Evaluation of Seeding Rate and Cultivar Effects on Peanut (*Arachis hypogaea* L.) Seeded in 76-cm Row Spacing

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ABSTRACT

Standard row spacing for peanut (*Arachis hypogaea* L.) in Georgia is 91-cm in a single-row pattern. Narrower row spacings are often used in crops grown in rotation with peanut. Therefore, converting peanut to narrower row spacing may be easier and beneficial to some growers if cultivars and seeding rates can be identified that can be grown in narrow rows without a reduction in yield and grade. Based on current University of Georgia recommendations, peanut is typically planted at 19 seed/m with a 91-cm row spacing. Using narrower row spacing and constant seeding rates, increased seed costs would be observed. The objectives of this research were to evaluate the influence of cultivars and seeding rate in peanut planted in 76-cm single rows on yield, grade, and tomato spotted wilt virus (*tospovirus*) (TSWV) incidence. Experiments were conducted in 2008, 2010, and 2014 in Tifton, GA and in 2014 at Camilla, GA. Treatments were comprised of three cultivars (varying each year) and three seeding rates (14, 17, and 19 seed/m). Results indicate that pod yield, grade, and TSWV incidence were not affected by seeding rate. Seeding rate significantly influenced plant density where 14, 17, and 19 seed/m seeding rates resulted in 12.1, 13.2, and 13.8 peanut plants/m, respectively equating to a 9% and subsequent 4% increase in plant density as seeding rate increased. Seeding rate did not affect the rate of canopy closure, but cv. Georgia-12Y and TUFRunner™ '511' had faster canopy closure than Georgia-06G. Peanut grade (total sound mature kernels) was not influenced by seeding rate, but did differ between cultivars. From these results, it can be concluded that 76-cm single-row can provide adequate yield and grade across multiple seeding rates. In addition, this study confirms that cultivar selection is the primary means for reducing TSWV incidence and altering grade in 76-cm peanut production.

Key Words: Row spacing, tomato spotted wilt virus, seed rate.

In the United States, Georgia is the largest peanut producing state, planting an average of 250,000 ha of peanut per year from 2010–2016 (NASS, 2017). Peanut contributed $502 million to the economy of Georgia in 2016 (NASS, 2017). Row spacing research was conducted in peanut as early as the 1930s (McClelland, 1931) with the goal of improving yield. Numerous researchers have evaluated planting peanut in narrow row spacings over the last 50 years and results have varied (Duke and Alexander, 1964; Cox and Reid, 1965; Harrison, 1970; Hauser and Buchanan, 1981; Monzingo and Coffelt, 1984; Kirby and Kitbamroong, 1986). From this research, conclusions have been that narrow row peanut can produce higher yields than the conventional 91-cm row spacing, especially in scenarios with high weed pressure (Hauser *et al*., 1982; Johnson *et al*., 2005), but runner-type peanut, the market type typically grown in Georgia, may not see that same yield advantage as market types with a more bunch, or erect growth habit. Although there were no reports suggesting yield disadvantages to planting peanut in narrow row spacing, most producers have not adopted this planting configuration because of cultivation, harvest equipment operations, and concerns about improper inversion at harvest.

Since tomato spotted wilt virus (*Tospovirus*) (TSWV) had a large economic impact on peanut in the mid-1990s, twin-row patterns were adopted by many farmers across the peanut belt (Brown *et al.,* 2005). Since then, the peanut quota system has ended and commodity prices in many crops have drastically changed causing crop acreage shifts from year to year, including increased peanut production and newly developing peanut producing regions (Dohlman and Livezey, 2005; Chapin *et al*., 2010). In response to the negative yield impacts of TSWV incidence in peanut, cultural practices and use of TSWV-resistant cultivars have been widely adopted by peanut farmers to minimize risk. With new cultivars, appealing commodity markets, reduced tillage practices,

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and higher investment prices for twin-row planters, planting in 76-cm single-row has become a renewed topic of interest. If 76-cm single row planting can increase or maintain yield, grade, and provide any other agronomic advantages, growers may have the option of sharing planting equipment across planted commodities in their rotations that show benefit with narrow row spacing such as corn (*Zea mays* L.) (Farnham, 2001) and soybean (*Glycine max* [L.] Merr.) (De Bruin and Pedersen, 2008). By utilizing one planter spacing for multiple crops, the ability to change annual crop production to follow the market is easier, reducing down-time to alter tractor and planter settings.

With the adoption of any new cultural practices in agriculture, research is often the basis of extension recommendations. The current University of Georgia (UGA) Extension recommendation for seeding rate in peanut is 19 seed/m (215,200 seed/ha) for both 91-cm single and 91-cm twin-row patterns (Beasley, 1997). Previous research in Georgia has shown that a final peanut plant stand of 13 plants/m is key to ensure optimum yield (Henning et al., 1979; Kemerait *et al.*, 2011; Tubbs *et al.*, 2011). As row spacing deviates from 91-cm, seeding rates (seed/m) must also change in order to keep the seed density (seed/ha) similar to what is recommended for 91-cm spacing. If seeding rate remained at 19 seed/m in 76-cm spacing, it would result in 258,200 seed/ha to be planted, so a reduction in seeding rate to 17 seed/m would be required to keep the equivalent seed density of 215,200 for the UGA recommended rate of 19 seed/m in 91-cm row spacing. Although adequate yields have been obtained in 76-cm single-row using seeding rates that provide populations comparable to 91-cm row spacing (Hauser and Buchanan, 1981), further investigations of 76-cm single row seeding rates are needed to support extension recommendations, especially with new high yielding and TSWV-resistant cultivars.

The main objective of this test was to determine if peanut cultivar and seeding rate affect yield, grade, and TSWV incidence when planted on 76-cm single row spacing. Results are directly applicable to many peanut producers across the U.S., including those who currently own a 76-cm planter for other crops, growers in newly expanded peanut regions, or peanut producers who want to know if 76-cm row peanut can provide production advantages such as reduced TSWV incidence and faster canopy closure.

Materials and Methods

This experiment was conducted at the Lang-Rigdon Farm of UGA Coastal Plain Experiment Station in Tifton, GA (31.51° N, -83.54° W) in 2008, 2010, and 2014. In 2014, this test was also conducted at the UGA C.M. Stripling Irrigation Research Park in Camilla, GA (31.28° N, -84.29° W). The experiment was a 3X3 factorial arrangement of treatments in a split-plot design, with four replications. The main plot effect was cultivar. The three cultivars used varied from year-to-year based on commercial availability, but were reflective of popular runner market-type cultivars planted at the time of each test. In 2008, cultivars were: Georgia Green (Branch, 1996), Georgia-06G (Branch, 2007), and AP-3 (Gorbet, 2007); in 2010: Georgia Green, Georgia-06G, and AP-4 (Tillman and Gorbet, 2008); and in 2014: Georgia-06G, Georgia-12Y (Branch, 2013), and TUFRunner™ '511'. Subplot treatments were three seeding rates. The seeding rates used were 14, 17, and 19 seed/m to establish targeted seed densities of 183,300, 223,000, and 249,300 seed/ha, respectively.

All treatments were planted with a vacuum planter (Monosem, Inc. Edwardsville, KS, USA) on 22 May 2008, 13 May 2010, 28 May 2014 in Tifton and 22 May 2014 in Camilla. Each main plot was made up of three subplots (three beds or six rows) wide. Each subplot was made up of one bed (two rows) that was approximately 1.52 m wide and 15.2, 21.3, 12.2, and 9.1 m long in 2008, 2010, and 2014 in Tifton and 2014 in Camilla, respectively, as a result of the shape and size of the field each year. The herbicide program utilized was representative of current production practices and followed recommendations from the Georgia Pest Management Handbook (UGA, 2008). A protective fungicide program was also employed which followed recommendations from the Georgia Pest Management Handbook (UGA, 2008) and the PeanutRx high-risk management program (Kemerait *et al.*, 2008) to control early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Cercosporidium personatum*) as well as stem rot (*Sclerotium rolfsii* Sacc.). Fungicides were first applied starting approximately 30 days after planting, at R1 (first bloom) growth stage (Boote, 1982), and continued throughout the season on 14 d spray intervals. All field study locations were irrigated on an as-needed-basis corresponding to the UGA Peanut Production Guide Checkbook method (Beasley, 2007).

Harvest determination consisted of the hull scrape and peanut maturity profile method (Williams and Drexler, 1981). For this experiment,

Table 1. Analysis of variance probability values for cultivar, seeding rate, and the interaction for 2008, 2010, and 2014.

	2008			2010			2014[a]			
	Plant Density	TSWV	Yield	Plant Density	TSWV	Yield	Plant Density	TSWV	Yield	Canopy Closure
	p-values									
Cultivar	0.0213	<0.0001	0.0317	0.0026	<0.0001	0.1183	<0.0001	0.0756	0.7670	0.0013
Seeding Rate (SR)	<0.0001	0.3385	0.8402	0.0024	0.5509	0.6854	<0.0001	0.2934	0.8438	0.9295
Cultivar*SR	0.6715	0.6829	0.6376	0.7106	0.0365	0.8086	0.4050	0.8156	0.6139	0.9993

[a]Data in 2014 pooled over location.

peanut digging and inversion was done with a 2-row digger/shaker/inverter (Kelley Mfg. Co., Tifton, GA) that was set up for twin-row pattern which altered blade angle and had longer blades to reduce harvest losses with the narrower row spacing than the typical single row digger. Once peanut had been inverted and dried to approximately 12–15% moisture, harvest began and consisted of using a 2-row KMC harvester (Kelley Mfg. Co., Tifton, GA); yields were adjusted to 7% moisture for uniformity of comparisons. Grade (the percentage of total sound mature kernels [TSMK]) was determined according to USDA-AMS grade standards (USDA-AMS, 1997).

Data collection throughout the growing season differed between years and locations due to logistics and labor. Data collected in 2008, 2010, and 2014 included peanut population/density (plants/m) at approximately 20 d after planting to ensure that adequate differences between seeding rates were attained, and TSWV incidence (percentage of infected row meters in each row) was determined with visual ratings of the two harvest rows prior to inversion (Rodriguez-Kabana *et al.*,1975; Culbreath *et al.,* 1997). In 2014 in Tifton, lapping dates (the number of days from planting until 50% of peanut vines in the harvest rows had covered the row middle) were also recorded. Statistical analyses were conducted using PROC GLIMMIX in SAS version 9.3 (SAS Institute, 2010). Data were analyzed by analysis of variance (ANOVA) and differences among least square means were determined by using multiple pairwise t-tests ($P = 0.05$) for each year. Combined analyses over years was not possible because of the differing cultivars among years. Analyses were combined over location in 2014 since cultivars were the same for both locations in that year and location was not significant ($P = 0.0835$).

Results and Discussion

Peanut pod yield was only affected by cultivar selection in 2008 (Table 1), where Georgia-06G had 15 and 13% higher pod yield than Georgia Green and AP-3, respectively (Table 2). No differences in cultivar were observed in 2010 or 2014 (Tables 1, 2, and 3). The ability of Georgia-06G to adapt to different environments, narrow or wide rows, or across a range of seeding rates may be one of the factors contributing to why this cultivar is popular throughout the southeastern U.S. Peanut pod yield was not affected by seeding rate in this study (Table 1) which is similar to findings by Tubbs *et al.* (2011), where single-row peanut yield was not significantly affected by seeding rate. By seeding peanut at a rate of 17 seed/m in 76-cm row spacing the plant population would be equivalent to

Table 2. Cultivar effects on plant density (plants/m), incidence (%) of tomato spotted wilt virus (TSWV), and peanut pod yield (kg/ha) in Tifton, GA 2008 and 2010.

Cultivar[a]	2008						2010					
	Plant Density[b]		TSWV		Pod Yield		Plant Density[b]		TSWV		Pod Yield	
	Plants/m		% Incidence		kg/ha[c]		Plants/m		% Incidence		kg/ha[c]	
Georgia Green	13.5	b	3.6	a	5200	b	12.0	a	2.3	b	2750	a
Georgia-06G	13.9	b	1.0	b	6180	a	10.9	b	6.8	a	3150	a
AP-3	15.0	a	0.5	b	5410	b	–		–		–	
AP-4	–		–		–		11.5	a	2.4	b	3070	a

[a]Data pooled over seeding rate. Means within a column followed by same lowercase letter are not significantly different according to pairwise t-tests at $P = 0.05$.

[b]Plants per meter of row counted 3 weeks after emergence.

[c]Yield adjusted to 7% moisture.

Table 3. Cultivar effects on plant density (plants/m), incidence (%) of tomato spotted wilt virus (TSWV), peanut pod yield (kg/ha), and days to 50% canopy closure in Tifton, GA and Camilla, GA in 2014.

	2014							
Cultivar[a]	Plant Density[b]		TSWV		Pod Yield		Tifton Canopy Closure	
	Plants/m		% Incidence		kg/ha[c]		days	
Georgia-12Y	14.1	a	3.4	a	8390	a	51	b
Georgia-06G	12.9	b	2.3	a	8620	a	55	a
TUFRunner™ '511'	12.7	b	4.9	a	8500	a	50	b

[a]Data pooled over seeding rate and location. Means within a column followed by same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[b]Plants per meter of row counted 3 weeks after emergence.

[c]Yield adjusted to 7% moisture.

current recommendations of 19 seed/m for peanut grown on 91-cm row spacing (Beasley, 1997).

Cultivar had significant effects on TSWV incidence in 2008 and 2010 (Table 1). In 2008, Georgia Green had 2.6 and 3.1% greater TSWV incidence than Georgia-06G or AP-3, respectively (Table 2). In 2010, Georgia-06G had 4.5 and 4.4 % greater TSWV incidence than either Georgia Green or AP-4, respectively (Table 2). No differences in TSWV incidence were observed in 2014 among cultivars (Tables 1 and 3). Although significant differences were observed among cultivars in 2008 and 2010, overall TSWV incidence recorded was less than 7% in both years. This may suggest that there were low levels of TSWV in 2008 and 2010 that aided in reducing the incidence of TSWV that was observed in each cultivar since Georgia Green typically has shown increased levels of TSWV susceptibility in years past (Kemerait *et al.*, 2011). Seeding rate did not have an effect on TSWV incidence (Table 1) which differs with the findings of Brenneman and Walcott (2001), who found that a high seeding rate had less TSWV incidence compared to a low seeding rate in 91-cm single-row peanut. In 2010, a significant interaction between cultivar and seeding rate was observed, where Georgia Green had less TSWV incidence at a seeding rate of 14 seed/m than either 17 or 19 seed/m rates (Table 5). In this case, Georgia Green had 3.5 and 2.9% less TSWV incidence when planted at low seeding rate than high or medium seeding rates, respectively. Sconyers *et al.* (2005) and Branch *et al.* (2003) found that low seeding rate (< 20 seed/m in 91-cm single-rows) had increased TSWV incidence, therefore differing with the results of this study. It is not known why TSWV was greater with increased seeding rate in this trial for Georgia Green. With the exception of the interaction of cultivar and seeding rate in 2010, cultivar selection was the primary factor affecting TSWV incidence in 76-cm single-rows in this study. It is possible that the genetic TSWV-resistance of each cultivar may have contributed to varying levels of TSWV incidence observed (Brown *et al.*, 2005).

Peanut plant population was affected by cultivar and seeding rate in each year of the study, with no interaction between treatments effects (Table 1). In 2008, AP-3 had 10 and 7% more plants/m emerged than either Georgia Green or Georgia-06G 20 days after planting (Table 2). In 2010, AP-4 and Georgia Green had 5 and 9% more plants/m emerged 20 days after planting than Georgia-06G (Table 2). In 2014, Georgia-12Y had 8 and 10% more plants/m emerged 20 days after planting than either Georgia-06G or TUFRunner™ '511', respectively (Table 3). With seeding rate averaged across

Table 4. Seeding rate effects on plant density (plants/m), incidence (%) of tomato spotted wilt virus (TSWV), and peanut pod yield (kg/ha) in Tifton, GA in 2008, 2010, and 2014, and Camilla, GA in 2014.

Seeding rate[a]	Plant Density[b]		TSWV		Pod Yield	
	Plants/m		% Incidence		kg/ha[c]	
14 seed/m	12.1	c	4.2	a	5530	a
17 seed/m	13.2	b	3.8	a	6140	a
19 seed/m	13.8	a	4.0	a	5870	a

[a]Data pooled over cultivar, year, and location. Means within a column followed by same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[b]Plants per meter of row counted 3 weeks after emergence.

[c]Yield adjusted to 7% moisture.

Table 5. Cultivar and seeding rate effects on tomato spotted wilt virus (TSWV) incidence (%) in Tifton, GA 2010.

Cultivar	Seeding Rate					
	Low (14 seed/m)		Medium (17 seed/m)		High (19 seed/m)	
	% TSWV Incidence[a]					
Georgia 06G	3.3	Aab	2.2	Ab	1.3	Ab
Georgia Green	4.6	Ba	7.5	Aa	8.1	Aa
AP-4	2.4	Ab	2.9	Ab	2.1	Ab

[a]Means within a row followed by same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05. Means within a column followed by same letter are not significantly different according to pairwise t-tests at P = 0.05.

cultivar, significant differences in plant population were observed at every increase of seeding rate (Table 4). Plant populations resulting from a seeding rate of 19 seed/m had 4% more plants/m than a seeding rate of 17 seed/m (Table 4). Similarly, a seeding rate of 17 seed/m had 9% more plants/m than a seeding rate of 14 seed/m (Table 4). From these results it can be observed that by increasing the seeding rate of peanut, plant population can also be increased.

At the Tifton location in 2014, lapping dates were recorded and significant differences between cultivars were observed (Table 1 and 3). Seeding rate did not significantly affect lapping date. Cultivars Georgia-12Y and TUFRunner™ '511' took 4 to 5 fewer days to cover the row middles than Georgia-06G (Table 3). Based on the tendency of Georgia-12Y and TUFRunner™ '511' to have a prostrate type growth habit compared to Georgia-06G, which has a more upright growth habit, it was hypothesized that these cultivars would lap the middles more quickly than Georgia-06G. Thus the growth habit of each cultivar can allow vine growth to grow laterally across the soil surface, covering the soil surface faster. By selecting cultivars that lap the middles more quickly, agronomic advantages may become evident such as increased weed suppression or reduced soil temperature during reproductive growth stages (Hauser *et al*., 1982; Boote, 1982). From the results in this study, the rate of canopy closure and TSWV incidence did not have an apparent affect on one another which would suggest that TSWV incidence is not directly influenced by canopy closure or row spacing, but by other factors such as thrips populations, flight patterns, or timing of feeding (often occurs early in the season prior to canopy closure) (Brown, 2009).

Peanut grade (TSMK) was also obtained. Seeding rate had no effect on grade, but significant differences between cultivars were observed (data not reported). It is not uncommon for cultivars to exhibit differences in grade (Faircloth and Prostko, 2010).

Conclusion

Seeding rate did not influence pod yield or TSWV incidence in 76-cm single-rows within any cultivar evaluated herein. As a result, increased flexibility in selecting seeding rates can be utilized. A seeding rate as low as 14 seed/m with a 76-cm row spacing would result in a 15% decrease in total seed planted compared to the UGA Extension recommendation of 19 seed/m in 91-cm spaced rows. This would result in a significant reduction in seed cost with no negative effect on yield or grade. Cultivar selection appears to be the best strategy for reducing TSWV incidence in narrow 76-cm single row peanut production. Although TSWV incidence differed between cultivars in 2008 and 2010, it did not have a direct effect on pod yield. Using other proven cultural control methods for reducing the risk for TSWV incidence would still be encouraged for 76-cm row spacing (Kemerait *et al.,* 2011), but further research is needed to confirm whether some of those practices are adequate with narrower row spacing. Overall, 76-cm single-row planted peanut can withstand reduced seeding rates therefore keeping seed cost equivalent to conventional 91-cm spaced rows.

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Literature Cited

Beasley, J.P. 1997. Peanut Production Field Guide. Coop. Ext. Serv. Bull. 1146:20. Univ. of Georgia, Athens, GA.

Beasley, J.P. 2007. Irrigation strategies. *In* E.P. Prostko, 2007 Peanut Update. Univ. of Georgia, Tifton, GA. [Online] Available at http://www.caes.uga.edu/commodities/fieldcrops/peanuts/2007peanutupdate/irrig.html. (verified 29 Jan. 2017) Univ. of Georgia, Tifton, GA.

Boote, K.J. 1982. Growth stages of peanut (*Arachis hypogaea* L.). Peanut Sci. 9:35–40.

Branch, W.D. 1996. Registration of 'Georgia Green' peanut. Crop Sci. 36:806.

Branch, W.D., J.A. Baldwin, and A.K. Culbreath. 2003. Genotype x seeding rate interaction among TSWV-resistant, runner-type peanut cultivars. Peanut Sci. 30:108–111.

Branch, W.D. 2007. Registration of 'Georgia-06G' peanut. J. Plant Registrations 1:120.

Branch, W.D. 2013. Registration of 'Georgia-12Y' peanut. J. Plant Registrations 7:151–153.

Brenneman, T., and R. Walcott. 2001. Defining the relationship between plant stand, tomato spotted wilt, and pod yield from peanut seed treatment trials. Proc. Am Peanut Res. Edu. Soc. 33:21–22.

Brown, S.L. 2009. Management of TSWV. [Online] Available at http://www.caes2.caes.uga.edu/tswv/vegcrops/tospoviruses/thripsinpnuts.html (verified 26 Jan 2018) Univ. of GA, Tifton, GA.

Brown, S.L., A.K. Culbreath, J.W. Todd, D.W. Gorbet, J.A. Baldwin, and J.P. Beasley. 2005. Development of a method of risk assessment to facilitate integrated management of spotted wilt of peanut. Plant Disease 89:348–356.

Chapin, J.W., J.S. Thomas, T.G. Isleib, F.M. Shokes, W.D. Branch, and B.L. Tillman. 2010. Field evaluation of Virginia-type peanut cultivars for resistance to tomato spotted wilt virus, late leaf spot, and stem rot. Peanut Sci. 37:63–69.

Cox, F.R. and P.H. Reid. 1965. Interaction of plant population factors and level of production on the yield and grade of peanuts. Agron. J. 57:455–457.

Culbreath, A.K., J.W. Todd, D.W. Gorbet, F.M. Shokes, and H.R. Pappu. 1997. Field response of new cultivar UF 91108 to tomato spotted wilt virus. J. Plant Dis. 81:1410–1415.

De Bruin, J.L. and P. Pedersen. 2008. Effect of row spacing and seeding rate on soybean yield. Agron. J. 100:704–710.

Dohlman, E. and J. Livezey. 2005. Peanut backgrounder. [Online] Available at https://www.ers.usda.gov/webdocs/publications/ocs05i01/29617_ocs05i01_002.pdf?v=41414 (verified 29 Jan. 2017) USDA, Washington, D.C. 1–30.

Duke, G.B. and M. Alexander. 1964. Effects of close row spacing on peanut production requirements. USDA Prod. Res. Bull. 77. 14 pp.

Faircloth, W.H. and E.P. Prostko. 2010. Effect of imazapic and 2,4-DB on peanut yield, grade, and seed germination. Peanut Sci. 37:78–82.

Farnham, D.E. 2001. Row spacing, plant density, and hybrid effects on corn grain yield and moisture. Agron. J. 93:1049–1053.

Gorbet, D.W. 2007. Registration of 'AP-3' peanut. J. Plant Registrations 1:126–127.

Harrison, A.L. 1970. The effect of seed rates and multiple rows per bed under irrigation. Proc. Amer. Peanut. Res. Educ. Assoc. 2:47–50.

Hauser, E.W. and G.A. Buchanan. 1981. Influence of row spacing, seeding rates, and herbicide systems on the competitiveness and yield of peanuts. Peanut Sci. 8:74–81.

Hauser, E.W., G.A. Buchanan, R.L. Nichols, and R.M. Patterson. 1982. Effects of Florida beggarweed (*Desmodium tortusum*) and sicklepod (*Cassia obtusifolia*) on peanut (*Arachis hypogaea*) yield. Weed. Sci. 30:602–604.

Henning, R.J., J.F. McGill, L.E. Samples, C.W. Swann, S.S. Thompson, and H. Womack. 1979. Growing peanuts in Georgia: A package approach. Bull. 640, Univ. of Georgia 46 pp.

Johnson, W.C. III, E.P. Prostko, and B.G. Mullinix Jr. 2005. Improving the management of dicot weeds in peanut with narrow row spacings and residual herbicides. Agron. J. 97:85–88.

Kemerait, R., A. Culbreath, and T. Brenneman. 2008. 2008 Peanut Disease Update. [Online] Available at caes2.caes.uga.edu/commodities/fieldcrops/peanuts/2008peanutupdate/diseases.html (verified 29 Jan. 2017). Univ. of Georgia, Tifton, GA.

Kemerait, R., A. Culbreath, J. Beasley, E. Prostko, T. Brenneman, N. Smith, S. Tubbs, R. Olantinwo, R. Srinivasan, M. Boudreau, B. Tillman, D. Rowland, N. Dufault, A. Hagan, and W. Faircloth. 2011. Peanut Rx, minimizing diseases of peanut in the southeastern United States – the 2011 version of the peanut disease risk index. pp. 100–116. *In* J.P. Beasley, Jr.(ed.).2011 Peanut Update. Spec. Pub. CSS-11-0110. Univ. of Georgia Coop. Ext. Serv., Athens, GA.

Kirby, J.S. and C. Kitbamroong. 1986. Peanut cultivar response to row spacing and plant density. Proc. Amer. Peanut Res. Educ. Soc. 18:48 (Abstr.).

McClelland, C.K. 1931. The peanut crop in Arkansas. Bull. 263, Arkansas Exp. Sta.

Monzingo, R.W. and T.A. Coffelt. 1984. Row pattern and seeding rate effects on value of Virginia-type peanut. Agron. J. 76:460–462.

[NASS] USDA National Agricultural Statistics Service. 2017. Quick Stats. [Online] Available at http://quickstats.nass.usda.gov/ (verified 29 Jan. 2017). USDA-NASS, Washington, D.C.

Rodriguez-Kabana, R., P.A. Backman, and J.C. Williams. 1975. Determination of yield losses to *Sclerotium rolfsii* in peanut fields. Plant Dis. Rep. 59:855–858.

SAS Institute. 2010. The SAS system for Windows. v. 9.3. SAS Inst., Cary, NC.

Sconyers, L.E., T.B. Brenneman, K.L. Stevenson, and B.G. Mullinix. 2005. Effects of plant spacing, inoculation date, and peanut cultivar on epidemics of peanut stem rot and tomato spotted wilt. Plant Dis. 89:969–974.

Tillman, B.L. and D.W. Gorbet. 2008. Registration of 'AP-4' peanut. J. Plant Registrations 3:138–142.

Tubbs, R.S., J.P. Beasley, A.K. Culbreath, R.C. Kemerait, N.B. Smith, and A.R. Smith. 2011. Row pattern and seeding rate effects on agronomic, disease, and economic factors in large-seeded runner peanut. Peanut Sci. 38:93–100.

University of Georgia. 2008. Peanut weed and disease control. *In* E.P. Prostko and R.C. Kemerait, T.B. Brenneman, and A.K. Culbreath, Georgia Pest Management Handbook. [Online] Available at http://www.caes.uga.edu/departments/entomology/extension/pest-management-handbook.html (verified 29 Jan. 2017) Univ. of Georgia Coop. Ext. Serv., Tifton, GA. 489–514.

USDA-AMS. 1997. United States standards for grades of shelled runner type peanuts. [Online] Available at https://www.ams.usda.gov/grades-standards/shelled-runner-type-peanuts-grades-and-standards (verified 29 Jan. 2017) USDA Agric. Marketing Serv., Washington, D.C.

Williams, E.J. and J.S. Drexler. 1981. A non-destructive method for determining pod maturity. Peanut Sci. 8:134–141.