). For the row spacing x planted row x plant number interaction (Figure 5.5), inoculated rows again had greater disease severity than their adjacent twin rows, and plants nearest the inoculation point had greater disease severity. Within the twin rows, the 10.2-cm twins had the greatest disease severity and spread

followed by the 20.3-cm twin rows. There was very little disease in the 30.5-cm twin rows (Fig. 5.5).

For the mean microclimate data across years for each treatment, there were no significant differences in mean temperature or RH among row spacings. Data were also analyzed across each growing season, and predicted ambient condition curves and valid microclimate data curves were produced. Missing data also made it difficult to discern differences between treatments. Additional data are presented in Appendix C.

Discussion

Results of this research document the ability of *S. rolfsii* to spread from plant to plant in various planting patterns in the field, as well as the influence of those planting patterns on disease development. In years of greater disease severity, closer planted twin rows can have greater disease than more widely spaced twin rows. This results from the plants which are originally infected having more severe disease symptoms, as well as a greater severity and incidence of disease in plants in the adjacent twin rows. The pathogen was able to grow between twin rows spaced 10 to 20 cm apart, but there was little spread at 30.5 cm. Similar results were observed in microplots and small-plot field studies (chapter 2). However, the presence of an adjacent twin row did not influence the spread of the disease in the originally infected row.

The mechanism underlying the observed low level of disease at wider row spacing is probably related primarily to the inability of the pathogen to physically

grow between more distant plants. Furthermore, inoculated plants with close twin rows developed more severe symptoms than those with distant twin rows. This could be due to a more crowded plant being somehow more susceptible to the pathogen, or perhaps to a more favorable microclimate for disease development. Although the latter seems more likely, data from this study suggest that differences in microclimate among the row patterns were minimal. Although there were some significant differences between canopy and ambient conditions, there were no differences between treatments for mean canopy temperature or RH. There were also some differences among treatments, when analyzed across the growing season, however, several days of the 20.3-cm twin row data was missing due to a faulty sensor. The ambient data that matched the days (N) in which the 20.3-cm logger recorded and the complete set of ambient data were significantly different (Tables 5.2 and 5.6) indicating a penalty due to loss of logger data. So, the differences seen in Tables 5.4 and 5.8 between the 20.3-cm data and other treatments may not be necessarily true due to missing data. There were significant differences between single rows and the 10.2-cm twin rows (Tables 5.4 and 5.8) with canopy temperature being greater in single rows than the twin rows, and humidity was greater in the twin rows than in the single row pattern. However, the relatively small magnitude of these differences makes it unlikely that they had much effect on disease progress.

S. rolfsii thrives in warm moist environments. The optimal temperature range for hyphal extension is 8-40°C with maximum growth at 27-30°C (Aycock,

1966; Punja 1985). Temperatures at or near this range were frequent in all treatments. Furthermore, any soil moisture level greater than 50% can initiate growth, and a relative humidity level greater than 90% can increase mycelial growth even more (Onkarayya and Appa Rao 1970; Rideout 2002.) Other than the very early part of the 2000 season, relative humidity levels were very similar among the twin row treatments. Microclimate conditions may explain disease development (or lack of) outside the optimal temperature or humidity range, but differences in stem rot epidemics in different row spacings seem to be explained better by the actual physical distance between peanut plants. The 10.2-cm twin rows had the greatest disease, followed by 20.3-cm and 30.5-cm twin rows, respectively. *S. rolfii* requires a plant bridge for growth, and thus the closer the plants are, the greater the disease.

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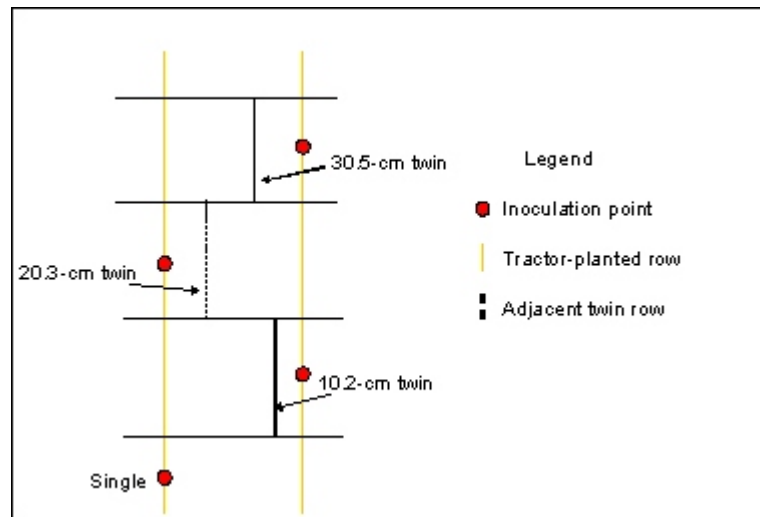


Figure 5.1. Diagram of single and twin row spacing treatments showing one replication of the field experiment conducted in 2000, 2001 and 2002. The tractor-planted rows were 91.4-cm apart, and each adjacent twin-row plot was 1.5 m long.

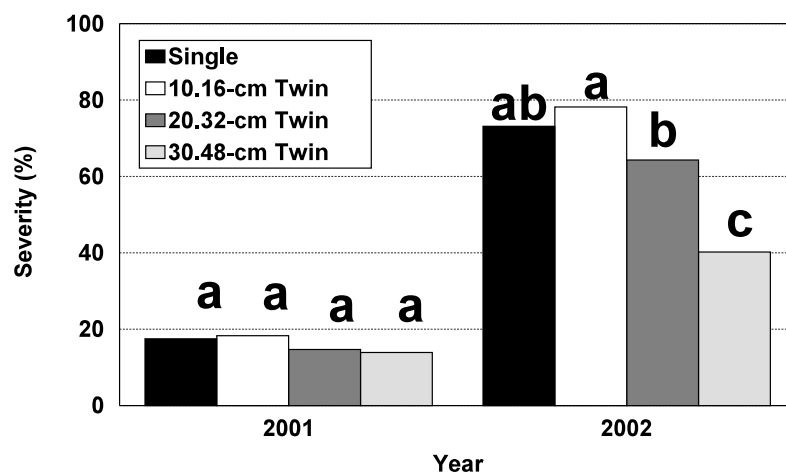


Figure 5.2. Influence of row spacing on mean stem rot severity of inoculated plant at harvest in 'AT1-1' peanuts in 2001 and 2002. Severity values with the same letter above vertical bars within each year are not significantly different at the 5% level of significance.

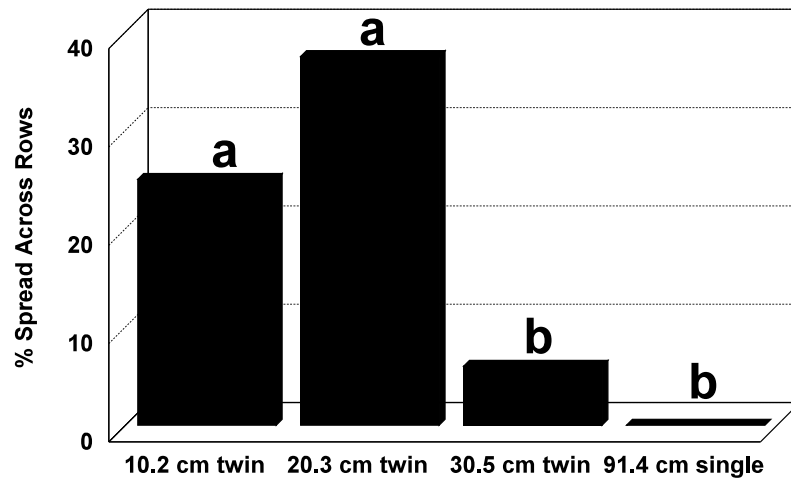


Figure 5.3. Influence of row spacing on the spread of stem rot across rows in 'AT1-1' peanuts for both 2001 and 2002 at harvest. Values with different letters above vertical bars are significantly different at $P \leq 0.05$.

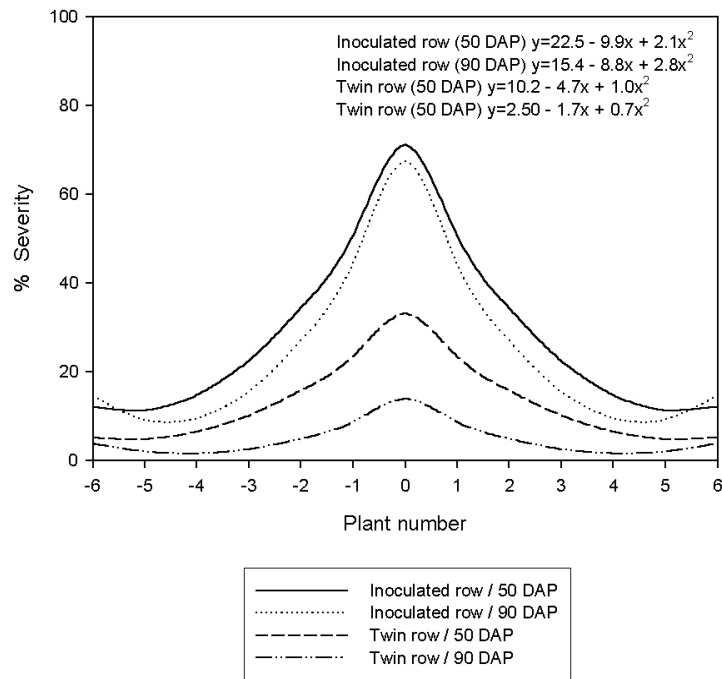


Figure 5.4. Influence of inoculation date, planted row (inoculated row or adjacent twin), and plant number (plant location in relation to inoculated plant, which is represented by '0') on predicted stem rot severity at harvest in 2002. Equations for regression lines are given only for the plants on the right side of inoculated plant since the regression lines for the left side are similar.

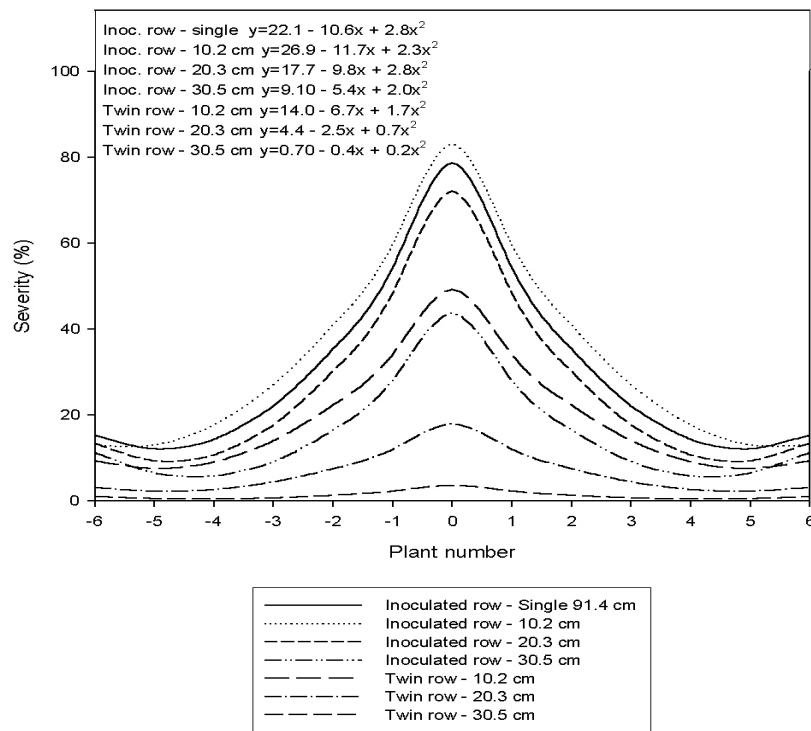


Figure 5.5. Influence of row spacing (single, 10.16-cm twin, 20.32-cm twin or 30.48-cm twin), planted row (inoculated row or adjacent twin), and plant number (plant location in relation to inoculated plant, which is represented by '0') on predicted severity at harvest in 2002. Equations for regression lines are given only for the plants on the right side of inoculated plant since the regression lines for the left side are mirror images.

CHAPTER 6

SUMMARY

Stem rot (*Sclerotium rolfsii* Sacc.) is a significant fungal disease problem for peanut producers. In Georgia alone, this disease cost producers \$24.8 million in losses and \$13.4 million in control costs on average for the last twelve years. An integrated pest management approach, including deep plowing, crop rotation with non-hosts, and fungicides, has generally been used to reduce the severity of stem rot epidemics. However, with the introduction of Tomato Spotted Wilt Virus (TSWV) in the mid-late 1980s, researchers began searching for cultural practices to reduce the major losses caused by this pathogen on peanut. They found that planting a higher seeding rate or a twin row pattern could significantly reduce the disease and increase yield, but the effect of these practices on actual incidence of virus infection was not known. The effect of some seeding rates and row patterns on stem rot have been compared, but not in a controlled study over a wide range of plant spacings. Also, it is not known what effects these planting practices have on the canopy microclimate, and whether or not this effects the development of stem rot.

This project quantified the relationship between plant spacing and stem rot development in controlled small plots with a wide range of plant spacings. Peanut plants planted close together had greater stem rot severity and spread.

The 5.1-cm spacing had the greatest level of stem rot, which is equivalent to the current recommendation of 6 seed/ft to reduce symptoms of TSWV. This indicates that relying solely on plant spacing will make it more difficult to manage one disease or the other. Closer spacings promote stem rot, and wider spacings promote spotted wilt. Furthermore, planting a genotype with a highly vegetative growth habit (such as 'Florida MDR-98'), may lead to even greater stem rot incidence, unless it has an inherent level of resistance to *S. rolfsii*.

To apply the findings on plant spacing, the effects of seeding rate and row pattern were examined with controlled inoculations, as well as in a field with a high level of natural inoculum. Regardless of seeding rate, there was less stem rot in the twin row pattern for both field studies. Twin rows planted close together (10.2-cm) had greater stem rot severity and spread than twin rows planted further apart. This confirms findings from the other two spacing studies. Stem rot reduction was even greater when fungicide (azoxystrobin) was applied, and equal efficacy was observed in single and twin rows. There were only slight differences in microclimate for the different treatments, indicating that plant spacing is probably the critical factor in stem rot development.

TSWV was also assessed, and tomato spotted wilt symptoms were indeed less in twin rows and high seeding rates, which verifies previous findings. However, DAS-ELISA revealed that the actual virus incidence was statistically the same regardless of row pattern or seeding rate. In 2002, there was 100% incidence in some plots, yet there were few symptoms. The mechanism for this

is unknown, but apparently planting pattern is influencing symptom expression regardless of infection incidence. Further research should be conducted to determine the actual virus concentration in this treatment. One possible hypothesis is that the difference in symptom expression could be due to the movement of thrips in the different canopy architectures. In any case, planting the twin row pattern seems to be the best practice to significantly reduce both stem rot and tomato spotted wilt and also increase yield.

The technique of inoculating plants with *S. rolfsii*, was very successful, resulting in consistent infection and disease development. For all of the inoculated tests, the effect of inoculation date on stem rot development was examined. By harvest, plots inoculated earlier in the season (50 DAP) had greater stem rot than the 70 or 90 DAP inoculations. However, the initial ratings 7 days after inoculation often showed the 90 DAP inoculations to have greater levels of disease. Although the disease was more explosive later in the year, overall the greater length of time to colonize additional tissue lead to more overall damage from early infections. This finding reinforces the importance of early season disease control.

All of this research will hopefully provide producers, as well as researchers, with critical information concerning both stem rot development and TSWV incidence. Further plant spacing studies should be conducted with new genotypes as they are developed to determine the optimum spacings to maximize yield while minimizing disease development. Such studies should

consider the effects on other diseases and pests as well, to develop the most efficient overall production systems.

With the research presented in this project, we can more fully understand the growth of *S. rolfsii* and the epidemiology of stem rot. For the last three years, this research project provided information that will be critical in deciding production inputs, as well as disease risk assessment. This is extremely important for producers during this time of economic instability, change in farm bill legislation and the removal of the peanut quota system.

APPENDIX A
APPENDIX TO CHAPTER 2 ¹

¹ Data included will not be published in other venues.

Microclimate data was analyzed across the entire growing season each year. Some seed spacing treatments did create a unique canopy microclimate (when compared to ambient conditions). Analysis of predicted microclimate values are shown in Tables A.1-A.14. Estimated intercept, slope and quadratic values for ambient temperature and humidity conditions which correspond to data loggers that recorded without missing any days during entire recording period are shown in Tables A.1 and A.8. Tables A.2, A.3, A.9 and A.10 show parameter estimates for ambient data that corresponds to valid recorded data. T-tests were conducted to determine differences between this matching ambient weather (corresponding to valid recording dates) with the complete ambient conditions for the entire recording period. If there were any differences ($t > 1.98$), then there is indication that the logger data recorded is questionable and is represented by a 'No' (Tables A.2, A.3, A.9 and A.10). Estimated intercept, slope and quadratic values for valid logger data only are presented in Tables A.4, A.5, A.11 and A.12. T-tests were also used to determine if there was a significant difference between the canopy conditions and ambient conditions (corresponding to the valid recording days). Some treatments were significantly different ($t > 1.98$), indicating a unique canopy environment and are represented as a 'Yes' (Tables A.4, A.5, A.11 and A.12). Testing of ambient data and logger data was also conducted for each treatment comparison (Tables

A.6, A.7, A.13 and A.14). Null hypotheses were set up for both ambient and logger data. Ambient data should remain the same ($t < 1.98$), regardless of the treatment comparison, and logger data (as well as the difference between ambient and logger data) should be different ($t > 1.98$) between treatments. If these null hypotheses have failed, then a 'No' is presented (Tables A.6, A.7, A.13 and A.14). There are some differences between some of the treatments based on these analyses. However, due to lacking data for some treatments (determined in Tables A.2, A.3, A.9 and A.10), some results for the treatment comparisons may be questionable.

Table A.1. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air temperature data for Tifton, Georgia for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2001 and 2002. Ambient data from State of Georgia Weather Service, Dr. Gerrit Hoogenboom. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Ambient Air Temperature	Yr	N ^a	Intercept			Linear			Quadratic			Air agrees with logger
			Est. ^b	SE ^c	t	Est.	SE	t	Est.	SE	t	
	01	131	26.44	0.244	-	-2.22e-02	2.66e-03	-	-1.20e-03	7.85e-05	-	-
	02	81	26.49	0.311	-	-2.10e-02	5.48e-02	-	-9.00e-05	2.62e-04	-	-
	T	212	26.47	0.198	-	-2.16e-02	2.74e-02	-	-6.45e-04	1.37e-04	-	-

^a N represents the number of days in which data loggers recorded the complete set (entire recording for growing season) of microclimate data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted complete ambient temperature in 2001 and 2002.

^c Standard error estimation for parameter estimates.

Table A.2 Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient temperature data that matches valid logger data in 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only corresponds to valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air agrees with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia Browne 7.62 cm	01	40	29.29	2.944	-0.96	1.54e-01	8.39e-02	-2.10*	1.09e-03	9.96e-04	-2.29*	No
	02	80	26.49	2.082	0.00	-2.10e-02	5.21e-03	0.00	-9.00e-05	2.49e-04	0.00	Yes
	T	120	27.89	1.803	-0.78	6.65e-02	4.20e-02	-1.76	5.00e-04	5.13e-04	-2.15*	No
Georgia Browne 15.24 cm	01	119	26.57	2.446	-0.05	-2.36e-02	2.56e-03	0.38	-1.25e-03	7.85e-05	0.45	Yes
	02	80	26.49	2.984	0.00	-2.10e-02	5.21e-03	0.00	-9.00e-05	2.49e-04	0.00	Yes
	T	199	26.53	1.929	-0.03	-2.23e-02	3.35e-03	0.03	-6.70e-04	1.30e-04	0.13	Yes
Georgia Browne 22.86 cm	01	119	26.57	2.291	-0.05	-2.36e-02	2.56e-03	0.38	-1.25e-03	7.85e-05	0.45	Yes
	02	42	26.07	3.857	0.11	-6.37e-02	4.80e-02	0.59	-9.80e-04	1.21e-03	0.72	Yes
	T	161	26.32	2.243	0.07	-4.37e-02	2.41e-02	0.60	-1.12e-03	6.08e-04	0.75	Yes
Georgia Browne 30.48 cm	01	46	29.59	2.746	-1.14	1.75e-01	7.80e-02	-2.53*	1.45e-03	9.28e-04	-2.85**	No
	02	80	26.49	2.984	0.00	-2.10e-02	5.21e-03	0.00	-9.00e-05	2.49e-04	0.00	Yes
	T	126	28.04	2.028	-0.77	7.70e-02	4.51e-02	-2.16*	6.80e-04	4.80e-04	-2.65**	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient temperature and ambient temperature (matching valid logger dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. * and ** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table A.3. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient temperature data that matches valid logger data in 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only corresponds to valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air agrees with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
MDR-98 7.62 cm	01	46	26.93	2.745	-0.18	2.57e-02	5.55e-02	-0.86	-3.40e-04	7.16e-04	-2.14*	No
	02	80	26.49	2.082	0.00	-2.10e-02	5.21e-02	-0.76	-9.00e-05	2.49e-04	-0.50	Yes
	T	126	26.71	1.723	-0.14	2.35e-03	2.79e-02	-0.61	-2.15e-04	3.79e-04	-2.13*	No
MDR-98 15.24 cm	01	52	27.21	3.701	-0.21	5.95e-02	5.40e-02	-1.51	1.65e-04	6.89e-04	-1.97	Yes
	02	80	26.49	2.984	0.00	-2.10e-02	5.21e-03	-0.76	-9.00e-05	2.49e-04	-0.50	Yes
	T	132	26.85	2.377	-0.16	1.93e-02	2.71e-02	-1.06	3.75e-05	3.66e-04	-1.75	Yes
MDR-98 22.86 cm	01	104	26.68	2.451	-0.10	-2.50e-02	2.66e-03	0.74	-1.28e-03	8.13e-05	-21.94**	No
	02	80	26.49	2.795	0.00	-2.10e-02	5.21e-03	-0.76	-9.00e-05	2.49e-04	-0.50	Yes
	T	184	26.59	1.859	-0.06	-2.30e-02	2.92e-03	0.06	-6.85e-04	1.31e-04	-7.02**	No
MDR-98 30.48 cm	01	45	29.41	2.776	-1.07	1.67e-01	8.32e-02	-2.27*	1.36e-03	9.79e-04	-2.61*	No
	02	80	26.49	2.984	0.00	-2.10e-02	5.21e-03	-0.76	-9.00e-05	2.49e-04	-0.50	Yes
	T	125	27.95	2.038	-0.72	7.30e-02	4.17e-02	-1.90	6.35e-04	5.05e-04	-2.45*	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient temperature and ambient temperature (matching valid logger dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. * and ** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table A.4. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air ≠with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia Browne 7.62 cm	01	40	28.13	3.201	-0.27	-1.51e-02	9.12e-02	-1.36	-1.07e-03	1.08e-03	-1.47	No
	02	80	26.09	2.264	-0.13	-4.48e-02	5.66e-03	-3.09**	1.35e-04	2.71e-04	0.61	Yes
	T	120	27.11	1.960	-0.29	-3.00e-02	4.57e-02	-1.55	-4.68e-04	5.58e-04	-1.28	No
Georgia Browne 15.24 cm	01	119	27.38	2.660	0.22	-3.20e-02	2.79e-03	-2.22*	-1.12e-03	8.56e-05	1.12	Yes
	02	80	26.02	3.245	-0.11	-5.46e-02	5.66e-03	-4.37**	4.21e-04	2.71e-04	1.39	Yes
	T	199	26.70	2.098	0.06	-4.33e-02	3.64e-03	-4.24**	-3.50e-04	1.42e-04	1.66	Yes
Georgia Browne 22.86 cm	01	119	27.55	2.491	0.29	-3.99e-02	2.79e-03	-4.31**	-1.25e-03	8.56e-05	0.00	Yes
	02	42	24.36	4.194	-0.30	-6.12e-02	5.22e-02	0.04	1.21e-04	1.32e-03	0.61	No
	T	161	25.96	2.439	-0.11	-5.06e-02	2.62e-02	-0.19	-5.65e-04	6.61 e-04	0.62	No
Georgia Browne 30.48 cm	01	46	34.91	2.985	1.31	3.43e-01	8.48e-02	1.46	3.14e-03	1.01e-03	1.23	No
	02	80	26.42	3.245	-0.02	-5.44e-02	5.66e-03	-4.34**	8.00e-05	2.71e-04	0.46	Yes
	T	126	30.67	2.205	0.88	1.44e-01	4.91e-02	1.01	1.61e-03	5.22e-04	1.31	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between valid logger data and ambient temperature (matching valid logger dates). This test determined whether there was a difference between the two sets of data. * and

** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then 'Yes' is recorded and that particular treatment did create a unique canopy temperature.

Table A.5. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air ≠with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
MDR-98 7.62 cm	01	46	25.32	2.985	-0.40	-2.13e-01	6.04e-02	-2.91**	-3.62e-03	7.79e-04	-4.55**	Yes
	02	80	25.83	2.264	-0.21	-5.21e-02	5.66e-03	-1.33	4.79e-04	2.71e-04	1.57	No
	T	126	25.58	1.873	-0.44	-1.33e-01	3.03e-02	-3.45**	-1.57e-03	4.12e-04	-3.36**	Yes
MDR-98 15.24 cm	01	52	24.93	4.024	-0.42	-1.65e-01	5.87e-02	-4.15**	-2.58e-03	7.49e-04	-3.96**	Yes
	02	80	26.88	3.245	0.09	-6.37e-02	5.66e-03	-0.78	-5.00e-05	2.71e-04	0.11	No
	T	132	25.91	2.585	-0.27	-1.14e-01	2.95e-02	-3.47**	-1.32e-03	3.98e-04	-4.32**	Yes
MDR-98 22.86 cm	01	104	27.05	2.665	0.10	-2.36e-02	2.89e-03	0.37	-8.90e-04	8.91e-05	3.45**	Yes
	02	80	25.63	3.039	-0.21	-4.87e-02	5.66e-03	-0.50	4.76e-04	2.71e-04	1.57	No
	T	184	26.34	2.021	-0.09	-3.62e-02	3.18e-03	2.15*	-2.07e-04	1.43e-04	2.52*	Yes
MDR-98 30.48 cm	01	45	28.31	3.018	-0.27	1.19e-02	8.98e-02	-1.86	-6.00e-04	1.06e-03	-2.00*	Yes
	02	80	26.09	3.245	-0.09	-5.20e-02	5.66e-03	-0.56	3.26e-04	2.71e-04	1.15	No
	T	125	27.20	2.216	-0.25	-2.01e-02	4.50e-02	-1.86	-1.37e-04	5.49e-04	-1.48	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between valid logger data and ambient temperature (matching valid logger dates). This test determined whether there was a difference between the two sets of data. * and

** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then 'Yes' is recorded and that particular treatment did create a unique canopy temperature.

Table A.6. Estimates and standard errors for intercept, linear and quadratic parameters for ambient air temperature that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Comparison	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth.
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia Browne vs MDR-98	Ambient	1173	0.68	2.011		5.85e-03	1.493e-02		-3.83e-04	3.500e-04		
	Logger	1173	5.41	2.100		3.23e-01	3.358e-02		3.46e-03	4.597e-04		
	Diff	2346	4.73	2.056	1.63	3.18e-01	2.599e-02	8.64**	3.84e-03	4.086e-04	6.65**	
15.24 cm vs 7.62 cm	Ambient	577	-1.22	1.974		-7.19e-02	2.867e-02		-9.18e-04	3.734e-04		
	Logger	577	-0.08	2.053		5.70e-03	3.119e-02		3.68e-04	4.061e-04		
	Diff	1154	1.14	2.014	0.40	7.76e-02	2.995e-02	1.83	1.29e-03	3.901e-04	2.33*	
22.86 cm vs 7.62 cm	Ambient	591	-1.69	1.917		-1.36e-01	2.798e-02		-2.09e-03	4.454e-04		
	Logger	591	-0.39	2.013		7.62e-02	3.043e-02		1.27e-03	4.844e-04		
	Diff	1182	1.30	1.966	0.47	2.12e-01	2.923e-02	5.12**	3.36e-03	4.653e-04	5.10**	
30.48 cm vs 7.62 cm	Ambient	497	1.39	1.903		8.12e-02	3.973e-02		1.03e-03	4.723e-04		
	Logger	497	5.18	1.989		2.87e-01	4.313e-02		3.51e-03	5.136e-04		
	Diff	994	3.79	1.947	1.38	2.06e-01	4.147e-02	3.51**	2.48e-03	4.934e-04	3.56**	
22.86 cm vs 15.24 cm	Ambient	676	-0.47	2.113		-6.37e-02	1.827e-02		-1.17e-03	3.666e-04		
	Logger	676	-0.31	2.205		7.05e-02	1.987e-02		8.98e-04	3.987e-04		
	Diff	1352	0.16	2.160	0.05	1.34e-01	1.909e-02	4.97**	2.07e-03	3.830e-04	3.82**	
30.48 cm vs 15.24 cm	Ambient	582	2.61	2.100		1.53e-01	3.361e-02		1.95e-03	3.988e-04		
	Logger	582	5.26	2.183		2.81e-01	3.647e-02		3.14e-03	4.337e-04		
	Diff	1164	2.65	2.142	0.87	1.28e-01	3.507e-02	2.59*	1.20e-03	4.166e-04	2.03*	
30.48 cm vs 22.86 cm	Ambient	596	3.08	2.047		2.17e-01	3.302e-02		3.12e-03	4.670e-04		
	Logger	596	5.57	2.146		2.11e-01	3.582e-02		2.25e-03	5.078e-04		
	Diff	1192	2.49	2.097	0.84	6.00e-03	3.445e-02	-0.12	8.75e-04	4.878e-04	-1.27	

Table A.7. Estimates and standard errors for intercept, linear and quadratic parameters for ambient air temperature that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Comparison	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth.
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia	Ambient	577	-1.50	1.974		-1.06e-01	2.867e-02		-1.42e-03	3.734e-04		
Browne vs MDR-98	Logger	577	-0.74	2.053		-3.23e-02	3.119e-02		-1.32e-04	4.061e-04		
15.24 cm vs 7.62 cm	Diff	1154	0.76	2.014	0.27	7.35e-02	2.995e-02	1.73	1.29e-03	3.901e-04	2.34*	
Georgia	Ambient	591	-1.45	1.917		-8.49e-02	2.798e-02		-1.15e-03	4.454e-04		
Browne vs MDR-98	Logger	591	-1.91	2.013		-1.17e-01	3.043e-02		-1.46e-03	4.844e-04		
22.86 cm vs 7.62 cm	Diff	1182	-0.46	1.966	-0.17	-3.26e-02	2.923e-02	-0.79	-3.10e-04	4.653e-04	-0.47	
Georgia	Ambient	497	-1.09	1.903		-6.02e-02	3.973e-02		-6.70e-04	4.723e-04		
Browne vs MDR-98	Logger	497	1.94	1.989		6.11e-02	4.313e-02		6.45e-04	5.136e-04		
30.48 cm vs 7.62 cm	Diff	994	3.03	1.947	1.10	1.21e-01	4.147e-02	2.07*	1.32e-03	4.934e-04	1.88	
Georgia	Ambient	676	0.05	2.113		2.09e-02	1.827e-02		2.73e-04	3.666e-04		
Browne vs MDR-98	Logger	676	-1.17	2.205		-8.51e-02	1.987e-02		-1.33e-03	3.987e-04		
22.86 cm vs 15.24 cm	Diff	1352	-1.22	2.160	-0.40	-1.06e-01	1.909e-02	-3.93**	-1.60e-03	3.830e-04	-2.95**	
Georgia	Ambient	582	0.41	2.100		4.56e-02	3.361e-02		7.53e-04	3.988e-04		
Browne vs MDR-98	Logger	582	2.68	2.183		9.34e-02	3.647e-02		7.77e-04	4.337e-04		
30.48 cm vs 15.24 cm	Diff	1164	2.27	2.142	0.75	4.78e-02	3.507e-02	0.96	2.45e-05	4.166e-04	0.04	
Georgia	Ambient	596	0.36	2.047	0.12	2.47e-02	3.302e-02	0.53	4.80e-04	4.670e-04	0.73	
Browne vs MDR-98	Logger	596	3.85	2.146	1.27	1.79e-01	3.582e-02	3.52*	2.11e-03	5.078e-04	2.93**	
30.48 cm vs 22.86 cm	Diff	1192	3.49	2.097	1.18	1.54e-01	3.445e-02	3.16**	1.63e-03	4.878e-04	2.36*	

Table A.8. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air humidity data for Tifton, Georgia for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2001 and 2002. Ambient data from State of Georgia Weather Service, Dr. Gerrit Hoogenboom. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Ambient Air Humidity	Yr	N ^a	Intercept			Linear			Quadratic			Air agrees with logger
			Est. ^b	SE ^c	t	Est.	SE	t	Est.	SE	t	
	01	131	91.63	1.222	-	-1.45e-02	1.33e-02	-	-2.02e-03	3.94e-04	-	-
	02	81	76.85	1.554	-	1.11e-01	2.47e-02	-	1.24e-03	1.31e-03	-	-
	T	212	84.24	0.988	-	4.80e-02	1.52e-02	-	-3.89-04	6.84e-04	-	-

^a N represents the number of days in which data loggers recorded the complete set (entire recording for growing season) of microclimate data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted complete ambient humidity in 2001 and 2002.

^c Standard error estimation for parameter estimates.

Table A.9. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient humidity data that matches valid logger data in 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only corresponds to valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air agrees with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia Browne 7.62 cm	01	40	73.34	16.356	1.12	-9.25e-01	4.66e-01	1.95	-1.22e-02	5.53e-03	1.83	No
	02	80	76.85	11.566	0.00	1.11e-01	2.89e-02	0.00	1.24e-03	1.38e-03	0.00	Yes
	T	120	75.09	10.016	0.91	-4.07e-01	2.33e-01	1.95	-5.47e-03	2.85e-03	1.73	No
Georgia Browne 15.24 cm	01	119	89.36	13.673	0.17	-6.52e-02	1.19e-01	0.42	-2.09e-03	1.88e-03	0.04	Yes
	02	80	76.85	16.677	0.00	1.11e-01	2.89e-02	0.00	1.24e-03	1.38e-03	0.00	Yes
	T	199	83.10	10.783	0.10	2.27e-02	7.07e-02	0.35	-4.24e-04	1.17e-03	0.03	Yes
Georgia Browne 22.86 cm	01	119	91.65	5.060	0.00	-1.30e-02	1.42e-02	-0.08	-2.11e-03	4.36e-04	0.15	Yes
	02	42	67.56	8.517	1.07	1.23e-00	2.67e-01	-4.18**	-2.37e-02	6.74e-03	3.63**	Yes
	T	161	79.61	4.954	0.92	6.09e-01	1.34e-01	-4.17**	-1.29e-02	3.38e-03	3.63**	Yes
Georgia Browne 30.48 cm	01	46	74.70	15.252	1.11	-8.79e-01	4.33e-01	2.00*	-1.19e-02	5.16e-03	1.92	No
	02	80	76.85	16.677	0.00	1.11e-01	2.89e-02	0.00	1.24e-03	1.38e-03	0.00	Yes
	T	126	75.77	11.300	0.75	-3.48e-01	2.51e-01	1.96	-5.35e-03	2.67e-03	1.80	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient humidity and ambient humidity(matching valid logger dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. * and ** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table A.10. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient humidity data that matches valid logger data in 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only corresponds to valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air agrees with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
MDR-98 7.62 cm	01	46	72.46	15.252	1.25	-9.45e-01	3.09e-01	3.01**	-1.24e-02	3.98e-03	2.60*	No
	02	80	76.85	11.566	0.00	1.11e-01	2.89e-02	0.00	1.24e-03	1.38e-03	0.00	Yes
	T	126	74.66	9.571	1.00	-4.17e-01	1.55e-01	2.99**	-5.58e-03	2.11e-03	2.35*	No
MDR-98 15.24 cm	01	52	71.89	20.684	0.95	1.03e-00	3.00e-01	-3.47**	-1.37e-02	3.83e-03	3.03**	Yes
	02	80	76.85	16.677	0.00	1.11e-01	2.89e-02	0.00	1.24e-03	1.38e-03	0.00	Yes
	T	132	74.37	13.285	0.74	5.69e-01	1.51e-01	-3.44**	-6.21e-03	2.03e-03	2.71**	Yes
MDR-98 22.86 cm	01	104	82.19	5.413	1.70	-1.16e-02	1.48e-02	-0.15	-2.07e-03	4.53e-04	0.08	No
	02	80	67.56	6.172	1.46	1.11e-01	2.89e-02	0.00	1.24e-03	1.38e-03	0.00	Yes
	T	184	74.88	4.105	2.22	4.97e-02	1.62e-02	-0.08	-4.14e-04	7.28e-04	0.03	No
MDR-98 30.48 cm	01	45	72.40	15.421	1.24	-9.85e-01	4.62e-01	2.10*	-1.31e-02	5.44e-03	2.03*	No
	02	80	76.85	11.566	0.00	1.11e-01	2.89e-02	0.00	1.24e-03	1.38e-03	0.00	Yes
	T	125	74.62	9.638	0.99	-4.37e-01	2.32e-01	2.09*	-5.91e-03	2.81e-03	1.91	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient humidity and ambient humidity (matching valid logger dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. * and ** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table A.11. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air ≠with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia Browne 7.62 cm	01	40	55.54	3.201	-1.07	-1.66e-00	4.99e-01	-1.45	-2.10e-02	5.93e-03	-1.09	No
	02	80	86.77	2.264	0.84	7.24e-02	3.10e-02	-1.23	1.67e-03	1.48e-03	0.21	No
	T	120	71.16	1.960	-0.39	-7.92e-01	2.50e-01	-1.52	-9.66e-03	3.05e-03	-1.00	No
Georgia Browne 15.24 cm	01	119	98.92	2.660	0.69	7.51e-01	1.27e-01	4.68**	9.08e-03	2.01e-03	4.06**	Yes
	02	80	93.86	3.245	1.00	2.56e-01	3.10e-02	3.43**	-2.57e-03	1.48e-03	-1.88	Yes
	T	199	96.39	2.098	1.21	5.04e-01	6.55e-02	4.99**	3.25e-03	1.25e-03	2.15*	Yes
Georgia Browne 22.86 cm	01	119	98.07	2.491	1.14	1.66e-01	1.53e-02	8.58**	-1.11e-03	4.67e-04	1.57	Yes
	02	42	72.83	4.194	0.56	1.72e-00	2.86e-01	1.25	-3.18e-02	7.22e-03	-0.82	No
	T	161	85.45	2.439	1.06	9.43e-01	1.43e-01	1.70	-1.64e-02	3.62e-03	-0.71	No
Georgia Browne 30.48 cm	01	46	43.86	2.985	-1.98	-1.92e-00	4.64e-01	-1.63	-2.03e-02	5.52e-03	-1.11	Yes
	02	80	90.76	3.245	0.82	3.23e-01	3.10e-02	5.00**	-1.88e-03	1.48e-03	-1.54	Yes
	T	126	67.31	2.205	-0.73	-7.97e-01	2.32e-01	-1.21	-1.11e-02	2.86e-03	-1.46	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between valid logger data and ambient humidity (matching valid logger dates). This test determined whether there was a difference between the two sets of data. * and ** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then 'Yes' is recorded and that particular treatment did create a unique canopy humidity.

Table A.12. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Cultivar/ Plant Spacing (cm)	Yr	N ^a	Intercept			Linear			Quadratic			Air ≠ with logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
MDR-98 7.62 cm	01	46	101.23	2.745	1.86	6.04e-01	3.30e-01	3.42**	6.17e-03	4.26e-03	3.19**	Yes
	02	80	91.01	2.082	1.20	1.80e-01	3.10e-02	1.62	-2.77e-03	1.48e-03	-1.98*	Yes
	T	126	96.12	1.723	2.21*	3.92e-01	1.66e-01	3.56**	1.70e-03	2.25e-03	2.36*	Yes
MDR-98 15.24 cm	01	52	96.11	3.701	1.15	6.05e-01	3.21e-01	-0.97	9.58e-03	4.10e-03	4.15**	Yes
	02	80	88.47	2.984	0.69	2.40e-01	3.10e-02	3.05**	-2.90e-04	1.48e-03	-0.76	No
	T	132	92.29	2.377	1.33	4.22e-01	1.61e-01	-0.66	4.65e-03	2.18e-03	3.65**	Yes
MDR-98 22.86 cm	01	104	95.59	2.451	2.26*	1.17e-01	1.58e-02	5.94**	-2.52e-03	4.86e-04	-0.68	Yes
	02	80	78.12	2.795	1.56	2.87e-01	3.10e-02	4.16**	-1.28e-03	1.48e-03	-1.24	Yes
	T	184	86.86	1.859	2.66**	2.02e-01	1.74e-02	-10.60**	-1.90e-03	7.80e-04	-1.39	Yes
MDR-98 30.48 cm	01	45	46.17	2.776	-1.67	-2.04e-00	4.95e-01	-1.56	-2.28e-02	5.82e-03	-1.22	No
	02	80	88.57	2.984	0.98	2.16e-01	3.10e-02	2.47*	-1.93e-03	1.48e-03	-1.57	Yes
	T	125	67.37	2.038	-0.74	-9.13e-01	2.48e-01	-1.40	-1.24e-02	3.00e-03	-1.57	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between valid logger data and ambient humidity (matching valid logger dates). This test determined whether there was a difference between the two sets of data. * and ** indicates significance at $P \leq 0.05$ and 0.01 , respectively.

^e If air does not agree with logger (determined by t-tests) then 'Yes' is recorded and that particular treatment did create a unique canopy humidity.

Table A.13. Estimates and standard errors for intercept, linear and quadratic parameters for ambient air humidity that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Comparison	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth.
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia Browne vs MDR-98	Ambientn	1173	0.68	2.011	0.24	5.85e-03	1.493e-02	0.28	-3.83e-04	3.500e-04	-0.77	
	Logger	1173	5.41	2.186	1.75	3.23e-01	3.358e-02	6.81**	3.46e-03	4.597e-04	5.32**	
	Diff	2346	4.73	1.485	2.25*	3.18e-01	1.838e-02	12.22**	3.84e-03	2.889e-04	9.41**	
15.24 cm vs 7.62 cm	Ambientn	577	-1.22	1.974	-0.44	-7.19e-02	2.867e-02	-1.77	-9.18e-04	3.734e-04	-1.74	
	Logger	577	-0.08	2.147	-0.03	5.70e-03	3.119e-02	0.13	3.68e-04	4.061e-04	0.64	
	Diff	1154	1.14	1.458	0.55	7.76e-02	2.118e-02	2.59*	1.29e-03	2.758e-04	3.30**	
22.86 cm vs 7.62 cm	Ambientn	591	-1.69	1.917	-0.62	-1.36e-01	2.798e-02	-3.43**	-2.09e-03	4.454e-04	-3.32**	
	Logger	591	-0.39	2.085	-0.13	7.62e-02	3.043e-02	1.77	1.27e-03	4.844e-04	1.85	
	Diff	1182	1.30	1.416	0.65	2.12e-01	2.067e-02	7.24**	3.36e-03	3.290e-04	7.21**	
30.48 cm vs 7.62 cm	Ambientn	497	1.39	1.903	0.52	8.12e-02	3.973e-02	1.44	1.03e-03	4.723e-04	1.54	
	Logger	497	5.18	2.069	1.77	2.87e-01	4.313e-02	4.70**	3.51e-03	5.136e-04	4.83**	
	Diff	994	3.79	1.406	1.91	2.06e-01	2.932e-02	4.96**	2.48e-03	3.489e-04	5.03**	
22.86 cm vs 15.24 cm	Ambientn	676	-0.47	2.113	-0.16	-6.37e-02	1.827e-02	-2.47*	-1.17e-03	3.666e-04	-2.26*	
	Logger	676	-0.31	2.298	-0.10	7.05e-02	1.987e-02	2.51*	8.98e-04	3.987e-04	1.59	
	Diff	1352	0.16	1.561	0.07	1.34e-01	1.350e-02	7.03**	2.07e-03	2.708e-04	5.41**	
30.48 cm vs 15.24 cm	Ambientn	582	2.61	2.100	0.88	1.53e-01	3.361e-02	3.22**	1.95e-03	3.988e-04	3.45**	
	Logger	582	5.26	2.283	1.63	2.81e-01	3.647e-02	5.45**	3.14e-03	4.337e-04	5.12**	
	Diff	1164	2.65	1.551	1.21	1.28e-01	2.480e-02	3.66**	1.20e-03	2.946e-04	2.87**	
30.48 cm vs 22.86 cm	Ambientn	596	3.08	2.047	1.06	2.17e-01	3.302e-02	4.64**	3.12e-03	4.670e-04	4.72**	
	Logger	596	5.57	2.225	1.77	2.11e-01	3.582e-02	4.16**	2.25e-03	5.078e-04	3.13**	
	Diff	1192	2.49	1.512	1.16	-6.00e-03	2.436e-02	-0.17	-8.75e-04	3.449e-04	-1.79	

Table A.14. Estimates and standard errors for intercept, linear and quadratic parameters for ambient air humidity that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Comparison	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth.
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Georgia Browne vs MDR-98 15.24 cm vs 7.62 cm	Ambientnt	577	-1.50	1.974	-0.54	-1.06e-01	2.867e-02	-2.61*	-1.42e-03	3.734e-04	-2.69**	
	Logger	577	-0.74	2.147	-0.24	-3.23e-02	3.119e-02	-0.73	-1.32e-04	4.061e-04	-0.23	
	Diff	1154	0.76	1.458	0.37	7.35e-02	2.118e-02	2.45*	1.29e-03	2.758e-04	3.31**	
Georgia Browne vs MDR-98 22.86 cm vs 7.62 cm	Ambientnt	591	-1.45	1.917	-0.53	-8.49e-02	2.798e-02	-2.14*	-1.15e-03	4.454e-04	-1.83	
	Logger	591	-1.91	2.085	-0.65	-1.17e-01	3.043e-02	-2.73**	-1.46e-03	4.844e-04	-2.13*	
	Diff	1182	-0.46	1.416	-0.23	-3.26e-02	2.067e-02	-1.11	-3.10e-04	3.290e-04	-0.67	
Georgia Browne vs MDR-98 30.48 cm vs 7.62 cm	Ambientnt	497	-1.09	1.903	-0.41	-6.02e-02	3.973e-02	-1.07	-6.70e-04	4.723e-04	-1.00	
	Logger	497	1.94	2.069	0.66	6.11e-02	4.313e-02	1.00	6.45e-04	5.136e-04	0.89	
	Diff	994	3.03	1.406	1.52	1.21e-01	2.932e-02	2.92**	1.32e-03	3.489e-04	2.67	
Georgia Browne vs MDR-98 22.86 cm vs 15.24 cm	Ambientnt	676	0.05	2.113	0.02	2.09e-02	1.827e-02	0.81	2.73e-04	3.666e-04	0.53	
	Logger	676	-1.17	2.298	-0.36	-8.51e-02	1.987e-02	-3.03**	-1.33e-03	3.987e-04	-2.36	
	Diff	1352	-1.22	1.561	-0.55	-1.06e-01	1.350e-02	-5.55**	-1.60e-03	2.708e-04	-4.18	
Georgia Browne vs MDR-98 30.48 cm vs 15.24 cm	Ambientnt	582	0.41	2.100	0.14	4.56e-02	3.361e-02	0.96	7.53e-04	3.988e-04	1.33	
	Logger	582	2.68	2.283	0.83	9.34e-02	3.647e-02	1.81	7.77e-04	4.337e-04	1.27	
	Diff	1164	2.27	1.551	1.03	4.78e-02	2.480e-02	1.36	2.45e-05	2.946e-04	0.06	
Georgia Browne vs MDR-98 30.48 cm vs 22.86 cm	Ambientnt	596	0.36	2.047	0.12	2.47e-02	3.302e-02	0.53	4.80e-04	4.670e-04	0.73	
	Logger	596	3.85	2.225	1.22	1.79e-01	3.582e-02	3.52**	2.11e-03	5.078e-04	2.93	
	Diff	1192	3.49	1.512	1.63	1.54e-01	2.436e-02	4.46**	1.63e-03	3.449e-04	3.33	

APPENDIX B
APPENDIX TO CHAPTER 3 ¹

¹ Data included will not be published in other venues.

Field one. Regression analysis of weather data across each growing season revealed some differences, but differences were not consistent and some data was compromised by logger failures. Mean canopy temperature and humidity were analyzed using regression analysis (Draper and Smith 1981) across each growing season, and predicted curves for all treatments and ambient conditions are shown in Figures B.1 and B.2. Analysis of these curves are shown in Tables B.1-B.14. Estimated intercept, slope and quadratic values for ambient temperature and humidity conditions which correspond to data loggers that recorded without missing any days during entire recording period are shown in Tables B.1 and B.8. Tables B.2, B.3, B.9 and B.10 show parameter estimates for ambient data that corresponds to valid recorded data. T-tests were conducted to determine differences between this matching ambient weather (corresponding to valid recording dates) with the complete ambient conditions for the entire recording period. If there were any differences ($t > 1.98$), then there is indication that the logger data recorded is questionable and is represented by a 'No' (Tables B.2, B.3, B.9 and B.10). Estimated intercept, slope and quadratic values for valid logger data only are presented in Tables B.4, B.5, B.11 and B.12. T-tests were also used to determine if there was a significant difference between the canopy conditions and ambient conditions (corresponding to the valid recording days). Some treatments were

significantly different ($t > 1.98$), indicating a unique canopy environment and are represented as a 'Yes' (Tables B.4, B.5, B.11 and B.12). Testing of ambient data and logger data was also conducted for each treatment comparison (Tables B.6, B.7, B.13 and B.14). Null hypotheses were set up for both ambient and logger data. Ambient data should remain the same ($t < 1.98$), regardless of the treatment comparison, and logger data (as well as the difference between ambient and logger data) should be different ($t > 1.98$) between treatments. If these null hypotheses have failed, then a 'No' is presented (Tables B.6, B.7, B.13 and B.14). There are some differences between some of the treatments based on these analyses. However, due to lacking data for some treatments (determined in Tables B.2, B.3, B.9 and B.10), some results for the treatment comparisons may be questionable.

Field two. Mean canopy temperature and humidity were analyzed using regression analysis (Draper and Smith 1981) across each growing season, and predicted curves for all treatments and ambient conditions are shown in Figures B.3 and B.4. Analysis of these curves are shown in Tables B.15-B.28. Estimated intercept, slope and quadratic values for ambient temperature and humidity conditions which correspond to data loggers that recorded without missing any days during entire recording period are shown in Tables B.15 and B.22. Tables B.16, B.17, B.23 and B.24 show parameter estimates for ambient data that corresponds to valid recorded data. T-tests were conducted to determine differences between this matching ambient weather (corresponding to

valid recording dates) with the complete ambient conditions for the entire recording period. If there were any differences ($t > 1.98$), then there is indication that the logger data recorded is questionable and is represented by a 'No' (Tables B.16, B.17, B.23 and B.24). Estimated intercept, slope and quadratic values for valid logger data only are presented in Tables B.18, B.19, B.25 and B.26. T-tests were also used to determine if there was a significant difference between the canopy conditions and ambient conditions (corresponding to the valid recording days). Some treatments were significantly different ($t > 1.98$), indicating a unique canopy environment and are represented as a 'Yes' (Tables B.18, B.19, B.25 and B.26). Testing of ambient data and logger data was also conducted for each treatment comparison (Tables B.20, B.21, B.27 and B.28). Null hypotheses were set up for both ambient and logger data. Ambient data should remain the same ($t < 1.98$), regardless of the treatment comparison, and logger data (as well as the difference between ambient and logger data) should be different ($t > 1.98$) between treatments. If these null hypotheses have failed, then a 'No' is presented (Tables B.20, B.21, B.27 and B.28). There are some differences between some of the treatments based on these analyses. However, due to lacking data for some treatments (determined in B.16, B.17, B.23 and B.24), some results for the treatment comparisons may be questionable.

Analysis of environmental data showed that temperature and relative humidity within the peanut canopy were consistently different than ambient conditions. Examination of the predicted curves for the canopy conditions and

corresponding analyses did not reveal large differences between treatments, at least not of a magnitude to biologically explain the obvious significant disease differences between treatments. Unfortunately data gaps with some sensors made it more difficult to distinguish differences due to planting pattern. In general, most of the mean canopy temperatures fell into the large temperature range for fungal growth (8-40°C and maximum growth at 27-30°C)(Aycok, 1966; Punja 1985). Perhaps, space between plants was the critical factor in *S. rolfsii* growth and subsequent stem rot development.

Table B.1. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air temperature data for Tifton, Georgia, for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2000, 2001 and 2002. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Row spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger
			Est. ^b	SE ^c	t	Est.	SE	t	Est.	SE	t	
Ambient Air Temp	00	77	26.41	0.276	-	1.74e-02	5.99e-03	-	-5.70e-04	3.01e-04	-	-
	01	122	26.41	0.245	-	-1.70e02	2.73e-03	-	-1.12e-03	8.13e-05	-	-
	02	84	26.54	0.272	-	-1.94e-02	5.25e-03	-	-1.70e-04	2.43e-04	-	-
	T	283	26.45	0.153	-	-6.33e-03	2.81e-03	-	-6.20e-04	1.32e-04	-	-

^aN represents the number of days in which data loggers recorded the complete set (entire recording for growing season) of microclimate data.

^bEstimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature in 2000, 2001 and 2002.

^cStandard error estimation for parameter estimates.

Table B.2. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row spacing/ seeding rate	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm	00	77	26.41	0.731	0.00	1.74e-02	5.46e-03	0.00	-5.70e-04	2.74e-04	0.00	Yes
	01	104	26.59	0.689	-0.25	-1.78e-02	2.83e-03	0.21	-1.19e-03	7.92e-05	0.62	Yes
	02	84	26.54	0.721	0.00	-1.94e-02	4.79e-03	0.00	-1.70e-04	2.21e-04	0.00	Yes
12.5 Seed/m	T	265	26.52	0.412	-0.14	-6.60e-03	2.60e-03	0.07	-6.43e-04	1.20e-04	0.13	Yes
Single 91.44 cm	00	71	26.63	0.731	-0.28	1.78e-02	5.46e-03	-0.05	-8.10e-04	2.90e-04	0.57	Yes
	01	121	26.54	0.691	-0.18	-1.71e-02	2.49e-03	0.03	-1.17e-03	7.78e-05	0.44	Yes
	02	40	26.14	0.747	0.50	-1.49e-02	5.81e-03	-0.58	5.20e-05	3.84e-04	-0.49	Yes
17.4 Seed/m	T	232	26.44	0.418	0.04	-4.73e-03	2.78e-03	-0.40	-6.43e-04	1.62e-04	0.11	Yes
Single 91.44 cm	00	68	26.43	0.730	-0.02	2.78e-02	6.30e-03	-1.20	-9.40e-04	2.93e-04	3.20**	No
	01	113	26.18	0.699	0.30	-5.89e-03	2.84e-03	-2.81**	-7.60e-04	9.12e-05	-2.95**	No
	02	63	26.65	0.734	-0.13	-1.11e-02	1.21e-02	-0.63	-3.00e-05	4.53e-04	-0.27	Yes
22.6 Seed/m	T	244	26.42	0.416	0.08	3.60e-03	4.64e-03	-1.83	-5.77e-04	1.83e-04	-0.19	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient temp (Table 3.1) and ambient temp (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *significant difference at 5% level and **indicates significance at 1% level.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.3. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row spacing/ seeding rate	Yr	N ^a	Intercept			Linear			Quadratic		t	Air Agrees With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE		
Twin 20.32 cm 6.2 Seed/m	00	72	26.56	0.757	0.19	1.75e-02	5.46e-03	0.01	-7.40e-04	2.87e-04	-0.41	Yes
	01	54	25.36	0.957	-1.06	0.00	-	-	0.00	-	-	-
	02	83	26.54	0.725	0.00	-1.91e-02	4.88e-03	0.04	-1.50e-04	2.28e-04	0.06	Yes
	T	209	26.16	0.474	-0.59	-8.00e-04	3.66e-03	1.20	-4.45e-04	1.83e-04	0.78	Yes
Twin 20.32 cm 8.9 Seed/m	00	77	26.41	0.702	0.00	1.74e-02	5.46e-03	0.00	-5.70e-04	2.74e-04	0.00	Yes
	01	54	25.36	1.035	-0.98	0.00	-	-	0.00	-	-	-
	02	24	27.16	0.964	0.62	-2.11e-02	2.49e-03	-0.29	-8.90e-04	7.35e-04	-0.93	Yes
	T	155	26.31	0.527	-0.25	-1.85e-03	3.00e-03	1.09	-7.30e-04	3.92e-04	-0.27	Yes
Twin 20.32 cm 11.5 Seed/m	00	77	26.41	0.686	0.00	1.74e-02	5.46e-03	0.00	-5.70e-04	2.74e-04	0.00	Yes
	01	108	26.45	0.716	0.06	-1.66e-02	2.54e-03	0.11	-1.15e-03	8.20e-05	-0.26	Yes
	02	84	26.54	0.636	0.01	-1.94e-02	4.79e-03	0.00	-1.70e-04	2.21e-04	0.00	Yes
	T	269	26.47	0.393	0.05	-6.20e-03	2.56e-03	0.03	-6.30e-04	1.21e-04	-0.06	Yes

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient temp (Table 3.1) and ambient temp (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *significant difference at 5% level and **indicates significance at 1% level.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.4. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row spacing/ seeding rate	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal with Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm 12.5 Seed/m	00	77	27.95	0.738	1.49	-1.66e-02	5.51e-03	-1.31	-1.62e-03	3.92e-04	-2.25*	Yes
	01	104	27.56	0.696	0.99	-2.91e-02	2.86e-03	-2.47*	-1.10e-03	1.13e-04	-1.80	Yes
	02	84	26.70	0.728	0.15	-3.76e-02	4.84e-03	-3.02**	1.10e-05	3.15e-04	1.01	Yes
	T	265	27.40	0.416	1.51	-2.78e-02	2.62e-03	-2.36*	-9.03e-04	1.72e-04	-1.18	Yes
Single 91.44 cm 17.4 Seed/m	00	71	27.90	0.737	1.22	-1.89e-02	5.51e-03	-1.49	-1.63e-03	4.14e-04	-2.19*	Yes
	01	121	27.14	0.687	0.61	-2.79e-02	2.52e-03	-2.38*	-1.19e-03	1.11e-04	-2.06*	Yes
	02	40	26.50	0.767	0.33	-3.71e-02	5.87e-03	-2.88**	1.10e-04	5.48e-04	0.88	Yes
	T	232	27.18	0.422	1.24	-2.80e-02	2.81e-03	-2.37*	-9.03e-04	2.32e-04	-1.09	Yes
Single 91.44 cm 22.6 Seed/m	00	68	27.27	0.736	0.81	-6.56e-03	6.36e-03	-0.51	-1.89e-03	4.19e-04	-2.66**	Yes
	01	113	27.09	0.706	0.92	-2.32e-02	2.87e-03	-1.97	-9.40e-04	1.30e-04	-1.33	No
	02	63	27.03	0.740	0.36	-3.86e-02	1.22e-02	-2.31*	-5.00e-04	6.47e-04	-0.06	Yes
	T	244	27.13	0.420	1.20	-2.28e-02	4.67e-03	-1.85	-1.11e-03	2.61e-04	-1.53	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient temp (matching valid logger data dates)(Table 3.2) and valid logger data. T-tests determined whether there was a difference between the two sets of data.

*significant difference at 5% level and **indicates significance at 1% level.

^e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy temperature.

Table B.5. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row spacing/ seeding rate	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal with Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Twin 20.32 cm	00	72	27.90	0.763	1.24	-1.75e-02	5.51e-03	-1.38	-1.31e-03	4.10e-04	-1.61	No
	01	54	27.01	0.966	1.21	0.00	-	-	0.00	-	-	No
6.2 Seed/m	02	83	27.00	0.733	0.44	-2.26e-02	4.93e-03	-1.82	-8.00e-05	3.25e-04	0.80	No
	T	209	27.30	0.478	1.70	-2.01e-02	2.46e-03	-1.72	-6.95e-04	1.74e-04	-0.63	No
Twin 20.32 cm	00	77	27.64	0.709	1.23	-2.82e-02	5.51e-03	-2.22*	-1.19e-03	3.92e-04	-1.42	Yes
	01	54	26.88	1.029	1.04	0.00	-	-	0.00	-	-	No
8.9 Seed/m	02	24	27.76	0.991	0.43	-8.28e-02	1.86e-02	-3.79**	-2.63e-03	1.05e-03	-1.97	?
	T	155	27.43	0.517	1.51	-5.55e-02	6.47e-03	-4.22**	-1.91e-03	3.74e-04	-2.88**	?
Twin 20.32 cm	00	77	27.68	0.693	1.30	-2.50e-02	5.51e-03	-1.97	-1.48e-03	3.92e-04	-1.98	No
	01	108	27.31	0.722	0.84	-3.16e-02	2.56e-03	-2.69**	-1.04e-03	1.17e-04	-1.63	Yes
11.5 Seed/m	02	84	27.19	0.642	0.72	-3.16e-02	4.84e-03	-2.54*	-5.00e-04	3.15e-04	-0.09	Yes
	T	269	27.39	0.396	1.65	-2.94e-02	2.59e-03	-2.50*	-1.01e-03	1.72e-04	-1.45	Yes

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient temp (matching valid logger data dates)(Table 3.3) and valid logger data. T-tests determined whether there was a difference between the two sets of data.

*significant difference at 5% level and **indicates significance at 1% level.

^e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy temperature.

Table B.6. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Test	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single Low vs Medium	Ambient	495	0.08	0.415	0.14	-1.87e-03	2.69e-03	-0.49	0.00e-00	1.43e-04	0.00	Yes
	Logger	495	0.22	0.419	0.37	2.00e-04	2.72e-03	0.05	0.00e-00	2.04e-04	0.00	No
	Diff	990	0.14	0.295	0.34	2.07e-03	1.91e-03	0.77	0.00e-00	1.25e-04	0.00	No
Single Low vs High	Ambient	507	0.10	0.414	0.17	-1.02e-02	3.76e-03	-1.92	-6.60e-05	1.55e-04	-0.30	Yes
	Logger	507	0.27	0.418	0.46	-5.00e-03	3.79e-03	-0.93	2.07e-04	2.21e-04	0.66	No
	Diff	1014	0.17	0.294	0.41	5.20e-03	2.67e-03	1.38	2.73e-04	1.35e-04	1.43	No
Single Medium vs High	Ambient	474	0.02	0.417	0.03	-8.33e-03	3.83e-03	-1.54	-6.60e-05	1.73e-04	-0.27	Yes
	Logger	474	0.02	0.417	0.03	-8.33e-03	3.83e-03	-1.54	-6.60e-05	1.73e-04	-0.27	No
	Diff	948	0.00	0.295	0.00	0.00e-00	2.71e-03	0.00	0.00e-00	1.22e-04	0.00	No
Twin Low vs Medium	Ambient	362	-0.15	0.501	-0.21	1.05e-03	3.35e-03	0.22	2.85e-04	3.06e-04	0.66	Yes
	Logger	362	-0.13	0.498	-0.18	3.54e-02	4.90e-03	5.11**	1.22e-03	2.92e-04	2.95**	Yes
	Diff	724	0.02	0.353	0.04	3.44e-02	2.97e-03	8.19**	9.30e-04	2.11e-04	3.11**	Yes
Twin Low vs High	Ambient	476	-0.31	0.435	-0.50	5.40e-03	3.16e-03	1.21	1.85e-04	1.56e-04	0.84	Yes
	Logger	476	-0.09	0.439	-0.14	9.30e-03	2.53e-03	2.60*	3.15e-04	1.77e-04	1.29	Yes
	Diff	952	0.22	0.309	0.50	3.90e-03	2.02e-03	1.36	1.30e-04	1.16e-04	0.79	No
Twin Medium vs High	Ambient	422	-0.16	0.465	-0.24	4.35e-03	2.79e-03	1.10	-1.00e-04	2.90e-04	-0.24	Yes
	Logger	422	0.04	0.460	0.06	-2.61e-02	4.93e-03	-3.75**	-9.00e-04	2.91e-04	-2.19*	Yes
	Diff	844	0.20	0.327	0.43	-3.05e-02	2.83e-03	-7.61**	-8.00e-04	2.05e-04	-2.75**	Yes

^a N represents the number of days in which data loggers recorded data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient temps (matching valid logger data dates) and valid logger data for each row spacing comparison. T-tests determined whether there was a difference between the two sets of data. *significant difference at 5% level and **indicates significance at 1% level.

^eNull hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger is that there will be differences between row spacings. Diff. is the difference between ambient and logger.

Table B.7. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Test	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
	Ambient	472	0.36	0.444	0.57	-5.80e-03	3.18e-03	-1.29	-1.98e-05	1.55e-04	-0.90	Yes
Low Single vs Twin	Logger	472	0.10	0.448	0.16	-7.70e-03	2.54e-03	-2.14*	-2.08e-04	1.73e-04	-0.85	Yes
	Diff	944	-0.26	0.315	-0.58	-1.90e-03	2.03e-03	-0.66	-1.00e-05	1.16e-04	-0.06	No
Medium Single vs Twin	Ambient	385	0.13	0.476	0.19	-2.88e-03	2.89e-03	-0.70	8.70e-05	3.00e-04	0.21	Yes
	Logger	385	-0.25	0.472	-0.37	2.75e-02	4.99e-03	3.90**	1.01e-03	3.11e-04	2.29*	Yes
	Diff	770	-0.38	0.335	-0.80	3.04e-02	2.88e-03	7.45**	9.20e-04	2.16e-04	3.01**	Yes
High Single vs Twin	Ambient	511	-0.05	0.405	-0.09	9.80e-03	3.75e-03	1.85	5.30e-05	1.55e-04	0.24	Yes
	Logger	511	-0.26	0.408	-0.45	6.60e-03	3.78e-03	1.24	-1.00e-04	2.21e-04	-0.32	No
	Diff	1022	-0.21	0.287	-0.52	-3.20e-03	2.66e-03	-0.85	-1.53e-04	1.35e-04	-0.80	No

^a N represents the number of days in which data loggers recorded data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient temps (matching valid logger data dates) and valid logger data for each row spacing comparison. T-tests determined whether there was a difference between the two sets of data. *significant difference at 5% level and **indicates significance at 1% level.

^eNull hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger is that there will be differences between row spacings. Diiff. is the difference between ambient and logger.

Table B.8. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air humidity data for Tifton, Georgia, for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2000, 2001 and 2002. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger
			Est. ^b	SE ^c	t	Est.	SE	t	Est.	SE	t	
Air	00	77	79.97	1.436	-	1.83e-01	3.11e-02	-	-1.20e-03	1.57e-03	-	-
	01	122	91.66	1.274	-	3.89e-03	1.42e-02	-	-2.05e-03	4.22e-04	-	-
	02	84	76.73	1.412	-	1.10e-01	2.73e-02	-	1.08e-03	1.26e-03	-	-
	T	283	82.79	0.794	-	9.89e-02	1.46e-02	-	-7.23e-04	6.85e-04	-	-

^aN represents the number of days in which data loggers recorded the complete set (entire recording for growing season) of microclimate data.

^bEstimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity in 2000, 2001 and 2002.

^cStandard error estimation for parameter estimates.

Table B.9. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm 12.5 seed/m	00	77	79.97	7.567	0.00	1.83e-01	3.11e-02	-0.01	-1.20e-03	1.57e-03	0.00	Yes
	01	104	91.49	6.869	0.02	3.38e-02	1.61e-02	-1.39	-2.54e-03	4.34e-04	0.81	Yes
	02	-	-	-	-	-	-	-	-	-	-	-
	T	181	85.73	5.110	-0.57	1.08e-01	1.75e-02	-0.42	-1.87e-03	8.14e-04	1.08	Yes
Single 91.44 cm 17.4 seed/m	00	71	78.32	5.522	0.29	1.80e-01	3.11e-02	0.06	6.44e-04	1.65e-03	-0.81	Yes
	01	121	91.93	6.312	-0.04	2.55e-03	1.42e-02	0.07	-2.15e-03	4.41e-04	0.16	Yes
	02	40	81.11	4.854	-0.87	1.08e-01	3.32e-02	0.05	-2.70e-03	2.19e-03	1.50	Yes
	T	232	83.79	3.230	-0.30	9.69e-02	1.59e-02	0.09	-1.40e-03	9.27e-04	0.59	Yes
Single 91.44 cm 22.6 seed/m	00	68	80.14	4.135	-0.04	2.19e-01	3.59e-02	-0.76	-2.69e-03	1.68e-03	1.61	Yes
	01	122	92.01	6.342	-0.05	2.50e-03	1.42e-02	0.07	-2.18e-03	4.39e-04	0.21	Yes
	02	63	76.29	3.868	0.11	1.03e-01	6.86e-02	0.09	1.41e-03	2.58e-03	-0.11	Yes
	T	253	82.81	2.834	-0.01	1.08e-01	2.62e-02	-0.31	-1.15e-03	1.04e-03	0.35	Yes

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient humidity (Table 3.8) and ambient humidity (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *significant difference at 5% level and **indicates significance at 1% level.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.10. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Twin 20.32 cm 6.2 seed/m	00	72	78.81	7.826	-0.15	1.82e-01	3.11e-02	-0.02	9.70e-05	1.63e-03	0.57	Yes
	01	54	71.64	9.533	-2.08*	0.00	-	-	0.00	-	-	?
	02	84	76.73	6.441	0.00	1.10e-01	2.73e-02	0.00	1.08e-03	1.26e-03	0.00	Yes
	T	210	75.73	4.639	-1.50	1.46e-01	2.07e-02	1.86	5.89e-04	1.03e-03	1.06	Yes
Twin 20.32 cm 8.9 seed/m	00	77	79.97	5.303	0.00	1.83e-01	3.11e-02	0.00	-1.20e-03	1.56e-03	0.00	Yes
	01	54	71.64	9.449	-2.10*	0.00	-	-	0.00	-	-	?
	02	24	67.79	6.267	-1.39	5.40e-01	8.98e-02	4.58**	1.91e-02	3.69e-03	4.62**	?
	T	155	73.13	4.173	-2.27*	3.62e-01	4.75e-02	5.28	8.95e-03	2.00e-03	4.57**	?
Twin 20.32 cm 11.5 seed/m	00	75	79.40	3.938	-0.14	1.80e-01	3.11e-02	-0.07	-5.80e-04	1.59e-03	0.28	Yes
	01	108	91.11	6.488	-0.08	2.53e-02	2.38e-02	0.77	-1.32e-03	6.71e-04	0.92	Yes
	02	84	76.73	3.350	0.00	1.10e-01	2.73e-02	0.00	1.08e-03	1.26e-03	0.00	Yes
	T	267	82.42	2.766	-0.13	1.05e-01	1.59e-02	0.29	-2.73e-04	7.12e-04	0.46	Yes

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient humidity (Table 3.8) and ambient humidity (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *significant difference at 5% level and **indicates significance at 1% level.

^e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.11. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal With Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm 12.5 seed/m	00	77	84.99	7.827	0.46	2.64e-01	3.22e-02	1.81	1.02e-03	1.62e-03	0.98	No
	01	104	85.67	7.134	-0.59	6.84e-02	1.67e-02	1.49	-1.74e-03	4.68e-04	1.25	No
	02	-	-	-	-	-	-	-	-	-	-	-
	T	181	85.33	5.295	-0.05	1.66e-01	1.81e-02	2.31*	-3.60e-04	843e-04	1.29	Yes
Single 91.44 cm 17.4 seed/m	00	71	86.14	5.711	0.98	2.74e-01	3.22e-02	2.10*	2.14e-03	1.71e-03	0.63	Yes
	01	121	94.15	6.586	0.24	1.17e-01	1.46e-02	5.61**	-2.19e-03	4.57e-04	-0.06	Yes
	02	40	89.45	5.094	1.18	5.90e-02	3.42e-02	-1.34	-2.60e-04	2.26e-03	0.77	Yes
	T	232	89.91	3.366	1.31	1.50e-01	1.64e-02	2.32*	-1.03e-04	9.58e-04	0.97	Yes
Single 91.44 cm 22.6 seed/m	00	68	75.60	4.277	-0.76	2.62e-01	3.71e-02	0.83	3.33e-03	1.73e-03	2.49*	Yes
	01	122	94.05	6.559	2.63**	9.40e-02	1.47e-02	4.48**	-1.93e-03	4.54e-04	0.40	Yes
	02	63	91.88	6.732	2.01*	2.45e-01	7.14e-02	1.43	3.06e-03	2.67e-03	0.60	Yes
	T	253	87.18	3.442	2.62*	2.00e-01	2.73e-02	2.44*	1.49e-03	1.07e-03	1.76	Yes

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient humidity(matching valid logger data dates)(Table 3.9) and valid logger data. T-tests determined whether there was a difference between the two sets of data. *significant difference at 5% level and **indicates significance at 1% level.

^e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy humidity.

Table B.12. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal with Matching ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Twin 20.32 cm 6.2 seed/m	00	72	80.56	8.095	0.16	2.04e-01	3.22e-02	0.49	7.84e-03	1.70e-03	3.37	Yes
	01	54	74.46	9.900	0.21	0.00	-	-	0.00	-	-	?
	02	84	91.58	5.831	1.71	3.58e-02	2.82e-02	-1.90	-2.30e-04	1.30e-03	0.47	No
	T	210	82.20	4.685	0.98	1.20e-01	2.14e-02	-0.88	3.81e-03	1.07e-03	2.96**	Yes
Twin 20.32 cm 8.9 seed/m	00	77	88.29	5.485	1.09	2.49e-01	3.22e-02	1.47	1.11e-03	1.62e-03	1.03	No
	01	54	73.63	9.860	0.15	0.00	-	-	0.00	-	-	?
	02	24	85.62	6.577	1.96	4.03e-01	9.33e-02	-1.06	1.52e-02	3.82e-03	-0.73	?
	T	155	82.51	4.118	1.60	3.26e-01	4.94e-02	-0.53	8.16e-03	2.07e-03	-0.28	?
Twin 20.32 cm 11.5 seed/m	00	75	84.64	4.073	0.92	3.06e-01	3.22e-02	2.82**	3.16e-03	1.65e-03	1.63	Yes
	01	108	95.62	6.972	0.47	-7.81e-03	2.47e-02	-0.88	-3.82e-03	6.94e-04	-2.59*	Yes
	02	84	82.49	5.831	0.86	3.60e-03	2.82e-02	-2.71**	4.33e-03	1.30e-03	2.99**	Yes
	T	267	87.58	3.320	1.20	1.01e-01	1.65e-02	-0.19	1.22e-03	7.37e-04	1.46	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient humidity (matching valid logger data dates)(Table 3.10) and valid logger data. T-tests determined whether there was a difference between the two sets of data. *significant difference at 5% level and **indicates significance at 1% level.

^e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy humidity.

Table B.13. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single Low vs Medium	Ambient	411	1.94	4.275	0.32	1.11e-02	1.67e-02	0.47	-4.70e-04	8.72e-04	-0.38	Yes
	Logger	411	-4.58	4.437	-0.73	1.60e-02	1.73e-02	0.65	-2.57e-04	9.02e-04	-0.20	No
	Diff	822	-6.52	3.080	-1.50	4.90e-03	1.20e-02	0.29	2.13e-04	6.28e-04	0.24	No
Single Low vs High	Ambient	432	2.92	4.132	0.50	0.00e-00	2.23e-02	0.00	-7.20e-04	9.34e-04	-0.55	Yes
	Logger	432	-1.85	4.466	-0.29	-3.40e-02	2.32e-02	-1.04	-1.85e-03	9.64e-04	-1.36	No
	Diff	864	-4.77	3.042	-1.11	-3.40e-02	1.61e-02	-1.50	-1.13e-03	6.71e-04	-1.19	No
Single Medium vs High	Ambient	483	0.98	3.038	0.23	-1.11e-02	2.17e-02	-0.36	-2.50e-04	9.85e-04	-0.18	Yes
	Logger	483	0.98	3.038	0.23	-1.11e-02	2.17e-02	-0.36	-2.50e-04	9.85e-04	-0.18	No
	Diff	966	0.00	2.149	0.00	0.00e-00	1.53e-02	0.00	0.00e-00	6.97e-04	0.00	No
Twin Low vs Medium	Ambient	363	2.60	4.412	0.42	-2.16e-01	3.66e-02	-4.72**	-8.36e-03	1.59e-03	-3.72**	?
	Logger	363	-0.31	4.411	-0.05	-2.06e-01	3.80e-02	-3.83**	-4.35e-03	1.65e-03	-1.86	?
	Diff	726	-2.91	3.119	-0.66	1.00e-02	2.64e-02	0.27	4.01e-03	1.15e-03	2.48*	?
Twin Low vs High	Ambient	475	-6.69	3.819	-1.24	4.10e-02	1.85e-02	1.57	8.62e-04	8.85e-04	0.69	Yes
	Logger	475	-5.38	4.060	-0.94	1.90e-02	1.91e-02	0.70	2.59e-03	9.18e-04	1.99	Yes
	Diff	950	1.31	2.787	0.33	-2.20e-02	1.33e-02	-1.17	1.73e-03	6.38e-04	1.92	No
Twin Medium vs High	Ambient	420	-9.29	3.540	-1.86	2.57e-01	3.54e-02	5.13**	9.22e-03	1.50e-03	4.34**	?
	Logger	420	-5.07	3.740	-0.96	2.25e-01	3.68e-02	4.32**	6.94e-03	1.56e-03	3.15**	Yes
	Diff	840	4.22	2.575	1.16	-3.20e-02	2.55e-02	-0.89	-2.28e-03	1.08e-03	-1.49	No

^a N represents the number of days in which data loggers recorded data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient humidity (matching valid logger data dates) and valid logger data for each row spacing comparison. T-tests determined whether there was a difference between the two sets of data. *significant difference at 5% level and **indicates significance at 1% level.

^e Null hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger is that there will be differences between row spacings. Diff. is the difference between ambient and logger.

Table B.14. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Low Single vs Twin	Ambient	389	10.00	4.880	1.45	-3.80e-02	1.92e-02	-1.40	-2.46e-03	9.28e-04	-1.87	Yes
	Logger	389	3.13	4.999	0.44	4.60e-02	1.98e-02	1.64	-4.17e-03	9.63e-04	-3.06**	Yes
	Diff	778	-6.87	3.493	-1.39	8.40e-02	1.38e-02	4.31**	-1.71e-03	6.87e-04	-1.81	Yes
Medium Single vs Twin	Ambient	385	10.66	3.731	2.02*	-2.65e-01	3.54e-02	-5.29**	-1.04e-02	1.56e-03	-4.70**	?
	Logger	385	7.40	3.761	1.39	-1.76e-01	3.68e-02	-3.38**	-8.26e-03	1.62e-03	-3.62**	?
	Diff	770	-3.26	2.649	-0.87	8.91e-02	2.55e-02	2.47*	2.09e-03	1.12e-03	1.31	?
High Single vs Twin	Ambient	518	0.39	2.800	0.10	3.00e-03	2.17e-02	0.10	-8.77e-04	8.91e-04	-0.70	Yes
	Logger	518	-0.40	3.382	-0.08	9.90e-02	2.25e-02	3.11**	2.70e-04	9.20e-04	0.21	Yes
	Diff	1036	-0.79	2.195	-0.25	9.60e-02	1.56e-02	4.34**	1.15e-03	6.40e-04	1.2	

^a N represents the number of days in which data loggers recorded data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient humidity (matching valid logger data dates) and valid logger data for each row spacing comparison. T-tests determined whether there was a difference between the two sets of data. *significant difference at 5% level and **indicates significance at 1% level.

^eNull hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger is that there will be differences between row spacings. Diiff. is the difference between ambient and logger.

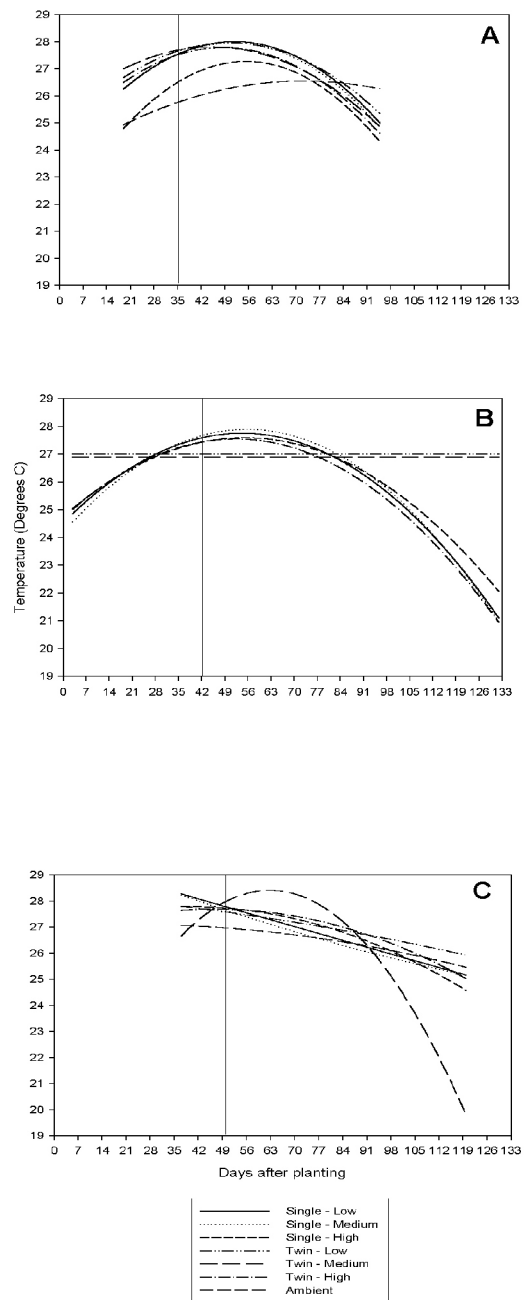


Figure B.1. Predicted response of canopy temperature (C) for the duration of growing season (in DAP) in 2000, 2001 and 2002 in field 1. Air temperature data from the Georgia Weather Network, G. Hoogenboom DAP 0: Julian Day =138 (2000), 141 (2001), and 142 (2002). *Vertical line represents approximate canopy closure dates for each year.

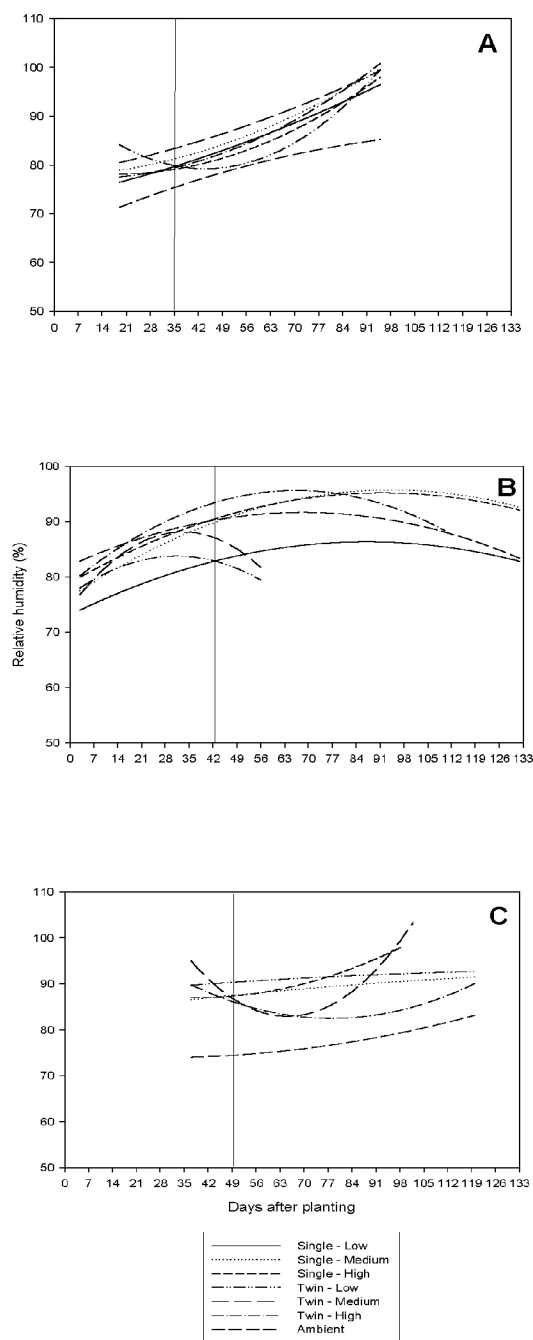


Figure B.2. Predicted response of canopy humidity (%) for the duration of growing season (in DAP) in 2000, 2001 and 2002 in field 1. Air humidity data from the Georgia Weather Network, G. Hoogenboom DAP 0: Julian Day =138 (2000), 141 (2001), and 142 (2002). *Vertical line represents approximate canopy closure dates for each year.

Table B.15. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air temperature data for Tifton, Georgia, for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2000, 2001 and 2002. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agree With Logger
			Est. ^b	SE ^c	t	Est.	SE	t	Est.	SE	t	
Air	00	77	26.26	0.259	-	4.34e-02	9.90e-03	-	-6.70e-04	2.96e-04	-	-
	01	130	26.43	0.240	-	-1.36e-02	2.69e-03	-	-1.12e-03	7.99e-05	-	-
	02	84	26.55	0.257	-	-1.93e-02	5.16e-03	-	-1.70e-04	2.38e-04	-	-
	T	291	26.42	0.146	-	3.51e-03	3.83e-03	-	-6.53e-04	1.29e-04	-	-

^a N represents the number of days in which data loggers recorded the complete set (entire recording for growing season) or microclimate data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature in 2000, 2001 and 2002.

^c Standard error estimation for parameter estimates.

Table B.16. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row Spacing Seed/m	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm 12.5 seed/m	00	77	26.26	0.657	0.00	4.34e-02	9.62e-03	0.00	-6.70e-04	2.87e-04	0.00	Yes
	01	48	26.21	0.647	0.32	8.41e-04	2.85e-02	-0.50	-6.50e-04	4.41e-04	-1.05	Yes
	02	43	26.11	0.646	0.64	2.00e-02	5.35e-02	-0.73	-9.00e-04	1.23e-03	0.58	Yes
	T	168	26.19	0.375	0.55	2.14e-02	2.05e-02	-0.86	-7.40e-04	4.46e-04	0.19	Yes
Single 91.44 cm 17.4 seed/m	00	77	26.26	0.727	0.00	4.34e-02	9.62e-03	0.00	-6.70e-04	2.87e-04	0.00	Yes
	01	122	26.53	0.503	-0.18	-1.36e-02	2.61e-03	0.00	-1.16e-03	8.06e-05	0.35	Yes
	02	84	26.55	0.698	0.01	-1.93e-02	5.01e-03	0.01	-1.70e-04	2.31e-04	0.00	Yes
	T	283	26.45	0.376	-0.08	3.50e-03	3.72e-03	0.00	-6.67e-04	1.26e-04	0.07	Yes
Single 91.44 cm 22.6 seed/m	00	77	26.26	0.791	0.00	4.34e-02	9.62e-03	0.00	-6.70e-04	2.87e-04	0.00	Yes
	01	100	26.72	0.901	-0.31	-1.64e-02	2.78e-03	0.72	-1.20e-03	8.41e-05	0.69	Yes
	02	84	26.55	0.826	0.00	-1.93e-02	5.01e-03	0.01	-1.70e-04	2.31e-04	0.00	Yes
	T	261	26.51	0.485	-0.19	2.57e-03	3.73e-03	0.18	-6.80e-04	1.26e-04	0.15	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between complete ambient temperature (Table 3.15) and ambient temperature (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *Indicates significance at 5% level and **indicates significance at 1% level.

e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.17. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Twin 20.32 cm 6.2 seed/m	00	70	26.46	0.690	0.27	5.57e-02	1.00e-02	0.87	-9.40e-04	2.93e-04	-0.65	Yes
	01	60	26.29	0.673	-0.20	1.28e-02	2.49e-02	1.05	-4.60e-04	3.93e-04	1.65	Yes
	02	84	26.55	0.713	0.00	-1.93e-02	5.01e-03	0.00	-1.70e-04	2.31e-04	0.00	Yes
	T	214	26.43	0.400	0.03	1.64e-02	9.11e-03	1.30	-5.23e-04	1.81e-04	0.58	Yes
Twin 20.32 cm 8.9 seed/m	00	77	26.26	0.727	0.00	4.34e-02	9.62e-03	0.00	-6.70e-04	2.87e-04	0.00	Yes
	01	113	26.19	0.759	-0.30	-3.60e-03	2.91e-03	2.53*	-7.60e-04	9.55e-05	2.89*	No
	02	56	26.62	1.105	0.06	-3.70e-04	1.95e-02	0.94	3.40e-04	6.36e-04	0.75	Yes
	T	246	26.36	0.509	-0.12	1.31e-02	7.31e-03	1.17	-3.63e-04	2.35e-04	1.08	Yes
Twin 20.32 cm 11.5 seed/m	00	77	26.26	0.791	0.00	4.34e-02	9.62e-03	0.00	-6.70e-04	2.87e-04	0.00	Yes
	01	121	26.46	0.806	0.04	-1.21e-02	2.64e-03	0.40	-1.09e-03	8.20e-05	0.26	Yes
	02	40	26.15	0.658	-0.57	-1.50e-02	5.98e-03	0.54	5.20e-05	4.02e-04	0.48	Yes
	T	238	26.29	0.436	-0.28	5.43e-03	3.88e-03	0.35	-5.69e-04	1.67e-04	0.40	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between complete ambient temperature (Table 3.15) and ambient temperature (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *Indicates significance at 5% level and **indicates significance at 1% level.

e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.18. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal With Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm 12.5 seed/m	00	77	26.42	0.682	0.17	2.34e-04	9.90e-03	-3.13**	-6.70e-04	3.40e-04	0.00	Yes
	01	48	26.66	0.821	0.43	-4.12e-02	2.93e-02	-0.99	-1.04e-03	4.53e-04	-0.62	No
	02	43	25.85	0.843	-0.24	-1.00e-02	5.51e-02	-0.39	-7.10e-04	1.27e-03	0.11	No
	T	168	26.31	0.680	0.15	-1.70e-02	2.11e-02	-1.31	-8.07e-04	4.63e-04	-0.10	Yes
Single 91.44 cm 17.4 seed/m	00	77	26.37	0.669	0.11	-1.26e-02	9.90e-03	-4.06**	-2.00e-04	2.96e-04	1.14	Yes
	01	122	27.14	0.586	0.79	-2.77e-02	2.69e-03	-3.76**	-1.02e-03	8.27e-05	1.21	Yes
	02	84	26.19	0.657	-0.38	-4.13e-02	5.16e-03	-3.06**	1.25e-04	2.38e-04	0.89	Yes
	T	283	26.57	0.369	0.22	-2.72e-02	3.83e-03	-5.75**	-3.65e-04	1.29e-04	1.67	Yes
Single 91.44 cm 22.6 seed/m	00	77	26.11	0.656	-0.15	-3.77e-03	9.90e-03	-3.42**	-9.00e-05	2.96e-04	1.41	Yes
	01	100	27.00	0.648	0.25	-3.22e-02	2.86e-03	-3.96**	-1.01e-03	8.70e-05	1.57	Yes
	02	84	26.09	0.654	-0.44	-3.56e-02	5.16e-03	-2.27*	2.90e-05	2.38e-04	0.60	Yes
	T	261	26.40	0.377	-0.18	-2.39e-02	3.84e-03	-4.94*	-3.57e-04	1.30e-04	1.79	No

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted canopy temperature in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between ambient temperature (matching valid logger dates) (Table3.16) and valid logger data. T-tests determined any differences between two sets of data. *indicates significance at 5% level and **indicates significance at 1% level.

e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy temperature.

Table B.19. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal With Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Twin 20.32 cm 6.2 seed/m	00	70	26.65	0.715	0.19	-1.34e-02	1.03e-02	-4.81**	-2.60e-04	3.01e-04	1.62	Yes
	01	60	27.68	0.735	1.40	-4.50e-02	2.57e-02	-1.62	-1.31e-03	4.05e-04	-1.51	No
	02	84	26.68	0.948	0.11	-4.89e-02	5.16e-03	-4.12**	3.35e-04	2.38e-04	1.52	No
	T	214	27.00	0.465	0.93	-3.58e-02	9.38e-03	-3.99**	-4.12e-04	1.86e-04	0.43	Yes
Twin 20.32 cm 8.9 seed/m	00	77	26.27	0.669	0.01	-2.27e-02	9.90e-03	-4.79**	1.26e-04	2.96e-04	1.93	Yes
	01	113	27.33	0.610	1.17	-2.86e-02	2.99e-03	-5.99**	-9.40e-04	9.83e-05	-1.31	Yes
	02	56	26.33	0.806	-0.21	-1.17e-02	2.01e-02	-0.41	9.70e-04	6.55e-04	0.69	No
	T	246	26.64	0.396	0.44	-2.10e-02	7.52e-03	-3.25**	5.20e-05	2.42e-04	1.23	Yes
Twin 20.32 cm 11.5 seed/m	00	77	25.58	0.656	-0.66	-1.30e-04	9.90e-03	-3.15**	-2.10e-04	2.96e-04	1.12	Yes
	01	121	27.70	0.589	1.24	-3.47e-02	2.71e-03	-5.97**	-1.26e-03	8.49e-05	-1.44	Yes
	02	40	26.15	0.948	0.00	-3.30e-02	6.15e-03	-2.10*	9.40e-05	4.13e-04	0.07	No
	T	238	26.48	0.431	0.30	-2.26e-02	3.99e-03	-5.04**	-4.59e-04	1.72e-04	0.46	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted canopy temperature in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between ambient temperature (matching valid logger dates) (Table3.16) and valid logger data. T-tests determined any differences between two sets of data. *indicates significance at 5% level and **indicates significance at 1% level.

e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy temperature.

Table B.20. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature, valid logger data and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions and valid logger data for each row spacing comparison.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Agree With Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single Low vs Medium	Ambient	449	-0.26	0.376	-0.49	1.79e-02	1.47e-02	0.86	-7.30e-05	3.28e-04	-0.16	Yes
	Logger	449	-0.26	0.547	-0.34	1.02e-02	1.51e-02	0.48	-4.42e-04	3.40e-04	-0.92	No
	Diff	898	0.00	0.322	0.00	-7.70e-03	1.06e-02	-0.52	-3.69e-04	2.36e-04	-1.11	No
Single Low vs High	Ambient	427	-0.32	0.434	-0.52	1.88e-02	1.47e-02	0.90	-6.00e-05	3.28e-04	-0.13	Yes
	Logger	427	0.10	0.656	0.11	-5.70e-03	5.16e-03	-0.78	9.60e-05	2.38e-04	0.29	No
	Diff	854	0.42	0.393	0.76	-2.45e-02	7.81e-03	-2.22*	1.56e-04	2.02e-04	0.55	Yes
Single High vs Medium	Ambient	542	-0.06	0.434	-0.10	9.30e-04	3.73e-03	0.18	1.30e-05	1.26e-04	0.07	Yes
	Logger	542	0.17	0.373	0.32	-3.20e-03	3.83e-03	-0.61	-8.00e-06	1.30e-04	-0.04	No
	Diff	1084	0.23	0.286	0.57	-4.23e-03	2.67e-03	-1.12	-2.10e-05	9.04e-05	-0.16	No
Twin Low vs Medium	Ambient	458	0.07	0.484	0.11	3.30e-03	8.26e-03	0.28	-1.60e-04	2.10e-04	-0.54	Yes
	Logger	458	0.36	0.432	0.59	-1.48e-02	8.50e-03	-1.23	-4.64e-04	2.16e-04	-1.52	No
	Diff	916	0.29	0.317	0.65	-1.81e-02	5.93e-03	-2.16*	-3.04e-04	1.50e-04	-1.43	Yes
Twin Low vs Medium	Ambient	450	0.14	0.418	0.24	1.10e-02	7.00e-03	1.11	4.60e-05	1.74e-04	0.19	Yes
	Logger	450	0.52	0.448	0.82	-1.32e-02	7.21e-03	-1.30	4.70e-05	1.79e-04	0.19	No
	Diff	900	0.38	0.307	0.88	-2.42e-02	5.02e-03	-3.40**	1.00e-06	1.25e-04	0.01	Yes
Twin High vs Medium	Ambient	482	0.07	0.474	0.10	7.67e-03	5.85e-03	0.93	2.06e-04	2.04e-04	0.71	Yes
	Logger	482	0.16	0.414	0.27	1.60e-03	6.02e-03	0.19	5.11e-04	2.10e-04	1.72	No
	Diff	964	0.09	0.315	0.20	-6.07e-03	4.20e-03	-1.02	3.05e-04	1.46e-04	1.48	No

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted ambient or canopy temperature in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between two sets of data (ambient or logger) for each spacing comparison. T-tests determined differences. *indicates significance at 5% level. **indicates significance at 1% level.

e Null hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger data is there will be differences between spacings. Diff. represents the differences between ambient and logger data.

Table B.21. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature, valid logger data and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions and valid logger data for each row spacing comparison.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Agree With Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Low Single vs Twin	Ambient	380	-0.24	0.388	-0.44	5.00e-03	1.59e-02	0.22	-2.17e-04	3.40e-04	-0.45	Yes
	Logger	380	-0.69	0.583	-0.84	1.88e-02	1.63e-02	0.82	-3.95e-04	3.53e-04	-0.79	No
	Diff	760	-0.45	0.350	-0.91	1.38e-02	1.14e-02	0.86	-1.78e-04	2.45e-04	-0.51	No
Medium Single vs Twin	Ambient	527	-0.10	0.665	-0.11	3.03e-02	8.54e-03	2.51**	-3.07e-04	2.62e-04	-0.83	No
	Logger	527	-0.07	0.383	-0.13	-6.20e-03	5.97e-03	-0.73	-4.17e-04	1.94e-04	-1.52	No
	Diff	1054	0.03	0.384	0.06	-3.65e-02	5.21e-03	-4.95**	-1.10e-04	1.63e-04	-0.48	Yes
High Single vs Twin	Ambient	497	0.22	0.461	0.34	-2.86e-03	3.81e-03	-0.53	-1.10e-04	1.48e-04	-0.53	Yes
	Logger	497	-0.08	0.405	-0.14	-1.30e-03	3.92e-03	-0.23	1.02e-04	1.52e-04	0.47	No
	Diff	994	-0.30	0.307	-0.69	1.56e-03	2.73e-03	0.40	2.13e-04	1.06e-04	1.42	No

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted ambient or canopy temperature in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between two sets of data (ambient or logger) for each spacing comparison. T-tests determined differences. *indicates significance at 5% level. **indicates significance at 1% level.

e Null hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger data is there will be differences between spacings. Diff. represents the differences between ambient and logger data.

Table B.22. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air humidity data for Tifton, Georgia, for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2000, 2001 and 2002. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Row Spacing	Yr	N	Intercept			Linear			Quadratic			Air Agree With Logger
			Est.	SE	t	Est.	SE	t	Est.	SE	t	
Air	00	77	82.35	1.375	-	1.36e-01	5.26e-02	-	-3.59e-03	1.57e-03	-	-
	01	130	91.65	1.278	-	1.00e-02	1.43e-02	-	-2.05e-03	4.24e-04	-	-
	02	84	76.68	1.363	-	1.09e-01	2.74e-02	-	1.08e-03	1.26e-03	-	-
	T	291	83.56	0.773	-	8.50e-02	2.04e-02	-	-1.52e-03	6.86e-04	-	-

^a N represents the number of days in which data loggers recorded the complete set (entire recording for growing season) or microclimate data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity in 2000, 2001 and 2002.

^c Standard error estimation for parameter estimates.

Table B.23. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agree With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm 12.5 seed/m	00	77	82.35	3.783	0.00	1.36e-01	5.35e-02	0.00	-3.59e-03	1.59e-03	0.00	Yes
	01	50	90.01	4.448	0.35	-1.68e-01	1.48e-01	1.20	-4.68e-03	2.34e-03	1.11	Yes
	02	43	65.00	4.605	2.43*	1.33e-00	2.97e-01	-4.09**	-2.37e-02	6.85e-03	3.56**	No
	T	170	79.12	2.479	1.71	4.33e-01	1.12e-01	-3.05**	-1.07e-02	2.47e-03	3.56**	No
Single 91.44 cm 17.4 seed/m	00	77	82.35	3.713	0.00	1.36e-01	5.35e-02	0.00	-3.59e-03	1.59e-03	0.00	Yes
	01	122	92.00	3.143	-0.10	9.05e-03	1.45e-02	0.05	-2.18e-03	4.48e-04	0.21	Yes
	02	84	76.68	3.631	0.00	1.09e-01	2.78e-02	0.00	1.08e-03	1.28e-03	0.00	Yes
	T	283	83.68	2.024	-0.05	8.47e-02	2.07e-02	0.01	-1.56e-03	6.98e-04	0.04	Yes
Single 91.44 cm 22.6 seed/m	00	77	82.35	3.642	0.00	1.36e-01	5.35e-02	0.00	-3.59e-03	1.59e-03	0.00	Yes
	01	100	92.76	3.592	-0.29	9.90e-05	1.55e-02	0.47	-2.36e-03	4.69e-04	0.49	Yes
	02	84	76.68	3.627	0.00	1.09e-01	2.78e-02	0.00	1.08e-03	1.28e-03	0.00	Yes
	T	261	83.93	2.090	-0.17	8.17e-02	2.07e-02	0.11	-1.62e-03	7.00e-04	0.11	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between complete ambient humidity (Table 3.22) and ambient humidity (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year was questionable. *Indicates significance at 5% level and **indicates significance at 1% level.

e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.24. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agree With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Twin 20.32 6.2 seed/m	00	70	81.66	3.968	-0.16	9.36e-02	5.57e-02	0.55	-2.62e-03	1.63e-03	0.43	Yes
	01	59	89.78	4.095	-0.44	-1.17e-01	1.39e-01	-0.77	-3.84e-03	2.18e-03	-0.80	Yes
	02	84	76.68	3.801	0.00	1.09e-01	2.78e-02	0.00	1.08e-03	1.28e-03	0.00	Yes
	T	213	82.71	2.285	-0.35	2.85e-02	5.07e-02	1.03	-1.79e-03	1.00e-00	-0.22	Yes
Twin 20.32 8.9 seed/m	00	77	82.35	3.713	0.00	1.36e-01	5.35e-02	0.00	-3.59e-03	1.59e-03	0.00	Yes
	01	115	92.00	3.238	0.10	1.38e-02	1.57e-02	1.12	-2.29e-03	4.78e-04	-0.38	Yes
	02	56	75.79	4.448	-0.19	-1.26e-01	1.08e-01	-0.15	-5.26e-03	3.54e-03	-1.11	Yes
	T	248	83.38	2.213	-0.08	7.93e-03	4.06e-02	1.70	-3.71e-03	1.30e-03	-1.48	Yes
Twin 20.32 11.5 seed/m	00	77	82.35	3.642	0.00	1.36e-01	5.35e-02	0.00	-3.59e-03	1.59e-03	0.00	Yes
	01	121	91.88	3.266	0.07	1.18e-02	1.46e-02	1.07	-2.06e-03	4.57e-04	-0.02	Yes
	02	40	81.06	5.257	0.81	1.12e-01	3.32e-02	-0.07	-2.70e-03	2.23e-03	-0.63	Yes
	T	238	85.10	2.394	0.61	8.66e-02	2.15e-02	-0.07	-2.78e-03	9.26e-04	-1.09	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002. c Standard error estimates for parameter estimates.

d Comparison between complete ambient humidity (Table 3.22) and ambient humidity (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *Indicates significance at 5% level and **indicates significance at 1% level.

e If air does not agree with logger (determined by t-tests) then logger data is questionable and 'No' is recorded.

Table B.25. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal with Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 12.5 seed/m	00	77	89.51	3.647	1.36	2.10e-01	5.15e-02	1.00	2.73e-04	1.54e-03	1.75	No
	01	50	89.37	4.287	-0.10	7.83e-02	1.42e-01	1.20	-7.40e-04	2.26e-03	1.21	No
	02	43	78.51	4.439	2.11*	1.26e-00	2.87e-01	-0.17	-2.19e-02	6.60e-03	0.19	Yes
	T	170	85.80	2.389	1.94	5.16e-01	1.08e-01	0.53	-7.46e-03	2.38e-03	0.95	No
Single 91.44 17.4 seed/m	00	77	89.12	3.579	1.31	1.92e-01	5.15e-02	0.75	-1.00e-04	1.54e-03	1.58	No
	01	122	95.36	3.132	0.76	1.53e-01	1.40e-02	7.15**	-2.35e-03	4.31e-04	-0.27	Yes
	02	84	87.51	3.514	2.14*	2.02e-01	2.68e-02	2.41*	2.08e-03	1.24e-03	0.56	Yes
	T	283	90.66	1.971	1.69	1.82e-01	1.99e-02	3.40**	-1.23e-04	6.73e-04	1.48	Yes
Single 91.44 22.6 seed/m	00	77	92.53	3.509	2.01	3.66e-01	5.15e-02	3.10**	-4.81e-03	1.54e-03	-0.55	Yes
	01	100	92.85	3.459	0.02	4.66e-02	1.49e-02	2.16*	-1.51e-03	4.52e-04	1.31	Yes
	02	84	88.91	3.494	2.43*	1.92e-01	2.68e-02	2.15*	-2.13e-03	1.24e-03	-1.80	Yes
	T	261	91.43	2.014	2.58*	2.02e-01	2.00e-02	4.17**	-2.82e-03	6.74e-04	-1.23	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted canopy humidity in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between ambient humidity (matching valid logger dates) (Table3.23) and valid logger data. T-tests determined any differences between two sets of data. *indicates significance at 5% level and **indicates significance at 1% level.

e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy humidity.

Table B.26. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row Spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agree With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Twin 20.32 6.2 seed/m	00	70	89.12	3.826	1.35	2.27e-01	5.36e-02	1.73	-7.10e-04	1.57e-03	0.84	No
	01	59	97.04	3.947	1.28	4.13e-01	1.34e-01	2.75**	2.24e-03	2.10e-03	2.01*	Yes
	02	84	89.45	3.494	2.47*	1.88e-01	2.68e-02	2.05*	-1.24e-03	1.24e-03	-1.30	Yes
	T	213	91.87	2.171	2.91**	2.76e-01	4.86e-02	3.52**	9.67e-05	9.67e-04	1.36	Yes
Twin 20.32 8.9 seed/m	00	77	88.83	3.580	1.26	2.91e-01	5.15e-02	2.09*	-2.20e-04	1.54e-03	1.52	Yes
	01	115	94.95	3.226	0.65	2.08e-01	1.51e-02	8.92**	-2.86e-03	4.60e-03	-0.86	Yes
	02	56	92.56	4.304	2.71**	-9.06e-02	1.04e-01	0.24	3.69e-03	3.41e-03	1.82	Yes
	T	248	92.11	2.154	2.83**	1.36e-01	3.91e-02	2.27*	2.03e-04	1.26e-03	2.17*	Yes
Twin 20.32 11.5 seed/m	00	77	100.00	3.510	3.49**	-2.22e-02	5.15e-02	-2.13*	-2.10e-04	1.54e-03	1.53	Yes
	01	121	96.12	3.145	0.94	1.94e-01	1.41e-02	8.97**	-9.10e-04	4.40e-04	1.81	Yes
	02	40	92.32	5.064	1.54	1.23e-01	3.20e-02	0.24	1.03e-03	2.15e-03	1.20	No
	T	238	96.15	2.306	3.32**	9.83e-02	2.08e-02	0.39	-3.00e-05	8.93e-04	2.14*	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted canopy humidity in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between ambient humidity (matching valid logger dates) (Table3.24) and valid logger data. T-tests determined any differences between two sets of data. *indicates significance at 5% level and **indicates significance at 1% level.

e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy humidity.

Table B.27. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature, valid logger data and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions and valid logger data for each row spacing comparison.

Row Spacing	Data	N ^a	Intercept			Linear			Quadratic			Agrees With Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single Low vs Medium	Ambient	451	-4.56	2.263	-1.42	3.48e-01	8.05e-02	3.06**	-9.14e-03	1.82e-03	-3.56**	No
	Logger	451	-4.86	2.190	-1.57	3.34e-01	7.77e-02	3.04**	-7.34e-03	1.75e-03	-2.97**	Yes
	Diff	902	-0.30	1.575	-0.13	-1.43e-02	5.59e-02	-0.18	1.80e-03	1.26e-03	1.01	No
Single Low vs High	Ambient	429	-4.81	2.293	-1.48	3.51e-01	8.05e-02	3.08**	-9.08e-03	1.82e-03	-3.54**	No
	Logger	429	-1.40	3.504	-0.28	1.00e-02	2.68e-02	0.26	4.21e-03	1.24e-03	2.41*	Yes
	Diff	858	3.41	2.094	1.15	-3.41e-01	4.24e-02	-5.69**	1.33e-02	1.10e-03	8.56**	Yes
Single Medium vs High	Ambient	542	-0.25	2.057	-0.09	3.00e-03	2.07e-02	0.10	6.00e-05	6.99e-04	0.06	Yes
	Logger	542	-0.77	1.993	-0.27	-2.00e-02	2.00e-02	-0.71	2.70e-03	6.73e-04	2.83**	Yes
	Diff	1084	-0.52	1.432	-0.26	-2.30e-02	1.44e-02	-1.13	2.64e-03	4.85e-04	3.84**	Yes
Twin Low vs Medium	Ambient	459	-0.67	2.249	-0.21	2.06e-02	4.59e-02	0.32	1.92e-03	1.16e-03	1.17	Yes
	Logger	459	-0.24	2.163	-0.08	1.40e-01	4.42e-02	2.24*	-1.06e-04	1.12e-03	-0.07	Yes
	Diff	918	0.43	1.560	0.19	1.19e-01	3.19e-02	2.65**	-2.03e-03	8.06e-04	-1.78	Yes
Twin Low vs High	Ambient	449	-2.39	2.340	-0.72	-5.81e-02	3.89e-02	-1.06	9.90e-04	9.64e-04	0.73	Yes
	Logger	449	-4.28	2.340	-1.35	1.78e-01	3.75e-02	3.35**	1.27e-04	9.30e-04	0.10	Yes
	Diff	898	-1.89	1.620	-0.83	2.36e-01	2.70e-02	6.17**	-8.63e-04	6.60e-04	-0.91	Yes
Twin Medium vs High	Ambient	484	-1.72	2.305	-0.53	-7.87e-02	3.25e-02	-1.71	-9.30e-04	1.13e-03	-0.58	Yes
	Logger	484	-4.04	2.231	-1.28	3.77e-02	3.13e-02	0.85	2.33e-04	1.09e-03	0.15	No
	Diff	968	-2.32	1.604	-1.02	1.16e-01	2.26e-02	3.65**	1.16e-03	7.84e-04	1.05	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted ambient or canopy temperature in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between two sets of data (ambient or logger) for each spacing comparison. T-tests determined differences. *indicates significance at 5% level. **indicates significance at 1% level.

e Null hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger data is there will be differences between spacings. Diff. represents the differences between ambient and logger data.

Table B.28. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature, valid logger data and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions and valid logger data for each row spacing comparison.

Test	Yr	N ^a	Intercept			Linear			Quadratic			Agrees With Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Low Single vs Twin	Ambient	381	-3.59	2.384	-1.06	4.05e-01	8.69e-02	3.29*	-8.91e-03	1.88e-03	-3.34**	No
	Logger	381	-6.07	2.283	-1.88	2.40e-01	8.38e-02	2.02*	-7.56e-03	1.82e-03	-2.94**	Yes
	Diff	762	-2.48	1.650	-1.06	-1.65e-01	6.04e-02	-1.93	1.35e-03	1.31e-03	0.73	No
Medium Single vs Twin	Ambient	529	-1.03	3.013	-0.24	1.28e-01	4.75e-02	1.91	1.20e-04	1.45e-03	0.06	Yes
	Logger	529	-1.45	2.065	-0.50	4.60e-02	3.10e-02	1.05	-3.26e-04	1.01e-03	-0.23	No
	Diff	1058	-0.42	1.826	-0.16	-8.21e-02	2.84e-02	-2.05*	-4.46e-04	8.84e-04	-0.36	Yes
High Single vs Twin	Ambient	497	-1.17	2.247	-0.37	-4.90e-03	2.11e-04	-0.16	1.16e-03	8.21e-04	1.00	Yes
	Logger	497	-4.72	2.165	-1.54	1.04e-01	2.04e-02	3.60**	-2.79e-03	7.91e-04	-2.49*	Yes
	Diff	994	-3.55	1.560	-1.61	1.09e-01	1.47e-02	5.24**	-3.95e-03	5.70e-04	-4.90**	Yes

a N represents the number of days in which data loggers recorded data.

b Estimation of intercept, slope (linear), and quadratic parameters for predicted ambient or canopy temperature in 2000, 2001 and 2002.

c Standard error estimates for parameter estimates.

d Comparison between two sets of data (ambient or logger) for each spacing comparison. T-tests determined differences. *indicates significance at 5% level. **indicates significance at 1% level.

e Null hypothesis for ambient data is there will be no difference between spacings. Null hypothesis for logger data is there will be differences between spacings. Diff. represents the differences between ambient and logger data.

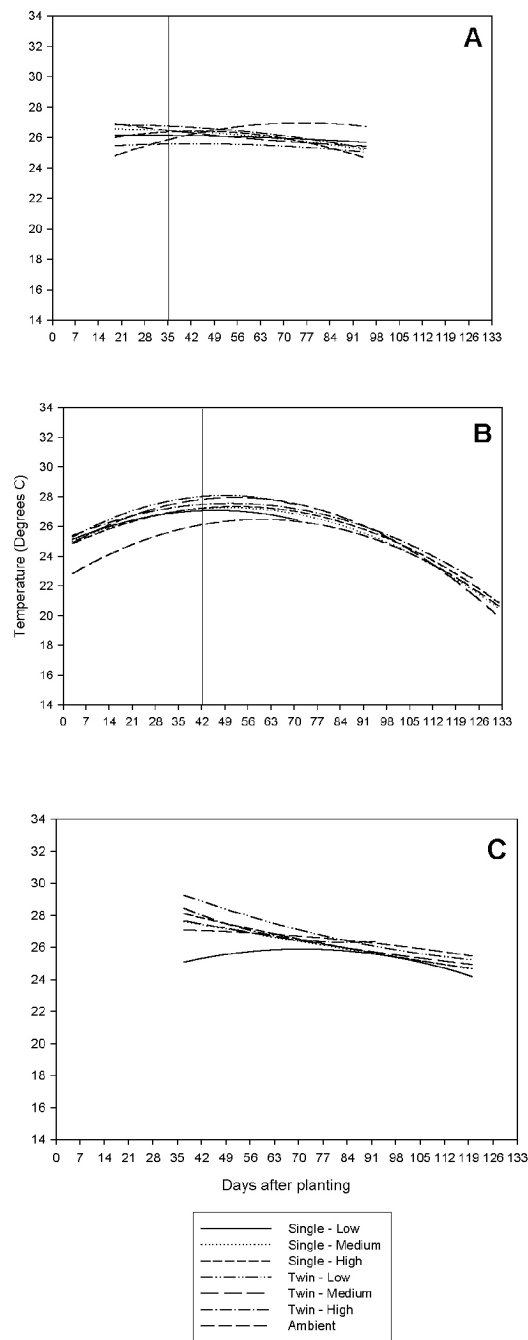


Figure B.3. Predicted mean temperatures (C) for each of the treatments and ambient conditions for 2000 (A), 2001 (B), and 2002 (C) for the duration of each growing season (DAP). *Vertical line represents approximate canopy closure dates for each year.

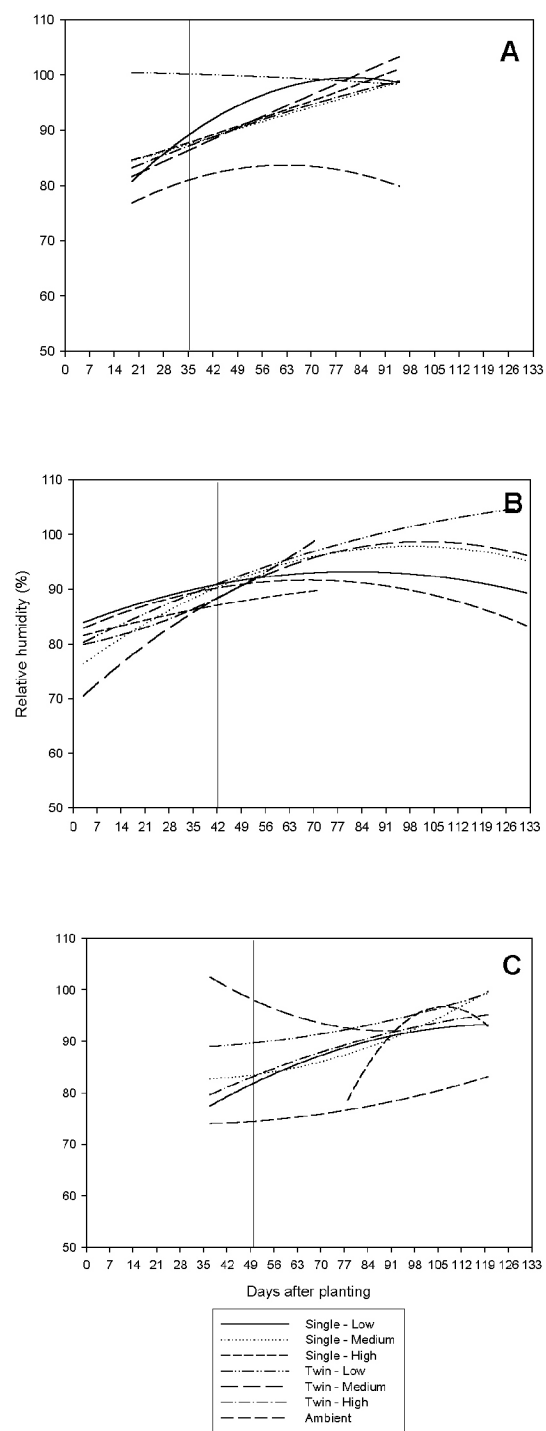


Figure B.4. Predicted mean humidity (%) for each of the treatments and ambient conditions for 2000 (A), 2001 (B), and 2002 (C) for the duration of each growing season (DAP). *Vertical line represents approximate canopy closure dates for each year.

APPENDIX C
APPENDIX TO CHAPTER 5 ¹

¹ Data included will not be published in other venues.

Data were also analyzed across each growing season, and predicted ambient condition curves and valid microclimate data curves were produced (Figs. C.1 and C.2). Intercept, slope and quadratic parameters were estimated for each of the curves (along with standard errors), and then valid microclimate logger data were compared to ambient values as well as other logger treatments (Tables C.1-C.8). Tables C.1 and C.5 show intercept, slope and quadratic parameter estimates for ambient temperature and humidity values which correspond to each growing season (Yr) and to microclimate loggers which had a complete set of data (N). No comparisons (no t-values) were made since complete ambient conditions are compared with ambient conditions. Tables C.2 and C.6 show intercept, slope and quadratic parameter estimates for ambient temperature and humidity values that correspond only to valid microclimate logger data (N). Comparisons (t-values) were made between the complete ambient temperature and humidity value estimates (Tables C.1 and C.5) and the ambient temperature and humidity value estimates which correspond with valid logger data (Tables C.2 and C.6) in order to determine if there was a penalty for missing logger data. Based on these comparisons, the logger that monitored temperature and humidity for the 20.3-cm twin row may be questionable ('No' in Tables C.2 and C.6). Estimates presented in tables C.3 and C.7 are for valid logger microclimate temperature and humidity only. Comparisons (t-values)

were made between valid microclimate data and ambient conditions (that matched only the days in which loggers recorded data). These comparisons were made to determine if there were any differences between the canopy microclimate and ambient conditions, and there were some differences (Tables C.3 and C.7). Table C.4 and C.8 show estimates and standard errors for intercept, slope and quadratic parameters for ambient temperature and humidity (that matches valid microclimate data dates), valid microclimate data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions corresponding to valid logger data and for comparison of valid logger treatments only. There were some differences among treatments for both temperature and humidity, when analyzed across the growing season, however, several days of the 20.3-cm twin row data was missing due to a faulty sensor (Tables C.4 and C.8).

Inoculated plants with close twin rows developed more severe symptoms than those with distant twin rows. This could be due to a more crowded plant being somehow more susceptible to the pathogen, or perhaps to a more favorable microclimate for disease development. Although the latter seems more likely, data from this study suggest that differences in microclimate among the row patterns were minimal. First, there were no differences between treatments for mean canopy temperature or RH. There were some significant differences between canopy and ambient conditions, so the peanut canopy did create a unique microclimate. There were also some differences among

treatments, when analyzed across the growing season, however, several days of the 20.3-cm twin row data was missing due to a faulty sensor. The ambient data that matched the days (N) in which the 20.3-cm logger recorded and the complete set of ambient data were significantly different (Tables C.2 and C.6) indicating a penalty due to loss of logger data. So, the differences seen in Tables C.4 and C.8 between the 20.3-cm data and other treatments may not be necessarily true due to missing data. There were significant differences between single rows and the 10.2-cm twin rows (Tables C.4 and C.8) with canopy temperature being greater in single rows than the twin rows, and humidity was greater in the twin rows than in the single row pattern. However, the relatively small magnitude of these differences makes it unlikely that they had much effect on disease progress. *S. rolfsii* thrives in warm moist environments. The optimal temperature range for hyphal extension is 8-40°C with maximum growth at 27-30°C (Aycock, 1966; Punja 1985). Temperatures at or near this range were frequent in all treatments. Furthermore, any soil moisture level greater than 50% can initiate growth, and a relative humidity level greater than 90% can increase mycelial growth even more (Onkarayya and Appa Rao 1970; Rideout 2002.) Other than the very early part of the 2000 season, relative humidity levels were very similar among the twin row treatments. Microclimate conditions may explain disease development (or lack of) outside the optimal temperature or humidity range, but differences in stem rot epidemics

in different row spacings seem to be explained better by the actual physical distance between peanut plants.

Table C.1. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air temperature data for Tifton, Georgia, for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2000, 2001 and 2002. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Row spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger
			Est. ^b	SE ^c	t	Est.	SE	t	Est.	SE	t	
Ambient Air Temp	00	77	26.72	0.253	-	2.53e-03	5.47e-03	-	-6.70e-04	2.67e-04	-	-
	01	122	26.12	0.227	-	2.02e-04	2.75e-03	-	-7.30e-04	8.75e-05	-	-
	02	84	26.54	0.249	-	-1.94e-02	4.80e-03	-	-1.70e-04	2.22e-04	-	-
	T	283	26.46	0.141	-	2.03e-03	2.60e-03	-	-5.23e-04	1.22e-04	-	-

^a N represents the number of days in which data loggers recorded the complete set (entire recording for growing season) of microclimate data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature in 2000, 2001 and 2002.

^c Standard error estimation for parameter estimates.

Table C.2. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm	00	77	26.72	0.446	0.00	2.53e-02	5.35e-03	0.00	-6.70e-04	2.76e-04	0.00	Yes
	01	74	25.72	0.352	0.95	-2.49e-02	1.47e-02	1.68	-1.04e-03	2.88e-04	1.03	Yes
	02	56	26.62	0.428	-0.16	-3.00e-05	1.89e-02	-1.00	3.40e-04	5.97e-04	-0.80	Yes
	T	207	26.35	0.238	0.39	1.23e-04	8.17e-03	0.22	-4.57e-04	2.40e-04	-0.25	Yes
Twin 10.16 cm	00	58	26.49	0.457	0.44	3.17e-02	5.72e-03	-0.81	-3.10e-04	2.97e-04	-0.89	Yes
	01	122	26.12	0.324	0.00	2.02e-04	2.68e-03	0.00	-7.30e-04	8.70e-05	0.00	Yes
	02	84	26.54	0.423	0.00	-1.94e-02	4.69e-03	0.00	-1.70e-04	2.22e-04	0.00	Yes
	T	264	26.38	0.234	0.28	4.17e-03	2.63e-03	-0.58	-4.03e-04	1.28e-04	-0.68	Yes
Twin 20.32 cm	00	47	25.26	0.464	2.76**	1.53e-02	6.11e-03	1.22	1.27e-03	4.24e-04	-2.99**	No
	01	106	26.22	0.333	-0.25	-1.22e-03	2.87e-03	0.36	-7.60e-04	8.63e-05	0.24	Yes
	02	77	26.47	0.430	0.14	-2.00e-02	4.81e-03	0.09	-1.00e-04	2.20e-04	-0.22	Yes
	T	230	25.98	0.239	1.72	-1.97e-03	2.77e-03	1.06	1.37e-04	1.62e-04	-3.25	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient temperature that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient temperature (Table 5.1) and ambient temperature (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *indicates a significant difference at the 5% level and ** indicates significant difference at 1% level.

^e If air does not agree with logger (which is determined by t-tests) then logger data is questionable and 'No' is recorded.

Table C.3. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row spacing	Yr	N ^a	Intercept			Linear			Quadratic			Logger ≠ With Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single 91.44 cm	00	77	26.07	0.181	-1.35	-8.95e-03	6.35e-03	-4.12**	-4.20e-04	3.20e-04	0.59	Yes
	01	74	26.67	0.334	1.96	-1.63e-02	1.74e-02	0.38	-8.50e-04	3.42e-04	0.42	No
	02	56	27.86	0.530	1.82	-1.53e-02	2.24e-02	-0.52	1.03e-03	7.15e-04	1.47	No
	T	207	26.87	0.218	1.60	-1.35e-02	9.70e-03	-1.08	-8.00e-05	2.85e-04	1.01	No
Twin 10.16 cm	00	58	25.81	0.188	-1.38	-1.19e-02	6.79e-03	-4.91**	-3.40e-04	3.53e-04	-0.07	Yes
	01	122	25.82	0.121	-0.87	-4.02e-02	3.19e-03	-9.69**	-1.30e-03	1.02e-04	-4.26**	Yes
	02	84	27.42	0.151	1.96	-5.33e-02	5.58e-03	-4.65**	-3.80e-04	2.57e-04	-0.62	Yes
	T	264	26.35	0.090	-0.12	-3.51e-02	3.12e-03	-9.63**	-6.73e-04	1.50e-04	-1.37	Yes
Twin 20.32 cm	00	47	27.34	0.214	4.07**	-4.37e-02	7.29e-03	-6.20**	2.08e-03	5.04e-04	1.23	Yes
	01	106	26.24	0.132	0.06	-4.15e-02	3.41e-03	-9.04**	-1.44e-03	1.03e-04	-5.06**	Yes
	02	77	26.97	0.153	1.10	-5.14e-02	5.72e-03	-4.43**	1.16e-04	2.61e-04	0.63	Yes
	T	230	26.85	0.099	3.36**	-4.55e-02	3.30e-03	-10.12**	2.52e-04	1.93e-04	0.46	Yes

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear), and quadratic parameters for predicted canopy temperature in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient temperature (matching valid logger data dates) (Table 5.2) and valid logger data. Test determined any differences between two sets of data. *indicates significant difference at 5% level and **indicates significant difference at 1% level.

^e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy temperature.

Table C.4. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air temperature that matches valid logger data, valid logger data, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments and for comparison of valid logger treatments only.

Row spacing	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single vs Twin 10.16	Ambient	469	-0.03	0.236	-0.09	-4.05e-03	6.07e-03	-0.47	-5.40e-05	1.92e-04	-0.20	Yes
	Logger	469	0.52	0.167	2.20*	2.16e-02	7.21e-03	2.12*	5.93e-04	2.28e-04	1.84	Yes
	Diff	938	0.55	0.144	2.69**	2.56e-02	6.66e-03	2.72**	6.47e-04	2.11e-04	2.17*	Yes
Single vs Twin 20.32	Ambient	435	0.37	0.239	1.10	2.09e-03	6.10e-03	0.24	-3.20e-04	2.05e-04	-1.11	Yes
	Logger	435	0.02	0.169	0.08	3.20e-02	7.25e-03	3.12**	1.72e-04	2.43e-04	0.50	Yes
	Diff	870	-0.35	0.207	-1.20	2.99e-02	6.70e-03	3.16**	4.92e-04	2.25e-04	1.55	Yes
Twin 10.16 vs Twin 20.32	Ambient	492	0.40	0.237	1.20	-2.20e-03	2.70e-03	-0.58	-5.40e-04	1.46e-04	-2.62**	No
	Logger	492	-0.50	0.095	-3.74**	1.04e-02	3.21e-03	2.29*	-9.25e-04	1.73e-04	-3.78**	Yes
	Diff	984	-0.90	0.180	-3.53**	1.26e-02	2.97e-03	3.00**	-3.85e-04	1.60e-04	-1.70	Yes

^a N represents the number of days in which data loggers recorded data

^b Estimation of intercept, slope (linear), and quadratic parameters for predicted ambient or canopy temperature in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient temperature (Table 5.2) and ambient temperature (matching valid logger data dates) or valid logger data. Test determined any differences between two sets of data. *indicates significant difference at 5% level and **indicates significant difference at 1% level.

^e Null hypothesis for ambient data is that there will be no difference between row spacings. Null hypothesis for logger data is that there will be differences between row spacings. Difference represents the difference between ambient and logger parameters. 'Yes' represents accepted null hypothesis and 'No' represents rejected null hypothesis.

Table C.5. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for complete air humidity (%) data for Tifton, Georgia, for period of time (N) which corresponds to experimental loggers which had a complete set of data in 2000, 2001 and 2002. No t-values or comparisons made since ambient conditions are being compared with ambient conditions.

Row spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger
			Est. ^b	SE ^c	t	Est.	SE	t	Est.	SE	t	
Air Humidity (Ambient)	00	77	83.54	1.436	-	3.96e-02	3.12e-02	-	-3.59e-03	1.57e-03	-	-
	01	122	91.31	1.295	-	2.49e-02	1.57e-02	-	-1.75e-03	4.96e-04	-	-
	02	84	76.73	2.003	-	1.10e-01	2.74e-02	-	1.08e-03	1.27e-03	-	-
	T	283	83.86	0.928	-	5.82e-02	1.49e-02	-	-1.42e-03	6.95e-04	-	-

^a N represents the number of days in which data loggers recorded the complete set (entire recording for growing season) of microclimate data.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity in 2000, 2001 and 2002.

^c Standard error estimation for parameter estimates.

Table C.6. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity data that matches valid logger data in 2000, 2001 and 2002. T-values were obtained to determine differences between complete ambient air conditions and ambient conditions that only matched the valid logger data.

Row spacing	Yr	N ^a	Intercept			Linear			Quadratic			Air Agrees With Logger ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
91.44 cm	00	77	83.54	2.556	0.00	3.96e-02	3.03e-02	0.00	-3.59e-03	1.53e-03	0.00	Yes
	Single	01	91.32	1.958	0.00	1.34e-02	8.28e-02	0.14	-1.98e-03	1.63e-03	0.13	Yes
	02	56	75.72	2.998	0.28	-1.31e-01	1.07e-01	2.18*	-5.26e-03	3.38e-03	1.76	Yes
	T	207	83.53	1.467	0.19	-2.60e-02	4.63e-02	1.73	-3.61e-03	1.35e-03	1.44	Yes
10.16 cm	00	58	85.36	2.610	-0.61	-1.80e-02	3.24e-02	1.28	-6.51e-03	1.67e-03	1.27	Yes
	Twin	01	91.31	1.797	0.00	2.49e-02	1.53e-02	0.00	-1.75e-03	4.81e-04	0.00	Yes
	02	84	76.73	2.315	0.00	1.10e-01	2.66e-02	0.00	1.08e-03	1.23e-03	0.00	Yes
	T	264	94.47	1.308	-0.38	3.90e-02	1.49e-02	0.91	-2.39e-03	7.09e-04	0.98	Yes
20.32 cm	00	47	94.66	2.641	-3.70**	5.45e-02	3.46e-02	-0.32	-1.66e-02	2.49e-03	6.67**	No
	Twin	01	91.15	1.852	0.07	3.38e-02	1.62e-02	-0.39	-1.83e-03	4.88e-04	0.11	Yes
	02	77	76.73	2.281	0.00	1.10e-01	2.66e-02	0.00	1.08e-03	1.23e-03	0.00	Yes
	T	230	87.52	1.317	-2.27*	6.61e-02	1.56e-02	-0.37	-5.78e-03	9.39e-04	3.73**	No

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear) and quadratic parameters for predicted ambient humidity that matches N days of valid logger data in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between complete ambient humidity (Table 5.5) and ambient humidity (matching valid logger data dates). This test determined whether there was a difference between the two sets of data. If there were differences, then logger data for that particular year is questionable. *indicates a significant difference at the 5% level and ** indicates significant difference at 1% level.

^e If air does not agree with logger (which is determined by t-tests) then logger data is questionable and 'No' is recorded.

Table C.7. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for valid logger humidity data in 2000, 2001 and 2002. T-values were obtained to determine differences between valid logger data and ambient air conditions that only matched the valid logger data.

Row spacing	Yr	N ^a	Intercept			Linear			Quadratic			Logger Unequal With Air ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
91.44 cm	00	77	91.78	3.73	1.59	2.28e-01	4.41e-02	3.07**	-4.41e-03	2.22e-03	-0.39	Yes
	Single	01	89.36	2.86	-0.49	1.07e-01	1.21e-01	0.77	-1.12e-03	2.37e-03	-0.11	No
	02	56	88.20	4.37	2.05*	-5.24e-02	1.55e-01	0.36	-8.06e-03	4.92e-03	-0.65	Yes
	T	207	89.78	2.14	2.10*	9.42e-02	6.72e-02	1.28	-4.53e-03	1.97e-03	-2.04*	Yes
10.16 cm	00	58	93.77	3.80	1.59	-9.80e-04	4.71e-02	1.22	1.06e-03	2.42e-03	0.08	No
	Twin	01	96.06	2.62	1.30	2.14e-01	2.21e-02	6.13**	-3.55e-03	7.01e-04	-0.32	Yes
	02	84	83.61	3.37	1.47	2.46e-01	3.87e-02	2.52*	4.69e-04	1.78e-03	0.03	Yes
	T	264	91.15	1.91	2.52*	1.53e-01	2.16e-02	3.78**	-6.74e-04	1.03e-03	-0.26	Yes
20.32 cm	00	47	93.68	3.84	-0.18	1.41e-01	5.04e-02	1.23	-6.29e-03	3.62e-03	-0.53	No
	Twin	01	94.81	2.70	0.97	2.54e-01	2.36e-02	6.70**	2.99e-03	7.11e-04	0.25	Yes
	02	77	85.17	3.32	1.82	2.63e-01	3.87e-02	2.84**	1.01e-04	1.79e-03	0.00	Yes
	T	230	91.22	1.92	1.38	2.19e-01	2.26e-02	4.87**	-1.07e-03	1.37e-03	-0.87	Yes

^a N represents the number of days in which data loggers recorded data. N for each year will not match due to missing logger data in that particular season.

^b Estimation of intercept, slope (linear), and quadratic parameters for predicted canopy humidity in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient humidity (matching valid logger data dates) (Table 5.2) and valid logger data. Test determined any differences between two sets of data. *indicates significant difference at 5% level and **indicates significant difference at 1% level.

^e If air is unequal with logger data (determined by t-tests) then 'Yes' is recorded and that particular row spacing did create a unique canopy humidity.

Table C.8. Estimates and standard errors (SE) for intercept, linear and quadratic parameters for ambient air humidity that matches valid logger humidity data, valid logger humidity data alone, and the difference between the two sets of data. T-values were obtained to determine differences between ambient air conditions for valid logger treatments, for comparison of valid logger treatments alone and for the difference between ambient and logger humidity.

Row spacing	Data	N ^a	Intercept			Linear			Quadratic			Agrees with Null Hypoth. ^e
			Est. ^b	SE ^c	t ^d	Est.	SE	t	Est.	SE	t	
Single vs Twin 10.16	Ambient	469	-0.94	1.963	-0.48	-6.50e-02	4.85e-02	-1.34	-1.22e-03	1.53e-03	-0.80	Yes
	Logger	469	-1.37	2.029	-0.68	-5.88e-02	5.00e-02	-1.18	-3.86e-03	1.58e-03	-2.45**	Yes
	Diff	938	-0.43	1.996	-0.22	6.20e-03	4.93e-02	0.13	-2.64e-03	1.55e-03	-1.70	No
Single vs Twin 20.32	Ambient	435	-3.99	1.968	-2.03*	-9.21e-02	4.88e-02	-1.89	2.17e-03	1.65e-03	1.32	Yes
	Logger	435	-1.44	2.033	-0.71	-1.25e-01	5.02e-02	-2.49*	-3.46e-03	1.70e-03	-2.04*	Yes
	Diff	870	2.55	2.001	1.27	-3.27e-02	4.95e-02	-0.66	-5.63e-03	1.67e-03	-3.37**	Yes
Twin 10.16 vs Twin 20.32	Ambient	492	-3.05	1.855	-1.64	-2.71e-02	2.15e-02	-1.26	3.39e-03	1.18e-03	2.90**	No
	Logger	492	-0.07	2.033	-0.03	-6.60e-02	5.02e-02	-1.32	3.96e-04	1.70e-03	0.23	No
	Diff	984	2.98	1.946	1.53	-3.98e-02	3.86e-02	-1.01	-2.99e-03	1.46e-03	-2.05*	Yes

^a N represents the number of days in which data loggers recorded data.

^b Estimation of intercept, slope (linear), and quadratic parameters for predicted ambient or canopy in 2000, 2001 and 2002.

^c Standard error estimates for parameter estimates.

^d Comparison between ambient humidity (Table 5.2) and ambient humidity (matching valid logger data dates) or valid logger data. T test determined any differences between two sets of data. *indicates significant difference at 5% level and **indicates significant difference at 1% level.

^e Null hypothesis for ambient data is that there will be no difference between row spacings. Null hypothesis for logger data is that there will be differences between row spacings. Difference represents the difference between ambient and logger parameters. 'Yes' represents accepted null hypothesis and 'No' represents rejected null hypothesis.

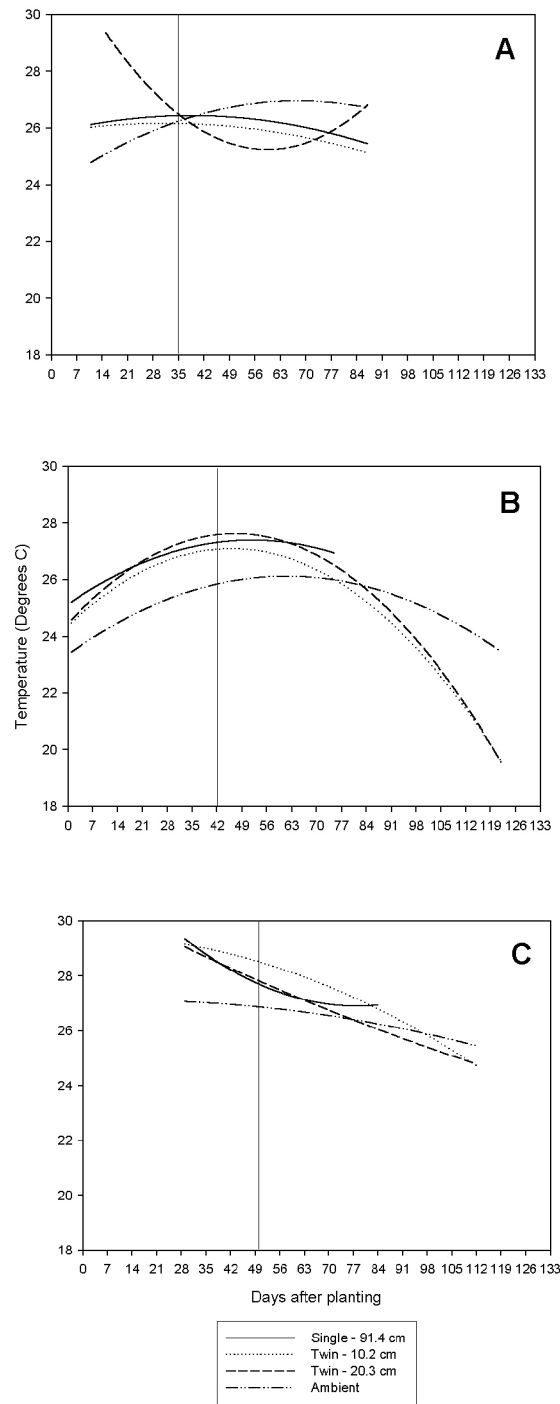


Figure C.1. Influence of row spacing on predicted canopy temperature (°C) in 'AT 1-1' peanuts for entire growing season (DAP) in 2000 (A), 2001(B) and 2002(C). Vertical line represents approximate canopy closure date for each growing season.

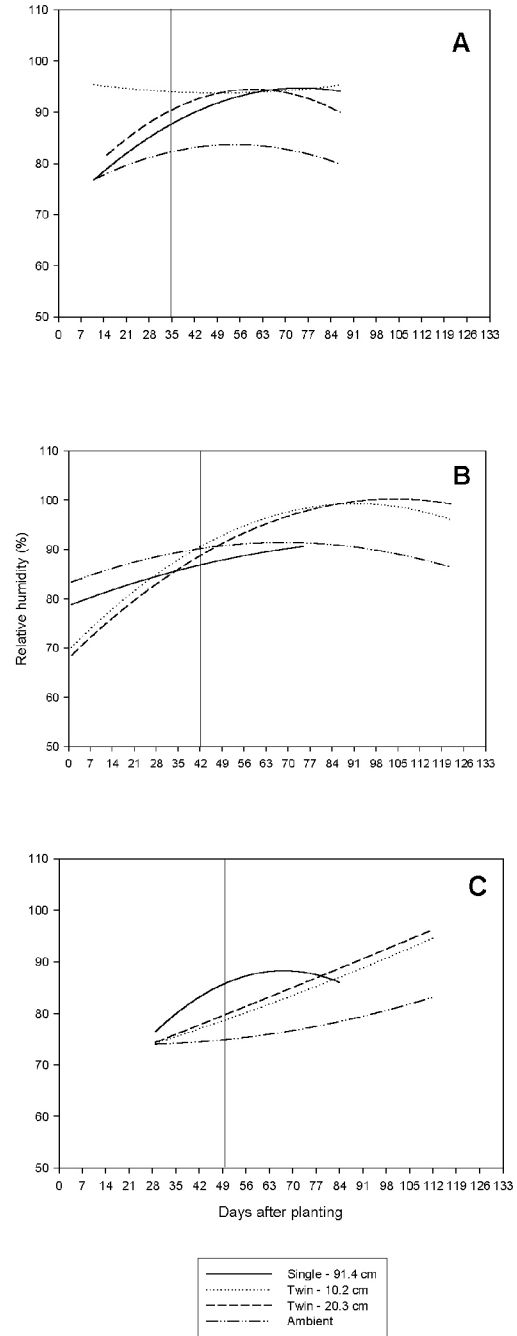


Figure C.2. Influence of row spacing on predicted canopy humidity (%) in 'AT 1-1' peanuts for entire growing season (DAP) in 2000 (A), 2001(B) and 2002(C). Vertical line represents approximate canopy closure date for each growing season.