Seeding Rate and Planting Date Impacts Stand Density, Diseases, and Yield of Irrigated Peanuts

A. K. Hagan, H. L. Campbell, and K. L. Bowen, Department of Entomology and Plant Pathology, Auburn University, Auburn, AL, 36849; and L. Wells, Wiregrass Research and Extension Center, Auburn University, Headland, AL 36849

Accepted for publication 16 February 2015. Published 20 April 2015.

Abstract


Release of peanut cultivars with enhanced tomato spotted wilt (TSW) resistance along with the decline in the incidence of this disease gives Alabama producers the option of earlier planting of irrigated peanuts to optimize farm operations and lower seeding rates to reduce input costs. Mid-April and mid-May plantings of the cvs. Florida-07, Georgia-06G, and Georgia Green at 6.6, 9.8, 13.1, and 19.7 seed/m were monitored over three years for TSW, stem rot, and leaf spot diseases as well as yield. Despite low TSW pressure and lack of a seeding rate response, disease incidence was higher in Georgia Green than Florida-07 and Georgia-06G with higher TSW indices noted for the April than May plantings of the former but not latter two cultivars. While not impacted by planting date, stem rot incidence, which was higher at 13.1 and 19.7 than 6.6 seed/m, was lower on Florida-07 than Georgia-06G and Georgia Green with the latter proving most susceptible. Although leaf spot intensity was not impacted by seeding rate, disease ratings were higher for May than April plantings, with Florida-07 and Georgia-06G having lower leaf spot ratings than Georgia Green in two of three study years. While planting date did not impact yield in two of three years, higher yields were recorded at 13.1 and 19.7 than 6.6 seed/m, with Florida-07 and Georgia-06G having higher yields than Georgia Green.

Seed accounts for up to 20% of variable production costs for peanut (Arachis hypogaea L.), particularly for the large seeded cvs. Georgia-06G and Florida-07 (Smith and Smith 2012). Reducing seeding rates is one option to help producers manage costs, particularly when peanut farm-gate prices are low. Previously, Wehtje et al. (1994) obtained similar yields with the peanut cv. Florunner planted at 55 to 122 kg seed/ha when irrigated, while Hauser and Buchanan (1981) reported lower yield with a reduced seeding rate compared to the recommended rate of 90 kg/ha, which equates to 19.7 seed/m. Augusto et al. (2010) noted that Nicaraguan farmers could increase their gross income by reducing seeding rates but are prevented by poor seed quality.

Following the appearance of the Tospovirus Tomato spotted wilt virus (TSWV) in Alabama, Florida, and Georgia peanuts in the late 1980s, significant disease intensification and yield declines were associated with reduced seeding rates of susceptible and, to a lesser extent, resistant cultivars (Branch et al. 2003; Culbreath et al. 2011; Weeks et al. 1994). Only Black et al. (2001) in Texas failed to link increased tomato spotted wilt (TSW) incidence and subsequent yield decline with reduced seeding rates. In contrast to TSW, stem rot, caused by Sclerotium rolfsii Sacc. (telemorph Athelia rolfsii (Cursii) Tu & Kibumoro), typically intensifies with increasing seeding rates (Augusto et al. 2010; Black et al. 2001). The effect of seeding rate on the intensity of early leaf spot, caused by Cercospora arachidicola Hori, and late leaf spot, caused by Cercosporidium personatum (Berk. & M.A. Curtis) Deighton, has not been examined.

Planting date also impacts TSW incidence in peanut. Prior to the appearance of TSW, the planting window for peanut ranged from mid-April into mid-May (Henning et al. 1982). Observations of higher TSW incidence and thrips vector populations (Weeks et al. 1994) along with thrips-related leaf damage (Weeks et al. 1992) in April- compared to May-planted peanuts in Alabama were later confirmed in Georgia by Brown et al. (1996). Delaying planting into May has less of an effect on TSW incidence and yield of a resistant than susceptible cultivar (Culbreath et al. 2010; Tillman et al. 2007). As a result of the TSW epiphytotic that began in the early 1990s, producers were advised to delay planting until mid-May (Brown et al. 2003; Brown et al. 2005; Hagan and Weeks 1993). Beginning with cv. Southern Runner (Black and Smith 1987; Weeks et al. 1994), runner market type peanut cultivars with constantly improving TSW resistance and yield potential have been released (Branch 1996; Branch 2007; Brown et al. 2005; Culbreath et al. 2011; Culbreath et al. 2010; Gorbet et al. 2009; Tillman et al. 2007). In 2010, Culbreath et al. (2010) noted that the level of resistance is sufficient in newly released cultivars to advance planting into April without elevating the risk of a TSW outbreak. Also, the marked decline in TSW incidence in Alabama in recent years (A. K. Hagan, personal observation), provides producers the opportunity to increase their April-planted peanut acreage.

Stem rot incidence and subsequent yield loss is generally higher in April- than May-planted peanuts (Bowen 2003; Brenneman and Hadden 1996; Hagan et al. 2001). Hagan et al. (2001) noted that disease incidence declined by nearly 50% for mid-May compared with mid-April planted peanuts. Impact of planting date on stem rot was more pronounced on the susceptible cvs. Andru 93 and Florunner than the partially resistant cv. Southern Runner, which may have matured after S. rolfsii activity in the rhizosphere peaked.
(Bowen 2003; Hagan et al. 2001). While Hagan et al. (2010) saw increased leaf spot intensity in later peanut plantings, the influence of planting date on leaf spot diseases has not been investigated.

Given the sharp decline in TSW intensity observed in Alabama’s peanut crop in recent years as well as higher seed costs, particularly for the extensively planted, large-seeded cv. Florida-07 and Georgia-06G, the need to reduce crop vulnerability to short term drought, and space out harvesting operations, there is an opportunity to reduce seeding rates as a means of improving profitability as well as advancing the planting of some of Alabama’s peanut acreage into April. Improved disease resistance of many recently released peanut cultivars also gives producers added flexibility when making production decisions. When compared to Georgia Green, Florida-07 and Georgia-06G have superior TSW resistance (Tubbs 2011) with the latter being the most widely planted cultivar across the southeast (Beasley 2013). Gorbet and Tillman (2009) reported that Florida-07 also possesses partial stem rot resistance. The objective of this study was to assess the impact of planting date, cultivar selection, seeding rate, and interactions between these variables on pod yield and stand density as well as their impact on the occurrence of TSW, stem rot, and leaf spot diseases of runner peanut cultivars in an irrigated production system.

**IMPACT OF PLANTING DATE, PEANUT VARIETY, AND SEEDING RATE ON DISEASE AND YIELD**

The research areas at the Wiregrass Research and Extension Center, which were planted to cotton (*Gossypium hirsutum* L.) prior to the 2010, 2011, and 2012 study year, was turned with a moldboard plow and worked to seedbed condition with a disk harrow. Rows were laid off in a Dothan fine sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) with a KMC strip till rig with rolling baskets. Leaf spot, thrips, and weed-control recommendations of the Alabama Cooperative Extension System were followed (Majumdar et al. 2015). Soil fertility and pH were adjusted in each year according to the results of a soil fertility assay done by the Auburn University Soil Testing Laboratory. The test area received a total of 17.1, 10.2, and 10.2 cm of water, in 2010, 2011, and 2012, respectively, via a center-pivot irrigation system. The experimental design was a factorial with four replications arranged as a split-split plot with planting date as the whole plot, cvs. Florida-07, Georgia Green, and Georgia-06G as the split-plot, and seeding rates of 6.6, 9.8, 13.1, and 19.7 seed/m² as the split-split plot treatment. Planting dates were 21 April and 20 May 2010, 21 April and 18 May 2011, and 24 April and 25 May 2012. In each study year, the smallest experimental unit consisted of four 9.1-m rows spaced 0.9 m apart. Stand counts, which are presented as the number of plants per 1 m of row, were made for the first and second planting dates on 3 June and 21 June 2010, 15 May and 14 June 2011, and 9 May and 6 June 2012 from one of two harvest rows. Inversion dates, which were determined using the hull scrape method described by Williams and Drexler (1981), are listed in the paragraph below by year.

**Disease assessment and yield.** Final TSW (Fig. 1A) and stem rot (Fig. 1B) incidence are expressed as the number of loci (1 locus ≤ 0.3 m of consecutive symptomatic plants per row) for each disease per 18.3 m of row (Rodriguez-Kabana et al. 1975). Incidence of TSW was assessed for the first and second planting dates on 7 September and 30 September 2010, 15 September and 14 October 2011, and 11 September and 14 October 2012, respectively; while stem rot incidence was determined immediately after plot inversion on 10 September and 1 October 2010, 15 September and 14 October 2011, and on 15 September and 15 October 2012 for the first and second planting dates, respectively. Leaf spotting (Fig. 1C) and defoliation (Fig. 1D) attributed to early and late leaf spot were assessed for the first and second planting dates on 7 September and 30 September 2010, 13 September and 14 October 2011, and 10 September and 5 October 2012, respectively, using the Florida peanut leaf spot scoring system (Chiteka et al. 1988). Yields are reported at 7% moisture.

**Statistical analysis.** Significance of interactions were evaluated using PROC GLIMMIX procedure in SAS v 9.3 with ddfm=satterthwaite option with year, planting date, cultivar, and seeding rate as fixed effects and year, replication-year, replication-planting date (year) and replication-planting date-cultivar (year) as random effects (SAS Institute Inc. 2013). Statistical analyses were done on rank transformations of plant population, TSW, leaf spot, and stem rot data to normalize variances, which were back transformed for presentation. Means were separated using Fisher’s protected least significant difference (LSD) test (P ≤ 0.05) except as otherwise indicated.

**PLANTING DATE, VARIETY, AND SEEDING RATE EFFECTS**

**Plant populations.** The significance of the year × planting date × cultivar interaction illustrated that plant populations of individual peanut cultivars over a range of seeding rates responded differently to planting date over time (Table 1). With Florida-07, higher plant populations were recorded at both 2010 and April 2011 planting dates compared with equally low values noted for the May 2011 and both 2012 planting dates (Table 2). Georgia-06G had higher plant populations in 2010 than 2011 or 2012 at the April but not May planting date, where similar stand counts were recorded. For Georgia Green, equally high plant populations were noted in 2010 and 2012 at the April planting date and in 2012 for the May planting date. At the April planting date, plant populations were higher for Georgia Green than Florida 07 and Georgia-06G in 2012 but not 2010 and 2011, while May-planted Florida-07 had lower plant populations in 2011 and 2012 than Georgia-06G and Georgia Green, which were...
similar. Influence of planting date differed by seeding rate (Table 1). At the highest but not the lower three seeding rates, plant populations were higher for April- than May-planted peanuts (Fig. 2). As previously noted by Culbreath et al. (2011), plant populations progressively increased as seeding rates rose.

Tomato spotted wilt. Incidence of TSW differed between cultivars by year and planting date (Table 1). Incidence of TSW was higher in Georgia Green than Florida-07 and Georgia-06G in two of three and all three study years, respectively (Fig. 3A). Disease incidence in Florida-07 and Georgia-06G was similarly low in 2010 and 2011 but not 2012 when the latter cultivar had lower ratings for TSW. When released in the mid-1990s, Georgia Green had better TSW resistance when compared with the majority of commercial cultivars (Black et al. 2001; Branch et al. 2003) but Florida-07 and Georgia-06G have superior TSW resistance and yield potential (Branch 2007; Gorbet and Tillman 2009; Tillman et al. 2007).

Planting date has previously been shown to impact TSW intensity in peanut (Brown et al. 1996; Culbreath et al. 2010; Nuti et al. 2014; Tillman et al. 2007; Weeks et al. 1994). For Georgia Green, TSW incidence was higher in April- than May-planted plots, while Georgia-06G or Florida-07 had similar disease indices regardless of planting date (Fig. 3B). Culbreath et al. (2010) and Hurt et al. (2005) previously noted that delayed planting resulted in greater reductions in TSW incidence in susceptible compared with resistant peanut cultivars. Nuti et al. (2014) reported reduced TSW incidence in later plantings of tolerant but not necessarily susceptible genotypes, including Georgia Green. Tillman et al. (2007) also noted less TSW in May- than April-plantings but disease-related yield losses were similar for susceptible and resistant cultivars at either planting date. In contrast to the above studies, McKinney and Tillman (2013) saw no planting date effect on TSW symptom expression or TSWV.

**TABLE 1**

<table>
<thead>
<tr>
<th>Source (F)</th>
<th>Plant populations</th>
<th>TSW</th>
<th>Stem rot</th>
<th>Leaf spot</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
<td>51.54***</td>
<td>1.97</td>
<td>9.36***</td>
<td>26.95***</td>
<td>70.44***</td>
</tr>
<tr>
<td><strong>Planting Date</strong></td>
<td>3.79^</td>
<td>24.31***</td>
<td>0.65</td>
<td>386.47***</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Year x Planting Date</strong></td>
<td>16.46***</td>
<td>2.04</td>
<td>1.01</td>
<td>29.59***</td>
<td>6.35**</td>
</tr>
<tr>
<td><strong>Cultivar</strong></td>
<td>25.75***</td>
<td>39.73***</td>
<td>22.98***</td>
<td>13.08***</td>
<td>32.23***</td>
</tr>
<tr>
<td><strong>Year x Cultivar</strong></td>
<td>22.39***</td>
<td>7.15***</td>
<td>1.98</td>
<td>2.74*</td>
<td>1.02</td>
</tr>
<tr>
<td><strong>Planting Date x Cultivar</strong></td>
<td>10.77***</td>
<td>12.61***</td>
<td>2.94^</td>
<td>13.78***</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Year x Planting Date x Cultivar</strong></td>
<td>7.61***</td>
<td>1.14</td>
<td>0.28</td>
<td>5.75***</td>
<td>1.73</td>
</tr>
<tr>
<td><strong>Seeding Rate</strong></td>
<td>398.90***</td>
<td>0.97</td>
<td>3.40*</td>
<td>3.29*</td>
<td>3.07*</td>
</tr>
<tr>
<td><strong>Year x Seeding Rate</strong></td>
<td>0.41</td>
<td>1.45</td>
<td>0.43</td>
<td>0.81</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>Planting Date x Seeding Rate</strong></td>
<td>4.71**</td>
<td>1.13</td>
<td>0.32</td>
<td>0.87</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Year x Planting Date x Seeding Rate</strong></td>
<td>2.72</td>
<td>0.79</td>
<td>0.31</td>
<td>0.72</td>
<td>1.23</td>
</tr>
<tr>
<td><strong>Cultivar x Seeding Rate</strong></td>
<td>1.51</td>
<td>0.21</td>
<td>1.14</td>
<td>0.78</td>
<td>1.61</td>
</tr>
<tr>
<td><strong>Year x Cultivar x Seeding Rate</strong></td>
<td>0.65</td>
<td>0.93</td>
<td>0.38</td>
<td>0.66</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>Planting Date x Cultivar x Seeding Rate</strong></td>
<td>0.42</td>
<td>0.78</td>
<td>0.39</td>
<td>0.54</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>Year x Planting Date x Cultivar x Seeding Rate</strong></td>
<td>1.46</td>
<td>0.83</td>
<td>0.61</td>
<td>0.37</td>
<td>0.64</td>
</tr>
</tbody>
</table>

z Significance at the 0.10, 0.05, 0.01, and 0.001 levels is indicated by ^, *, **, or ***, respectively.

**TABLE 2**

Influence of year and planting date on the plant populations of three peanut cultivars in 2010, 2011, and 2012.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida-07</td>
<td>8.3 abz</td>
<td>7.7 abcd</td>
<td>6.4 defg</td>
<td>7.7 abcd</td>
<td>5.9 fg</td>
<td>5.6 g</td>
</tr>
<tr>
<td>Georgia-06G</td>
<td>8.5 ab</td>
<td>6.2 cefg</td>
<td>6.7 defg</td>
<td>7.2 cdef</td>
<td>7.4 abcde</td>
<td>7.7 a-d</td>
</tr>
<tr>
<td>Georgia Green</td>
<td>8.1 abc</td>
<td>6.6 defg</td>
<td>8.3 abc</td>
<td>7.2 b-f</td>
<td>7.0 cdef</td>
<td>8.6 a</td>
</tr>
</tbody>
</table>

y Plant populations, expressed as the number of plants per m of row, were determined approximately 30 DAP.

z Means in columns and rows followed by the same letter are not significantly different according to Fishers’ protected least significant difference test (P ≤ 0.05).

**FIGURE 2**

Planting date and seeding rate impact on plant population. Different letters above bars indicate significant differences using Fishers’ protected least significant difference test (P ≤ 0.05).
infection levels in four peanut cultivars, including Georgia Green and Florida-07.

In contrast to previous studies (Branch et al. 2003; Culbreath et al. 2011), seeding rate had no impact on TSW incidence (Tables 1 and 3). Absence of a seeding rate response can be attributed to the very low TSW incidence observed during the study period, as well as the high level of cultivar resistance, particularly in Florida-07 and Georgia-06G, to this disease. These results agree with those of Black et al. (2001) who also failed to observe an increase in TSW incidence with declining seeding rates.

**Stem rot.** Incidence of stem rot differed among years (Table 1) and was higher in 2010 than in 2011 and 2012 with the former having the lowest rating for this disease (Fig. 4A). Lower stem rot damage in the latter two study years may be attributed to lower than average temperatures (± 24°C) for September, when most pod fill occurs, compared with the same month (27°C) in 2010 (Fig. 5). Higher temperatures at pod fill have previously been linked with elevated stem rot incidence in peanut (Backman and Brenneman 1993; Bowen et al. 1992). While no direct comparisons have been made, the cv. Florunner used in earlier studies probably is more susceptible to stem rot than the cultivars used in the current study (Branch and Brenneman 1993), which along with low inoculum pressure due to the cotton rotation partner, may account for the absence of a planting date response (Gorbet et al. 2004).

As indicated by a significant planting date × cultivar interaction \[P \leq 0.10\], stem rot incidence differed by planting date among the three peanut cultivars (Fig. 4B). While Georgia Green suffered higher damage at both planting dates than either of the remaining cultivars, Florida-07 had a lower incidence of stem rot than Georgia-06G at the May but not April planting date. In registration documents, stem rot resistance was reported for Florida-07 (Gorbet and Tillman 2009) but not Georgia Green (Branch 1996) or Georgia-06G (Branch 2007). Tubbs et al. (2011) also saw a higher stem rot incidence in Georgia Green compared with Florida-07 and Georgia-06G, which had similarly low ratings for this disease. In prior studies (Bowen 2003; Brenneman and Hadden 1996; Hagan et al. 2001), stem rot incidence declined as planting dates advanced from mid-April into early June.

Study results confirm previous observations (Augusto et al. 2010; Black et al. 2001; Sconyers et al. 2007) that stem rot intensifies with increasing seeding rates. Lower disease indices were noted at 6.6 than 13.1 and 19.7 seed/m² rates with the 9.8 seed/m² rate having an intermediate rating for stem rot (Table 3). Closer plant proximity obtained at higher seeding rates facilitates disease spread down the row (Backman and Brenneman 1993; Bowen et al. 1992). As previously noted by Augusto et al. (2010), the dense canopy obtained at higher seeding rates would intercept stem rot fungicides in the upper canopy, which would interfere with residue redistribution to **S. rolfsii** infection sites at or below the soil surface. In addition, the dense canopy would increase moisture retention in the lower

---

**FIGURE 3**
TSW incidence as influenced by (A) year and peanut cultivar, and (B) planting date and peanut cultivar. Different letters above bars indicate significant differences using Fishers’ protected least significant difference test \((P \leq 0.05)\).

**FIGURE 4**
Stem rot incidence in response to (A) year and (B) cultivar. Different letters above indicate significant differences using Fishers’ protected least significant difference test for A at \((P \leq 0.05)\) and B at \((P \leq 0.10)\).
canopy, thereby favoring *S. rolfsii* growth (Csinos and Kvein 1988; Zhu et al. 2003). It must be noted, however, that the magnitude of the effect of seeding rate on stem rot incidence, while significant, probably was insufficient to impact fungicide use.

**Leaf spot diseases.** Leaf spot intensity was influenced by planting date, cultivar, and seeding rate (Table 1). Over the study period, early leaf spot was the dominant leaf spot disease but disease intensity levels were probably insufficient to impact pod yield. Leaf spot intensity was usually lower in the April- than May-planted peanuts (Table 4). For April-planted peanuts, disease ratings were higher in 2011 than 2010 and 2012 with minimal leaf spot development seen in the latter year. Study results confirm observations by Hagan et al. (2010) and Lewin et al. (1973) that leaf spot diseases intensify as the planting date advances. Porter et al. (1995) advanced early planting as a strategy to avoid leaf spot epidemics in peanut. As noted by Nsaa et al. (2005), April-planted peanuts may serve as an inoculum source for those planted later, thereby increasing disease intensity and risk of significant yield loss.

While few differences in leaf spot intensity were noted between cultivars planted in April, cultivar response in May plantings differed between study years (Table 4). In May 2010 plantings, disease intensity was higher in Georgia Green than Georgia-06G but not Florida-07. In the following year, Georgia Green had higher leaf spot ratings than Georgia-06G and Florida-07 with the latter having the lowest leaf spot rating. In 2012, equally higher leaf spot intensity values were recorded for Georgia Green and Georgia-06G than Florida-07. While Georgia-06G (Branch 2007) and Florida-07 (Burns and Gallo 2010) are not considered resistant to either early or late spot, both had lower leaf spot ratings in two of three study years than Georgia Green. Others have similarly observed that Georgia Green is more susceptible to leaf spot diseases than other cultivars (Cantonwine et al. 2006; Monfort et al. 2007; Woodward et al. 2008). Lower disease intensity values recorded for Florida-07 than Georgia-06G in two of three study years suggests that the former cultivar may have partial resistance to early leaf spot.

Leaf spot diseases intensified as seeding rate increased. Higher leaf spot ratings were noted at 19.7 than 6.6 seed/m, while those recorded for 9.7 and 13.1 seed/m seeding rates were intermediate (Table 3). As noted with stem rot (Augusto et al. 2010; Csinos and Kvein 1988), the denser canopy that develops at higher seeding rates would create a more favorable micro-environment for infection as well as interfere with fungicide redistribution to the lower leaves. While this study is the first to link increasing seeding rates with an intensification of leaf spot diseases, differences in disease across seeding rates are insufficient to impact fungicide selection and application timing for controlling of leaf spot diseases in peanut.

**Yield.** Similarly higher pod yields were recorded at the three highest seeding rates with lower yields noted at 6.6 compared with 13.1 and 19.7 seed/m (Table 3). Study results concur with Culbrea et al. (2011), who reported lower yield and higher TSW incidence in breeding lines at 9.8 than 19.7 seed/m. Similarly, Tubbs et al. (2011) reported that seeding rates for TSW-resistant peanut varieties may be reduced under irrigation without increasing disease incidence or sacrificing yield. Seeding rates of 6.6, 9.8, 13.1, and 19.7 seed/m evaluated here were, however, generally lower than the 17, 20.3, and 23.3 seed/m employed by Tubbs et al. (2011), which differ little from the recommended single row seeding rate of 19.7 seed/m (Tubbs and Beasley 2012). Conversely, equally high yields were found in non-irrigated fields of Georgia Green in Nicaragua at 7 to 17 seed/m (Augusto et al. 2010). Under high TSW pressure, Branch et al. (2003) noted a sizable increase in disease incidence and a yield decline in seven commercial cultivars including Georgia Green as seeding rate dropped from 23 to 16.5, and finally to 9.8 seed/m. Previously, Gorbat and Shokes (1994) reported yield reductions and increased TSW at lower seeding rates for susceptible but not resistant cultivars. Higher yields exhibited by Georgia-06G and Florida-07

### FIGURE 5
Mean monthly temperatures for April, May, June, July, August, and September for each study year were measured electronically at a height of 1.5 m approximately 2 km from the study site.

### TABLE 3
**Influence of seeding rate on TSW and stem rot incidence, leaf spot intensity, and yield.**

<table>
<thead>
<tr>
<th>Seeding rate (no. seed/m row)</th>
<th>Disease incidence</th>
<th>Leaf spot intensity</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSW</td>
<td>Stem rot</td>
<td></td>
</tr>
<tr>
<td>6.6</td>
<td>1.4 a</td>
<td>2.7 b</td>
<td>3.0 b</td>
</tr>
<tr>
<td>9.8</td>
<td>1.1 a</td>
<td>3.5 ab</td>
<td>3.1 ab</td>
</tr>
<tr>
<td>13.1</td>
<td>1.1 a</td>
<td>3.9 a</td>
<td>3.1 ab</td>
</tr>
<tr>
<td>19.7</td>
<td>1.1 a</td>
<td>4.3 a</td>
<td>3.2 a</td>
</tr>
</tbody>
</table>

*a TSW and stem rot incidence expressed as the number of hits of each disease per 18.3 m of row.*

*b Early and late leaf spot severity rated using the Florida 1 to 10 leaf spot rating scale.*

*c Means in columns followed by the same letter are not significantly different according to Fishers’ protected least significant difference test (P \( \leq 0.05 \)).*

### TABLE 4
**Leaf spot intensity as influenced by an interaction of year, planting date, and peanut cultivar.**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>April</th>
<th>May</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida-07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>2.6 g</td>
<td>2.6 g</td>
</tr>
<tr>
<td>2011</td>
<td>3.1 e</td>
<td>3.1 e</td>
</tr>
<tr>
<td>2012</td>
<td>2.3 hi</td>
<td>2.3 hi</td>
</tr>
<tr>
<td>Florida-06G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>2.5 gh</td>
<td>2.5 gh</td>
</tr>
<tr>
<td>2011</td>
<td>2.9 ef</td>
<td>2.9 ef</td>
</tr>
<tr>
<td>2012</td>
<td>1.8 j</td>
<td>1.8 j</td>
</tr>
<tr>
<td>Georgia Green</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>2.7 fg</td>
<td>2.7 fg</td>
</tr>
<tr>
<td>2011</td>
<td>3.0 e</td>
<td>3.0 e</td>
</tr>
<tr>
<td>2012</td>
<td>2.1 ij</td>
<td>2.1 ij</td>
</tr>
</tbody>
</table>

*d Early and late leaf spot intensity was rated using the 1 to 10 Florida leaf spot rating scale.*

*e Means in columns and rows followed by the same letter are not significantly different according to Fishers’ protected least significant difference test (P \( \leq 0.05 \)).*
compared with Georgia Green can be partially attributed to superior resistance to stem rot (Gorbet and Tillman 2009) and TSW (Branch 1996; Branch 2007; Culbreath et al. 2011, Hagan et al. 2010), despite low disease pressure over all study years, and possibly early leaf spot resistance (Fig. 6).

The impact of planting date on yield is mixed. While lower yields were noted for May- than April-planted peanuts in 2010, planting date did not impact yield in either 2011 or 2012 (Fig. 7). Yields were lower in 2010 than in 2011 and 2012. Cooler temperatures in August and/or September, which may have suppressed stem rot (Bowen 1992), may account for the higher yields in the latter two study years (Fig. 5). Results herein also concur with Padmalatha et al. (2006) who noted that elevated night temperatures were positively correlated with declining pod yield. Prior to the TSW epiphytotic that began in the early 1990s, the peanut planting window for Alabama, Georgia, and Panhandle Florida ran from mid-April to mid-May (Henning et al. 1982).

Once TSW became established in the Southeast, May-sown peanuts produced higher yields along with lower disease indices (Culbreath et al. 2010; Hurt et al. 2005; Nuti et al. 2014; Tubbs and Beasley 2012). Near trace levels of TSW in peanut in recent years as documented here and by Tubbs et al. (2011), as well as the availability of resistant varieties (Black et al. 2001; Culbreath et al. 2010), gives producers the option of sowing peanuts in April, which also gives some measure of protection from drought, particularly in rainfed fields (Mozingo et al. 1991), takes advantage of early season soil moisture (Tillman et al. 2007) and extends the harvest window for peanut (Culbreath et al. 2010) and other summer crops.

**IMPACT ON PEANUT PRODUCTION**

The intensification of TSW in the early 1990s fundamentally changed peanut production in the southeastern United States. Management of this disease has largely depended on delaying planting to reduce seedling exposure to peak thrips populations in late April to early May, maintaining high seeding rates to minimize the percentage of virus-infected plants, and establishing a TSW-resistant cultivar, preferably under strip tillage (Brown et al. 2005; Brown et al. 2003; Hagan et al. 2010). Elevated seeding rates deemed necessary to reduce TSW risk, however, add to variable production costs (Smith and Smith 2012; Tubbs et al. 2011). The recent decline in TSW intensity in Alabama, as detailed here, along with the introduction of cultivars with superior TSW resistance allows, as previously noted by Culbreath et al. (2010), the planting window to be advanced from mid-May into mid- to late April.

As noted in this study, reduced leaf spot pressure is an additional benefit of an earlier planting date, which may allow for a reduction in the number of fungicide applications recommended for leaf spot control according to the Peanut Rx program (Kemeriat et al. 2014). In contrast, later planted peanuts, which are at increased risk for leaf spot diseases, may require the standard 7-application calendar fungicide program to obtain optimum season-long disease control (Majumdar et al. 2015). Elevated stem rot damage sometimes associated with April plantings (Augusto et al. 2010; Black et al. 2001; Bowen et al. 1992; Hagan et al. 2001), which was not corroborated here, can be minimized with the establishment of partially resistant cultivar such as Florida-07, timely application(s) of one of many generic or branded stem rot fungicides (Majumdar et al. 2015), and crop rotation (Backman and Brenneman 1997).

Study results agree with Tubbs et al. (2011) that decreasing seeding rates for single row peanuts below the recommended 19.7 seed/m can lower production costs without increasing TSW incidence or jeopardizing pod yields in an irrigated production system, where impact of early season drought on stand establishment, seedling growth rate, and herbicide activation are minimized. Our observations of increased leaf spot and stem rot intensities with higher seeding rates corroborate results of previous studies (Augusto et al. 2010; Black et al. 2001; Sconyers et al. 2007); however, it remains difficult to determine whether increases in leaf spot intensity and stem rot incidence were sufficient to justify adjustments in fungicide choice or treatment schedules. However, reducing seeding rates below the 13 seed/m for irrigated peanuts increases the risk that stand losses due to seeding diseases and inclement weather may reduce pod yield. Reduced seeding rates in rainfed fields could, under adverse weather conditions, result in significant stand and yield losses as

**FIGURE 6**

The mean yield response of each peanut cultivar for the three years of this study (2010 to 2012). Different letters above bars indicate significant differences according to Fishers’ protected least significant difference test ($P \leq 0.05$).

**FIGURE 7**

Year and planting date impact pod yield. Different letters above bars indicate significant differences according to Fishers’ protected least significant difference test ($P \leq 0.05$).
well as increased TSW risk. As a result, plantings of rainfed
peanuts, which encompass 70% of Alabama’s acreage, should be
strip-till and planted to a TSW resistant cultivar at
recommended seeding rates.

Since this and all preceding seeding rate and/or planting date
studies (Brenneman and Hadden 1996; Culbreath et al. 2011;
Culbreath et al. 2010; Nuti et al. 2014; Tubbs et al. 2011; Wehtje
et al. 1994) were irrigated, studies need to be conducted under
rainfed conditions to assess the impact of planting date and
seeding rate on the occurrence of diseases and yield response of
commercial cultivars. Higher yields exhibited by Georgia-06G
and Florida-07 when compared with Georgia Green, which is a
trend noted in previous studies (Branch 1996; Branch 2007;
Culbreath et al. 2011; Gorbet and Tillman 2009) may also be
partially attributed to a superior disease resistance package of the
two former cultivars. Continued release of peanut germplasm with
superior resistance to TSW, stem rot, and possibly leaf spot
diseases suggests that their impact on pod yield and seed quality
as well as the need for costly insecticide and fungicide inputs may
be reduced.

ACKNOWLEDGMENTS

Funding for this project was obtained from the Alabama Peanut
Grower Association and the Southeastern Peanut Research Initiative,
National Peanut Board.

LITERATURE CITED

Maximizing economic returns and minimizing stem rot incidence with

Branch, W. D., and Brenneman, T. B. 1993. White mold and Rhizoctonia limb
diseases suggests that their impact on pod yield and seed quality
as well as the need for costly insecticide and fungicide inputs may
be reduced.

ACKNOWLEDGMENTS

Funding for this project was obtained from the Alabama Peanut
Grower Association and the Southeastern Peanut Research Initiative,
National Peanut Board.

LITERATURE CITED

Maximizing economic returns and minimizing stem rot incidence with

Branch, W. D., and Brenneman, T. B. 1993. White mold and Rhizoctonia limb
diseases suggests that their impact on pod yield and seed quality
as well as the need for costly insecticide and fungicide inputs may
be reduced.

ACKNOWLEDGMENTS

Funding for this project was obtained from the Alabama Peanut
Grower Association and the Southeastern Peanut Research Initiative,
National Peanut Board.

LITERATURE CITED

Maximizing economic returns and minimizing stem rot incidence with

Branch, W. D., and Brenneman, T. B. 1993. White mold and Rhizoctonia limb
diseases suggests that their impact on pod yield and seed quality
as well as the need for costly insecticide and fungicide inputs may
be reduced.

ACKNOWLEDGMENTS

Funding for this project was obtained from the Alabama Peanut
Grower Association and the Southeastern Peanut Research Initiative,
National Peanut Board.
on yield of early and late maturing peanut cultivars grown under rainfed conditions in Ghana. Crop Prot. 24:325-332.