Disease Management and Variable Planting Patterns in Peanut

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ABSTRACT

Peanut (*Arachis hypogea* L.) is typically sown in single or twin rows centered on 91-cm beds. A planter capable of sowing 8 peanut rows on a 182-cm bed was developed by USDA-ARS. This planting pattern optimizes plant spacing and may contribute to crop advantages. Management of soil borne diseases in peanut may be affected by planting patterns. Replicated field experiments were conducted in 2002, 2003, and 2004 at two locations each year near Dawson, Georgia to compare interactions of planting patterns and disease management programs. Three fungicide application regimes were factored over single row, twin row, and diamond planting patterns, for a total of 9 treatments. A block calendar schedule with 14-d intervals was compared with two weather advisory programs, including AU-Pnuts and an experimental version of AU-Pnuts using minimum daily soil temperature (MDST) as a guide for fungicide selection. The seeding rate of each planting pattern was 22 seed/m^2. There were no planting pattern by fungicide program interactions. Twin row and diamond planting patterns were often superior in yield than single rows; however, diamond patterns did not yield better than twin rows. Incidence of peg, pod, and limb rot caused by *Rhizoctonia solani* and stem rot caused by *Sclerotium rolfsii* was not severe in any trial and was not affected by planting pattern. Despite low disease presence, the calendar program was consistently better for yield and overall disease control than the two advisory programs. Yield was similar for the three fungicide treatments in four of six experiments. Grade of twin row and diamond planted peanut was 0.7 points better than single row peanut over three years at one location. Net return based on crop value less fungicide program cost was more closely tied to yield than variable input costs for fungicide programs.

Key Words: AU-Pnuts, chlorothalonil, diamond planting, geocarposphere, groundnut, peanut, single row, tebuconazole, twin row.

Peanut (*Arachis hypogea* L.) is typically sown in single or twin rows centered on 91 to 102 cm beds. A number of crops have responded favorably to planting patterns that space seed more evenly than the traditional single row pattern. These include twin and narrow row arrangements commonly used in peanut (Lanier *et al.*, 2004), soybean [*Glycine max* (L.) Merr.] (Janovicek *et al.*, 2006), and cotton (*Gossypium hirsutum* L.) (Jost and Cothren, 2001). The majority of runner market type peanut in the southeastern US are currently planted in a twin row pattern. Although the twin row arrangement is an improvement over single row planting, it could be improved upon to provide a more optimal plant spatial relationship. Increasing the number of rows planted on a bed to the point that seedling spacing becomes equidistant, would maximize plant row coverage during early crop growth. This arrangement may reduce competition for resources among seedlings and contribute to earliness. Sharratt and McWilliams (2005) concluded that corn (*Zea mays* L.) grown in narrow rows captured more light and soil moisture by establishing more uniform root systems and leaf canopies, which led to lower soil temperatures compared to corn grown in wide rows. Achieving ground cover sooner leads to the potential of decreased soil moisture lost to evaporation (Krieg, 1996), making the crop more competitive against weed escapes (Johnson *et al.*, 2005) and ultimately improving yield.

A vacuum planter capable of planting 8 rows on a 182-cm bed was developed at the USDA-ARS, National Peanut Research Laboratory in Dawson, GA. This planter places seed in an even diamond pattern in order to optimize plant spatial relationships as described by Sorensen *et al.* (2004). A diamond pattern (Figure 1) seed placement may result in ground cover significantly sooner (Mozingo and Wright, 1984) than peanuts planted in single or twin rows.

Daily measurements of soil temperature in the geocarposphere are useful to describe some phenomena common to peanut production and can be used as a guideline for peanut management. Cole *et al.* (1985) found that undamaged peanuts under drought stress had preharvest invasion of *Aspergil-*

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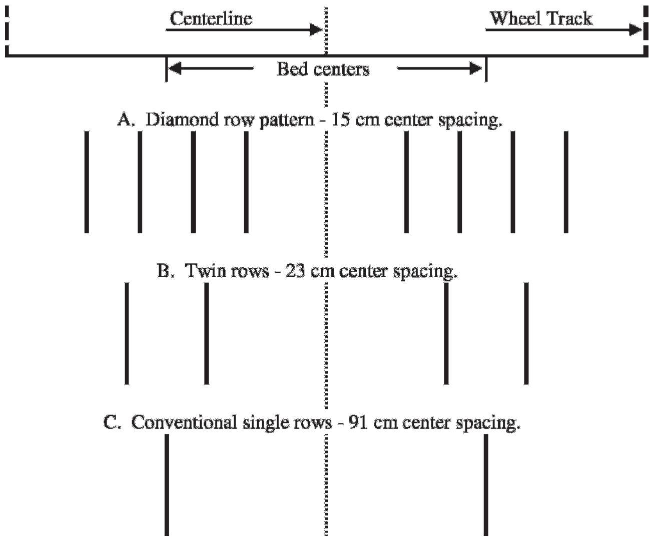

Fig. 1. Outlay of planting patterns including: (A) diamond row pattern with 15 cm spacing, (B) twin row pattern with 23 cm spacing, and (C) conventional row pattern with 91 cm spacing. Heavy dashed lines simulate wheel tracks, light dashed lines designate a centerline between planting beds, and seeding rows are illustrated by solid lines.

lus flavus and aflatoxin contamination when mean geocarposphere temperatures were between 26.0 and 29.6°C. Other projects have used maximum and minimum daily geocarposphere temperature for determining irrigation scheduling (Davidson *et al*., 1986) and to predict crop yield and quality (Davidson *et al*., 1989). The potential for using minimum daily soil temperature (MDST) in the geocarposphere to improve fungicide selection for control of soil borne diseases in peanut has also been published by Davidson *et al*. (1987, 1991). This work provides information showing that stem rot (*Sclerotium rolfsii*) pressure became severe when MDST in the geocarposphere exceeded 23.9°C. It was also noted that peg, pod, and limb rot (*Rhizoctonia spp.*) became severe when MDST in the geocarposphere decreased below 21.1°C. In those experiments, it appeared that MDST could be used to improve the selection and timing of fungicide applications for controlling those two soil borne diseases. When MDST was outside the range favoring growth of soil borne pathogens, a less expensive fungicide for maintaining control of foliar diseases could be used to improve net return potential for growers. Most of the current successful recommended fungicide regimes for peanut are based on calendar schedules, climatic conditions, and planting date. These programs recommend the use of products which control foliar pathogens during early vegetative growth and for maintenance of foliage at the end of the season. During the middle of the season, when pods are susceptible to soil borne diseases, more costly products are used to control soil borne pathogens as well as maintain control of foliar diseases.

The purpose of the current study is to evaluate the relationship between planting patterns and management of peanut diseases. Secondary objectives included the evaluation of MDST in the 21.1°C and 23.9°C range as a means of proper fungicide selection. Yield and grade factors are used to determine net return less the cost of respective fungicide programs.

Materials and Methods

Replicated field experiments were conducted at the Fiveash farm [Americus (Sandy, siliceous, thermic Rhodic Paleudults)] and Payne farm [Faceville (Fine, kaolinitic, thermic Typic Kandiudults)] near Dawson, GA in 2002, 2003, and 2004. A uniform population of peanut cultivar ‘Georgia Green’ was sown at 22 seed/m^2 to establish single row, twin row, and diamond planting patterns. A factorial treatment arrangement using three fungicide application regimes and three planting patterns was replicated four times in a randomized complete block design. The first fungicide regime was a standard block calendar schedule (spray every 10 to 14 days) starting 14 days after planting (DAP) with two chlorothalonil (tetrachloroisophthalonitrile) (Bravo Weather Stik[3], Syngenta Crop Protection, Greensboro, NC) applications followed by four tebuconazole (Folicur, Bayer CropScience; Research Triangle Park, NC) applications and a final application of chlorothalonil. The second fungicide regime followed the AU-Pnuts advisory based decision model (Agricultural Weather Information Service, Inc., 1998; Jacobi and Backman, 1995). This method calls for fungicide application based on rainfall events and the 5 day weather forecast and recommends chlorothalonil during the first 49 DAP, tebuconazole between 50 and 100 DAP, and chlorothalonil after 101 DAP. The third disease management strategy incorporated AU-Pnuts with MDST. This strategy followed AU-Pnuts for triggering fungicide applications; however, product selection was determined by MDST from 1 July until harvest. Tebuconazole was selected when MDST was below 21.1°C and above 23.9°C to target peg, pod, and limb rot and stem rot, which are more prevalent with lower and higher MDST, respectively (Da-

[3]Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture, nor implies approval of a product to the exclusion of others that may be suitable.

vidson, *et al.*, 1987; 1991). Chlorothalonil was applied as recommended by AU-Pnuts when MDST was between 21.1 and 23.9°C to maintain control of early leaf spot (*Cercospora arachidicola* Hori.) and late leaf spot (*Cercosporidium personatum* Berk. and M. A. Curtis). All chlorothalonil applications were 1.26 kg ai/ha and tebuconazole was applied at 227 g ai/ha.

Plots were planted 17 May in 2002 and 18 May in 2003 and 2004. Acephate (*O*,*S*-Dimethyl acetylphosphoramidothioate) (Orthene, Valent USA Corporation, Walnut Creek, CA) was applied to peanut seed for all treatments because the diamond planter was not capable of delivering granular insecticides. A two-row KMC digger/inverter (Kelley Manufacturing Company, Tifton, GA) was modified in order to effectively handle peanuts evenly spread over a 182-cm bed to dig the diamond pattern plots. Prior to digging, foliage was visually rated for leaf spot using the Florida 1–10 Scale (Chiteka *et al.*, 1988). While peanut plants were freshly dug, incidence of stem rot, peg, pod, and limb rot, and tomato spotted wilt virus (TSWV) was recorded from 28 m^2 in each plot. When a disease was identified, it was assigned an index number for severity as a disease hit separately for each 0.28 m^2 of row. Disease hits were defined as *light* (1) if disease was present, *moderate* (3) if disease was present and obviously affected yield, and *severe* (6) if disease devastated yield within that 0.28 m^2 of row. The weighted scores for light, moderate, and severe disease hits were summed separately by disease for each plot. This sum was used as the disease index, which could range from 0 to 600. For example, a plot totally devastated by a given disease would receive a score of 6 for each 0.28 m^2 of row totaling 600 for the 28 m^2 area in the entire plot. Plots were machine harvested and grade samples were uniformly obtained from the harvested sample.

Cost analysis was performed assuming that all production costs were equal on a land area basis between treatments except variable costs for fungicides and application. Fungicide costs were obtained from 2006 figures and were $14.36/ha for chlorothalonil and $32.66/ha for tebuconazole per application. Cost for each application was $9.88/ha. Farmer stock value/Mg was calculated based on grade factors and the 2006 national average support price of $391.79/Mg (USDA-FSA, 2006) in the same fashion described by Lamb *et al.* (2003).

Data from these six studies were analyzed with locations combined over years. Significant interactions were further examined and are reported explaining significant main effects. Data were analyzed in SAS (version 9.1) under the general linear model and means were separated using Fisher's Protected LSD at $\alpha \leq 0.05$. Treatment effect F tests were carried out against their specific error source. In statistical analyses, years were treated as a random source of replication, and year by main effect interactions were ignored when main effects were strong (F values of $\geq$ 4 fold) and did not crossover between years (Gomez and Gomez, 1984). Main effect means for years were pooled when interaction was not significant.

Results

In 2002, TSWV was so heavy at the Payne farm that rating soil borne diseases was not possible. Early and late leaf spot were the only diseases rated in that trial. Early and late leaf spot were not rated at the Fiveash farm in 2004.

During the three years of this study, the greatest average disease index for stem rot was less than 25. Over the five trials used in analysis, peanut planted in single rows averaged 41% higher disease index for stem rot compared to diamond planted peanuts, 11.6 and 8.2, respectively ($p = 0.0362$). Twin row patterns had a stem rot disease index of 10.4, which was similar to other planting patterns. The interaction of fungicide program, location, and years on stem rot was significant, so locations are reported separately by year (Table 1). At the Payne farm, the block calendar schedule reduced stem rot disease incidence in 2004 by about 45% compared to the advisory programs. At the Fiveash farm in 2003, the advisory program using MDST had a stem rot disease index of 22.3, which was greater than the other two fungicide programs. In the 3 trials where fungicide programs performed similarly, stem rot disease index ranged from 7 to 13.

Incidence of leaf spot was low in all experiments with the highest average rating for any treatment being 5.2. Planting pattern did not affect incidence of leaf spot. There was a significant year by location interaction for leaf spot rating, so data were analyzed separately by location. Average leaf spot rating of peanut grown at the Fiveash Farm in 2002 and 2003 ranged between 2.3 and 2.8 and no main effects were significant (Table 2). The interaction between year and fungicide program for leaf spot was significant at the Payne Farm, and years are reported separately. In 2002, the advisory program using MDST provided better leaf spot control compared to the advisory program alone and the calendar schedule. The calendar schedule provided better leaf spot control than both advisory programs in 2003 and all three fungicide programs performed similarly in 2004 averaging

Table 1. Stem rot disease index ratings at harvest for two locations near Dawson, Georgia 2002–2004.[a]

	Payne Farm			Fiveash Farm		
Fungicide schedule	2002	2003	2004	2002	2003	2004
	Disease index					
Calendar	-	7.6 a	5.4 b	7.0 a	7.7 b	12.3 a
AU-Pnuts	-	7.3 a	10.3 a	13.0 a	6.8 b	12.0 a
AU-Pnuts plus MDST	-	10.5 a	10.0 a	7.0 a	22.3 a	11.3 a

[a]Means followed by the same letter within a location and year are not statistically different according to Fisher's Protected LSD at $\alpha = 0.05$. Data are pooled over planting patterns.

3.8. Levels of peg, pod, and limb rot were very low in all experiments and no main effects were significant with disease index averages being 1.5 or less (data not shown). Incidence of TSWV was not affected by the variability in fungicide programs or planting patterns. Disease index for TSWV ranged from 71 to 87, 3 to 4, and 11 to 17 in 2002, 2003, and 2004, respectively at the Fiveash farm. No ratings for TSWV were recorded in 2002 at the Payne farm and ratings ranged between 3 and 21 in 2003 and 2004 at that location.

Cost for fungicide programs varied among years (Table 3), but on average, the calendar schedule was most expensive ($232.80) and the advisory program using MDST ($213.5) required the least input. Different yield potential and disease pressure at the two locations caused significant interactions, thus planting pattern and fungicide affects on net return are analyzed separately by location.

Farmer stock yield and grade were strongly affected by location. The interaction of location by planting pattern by year for yield was significant, so planting pattern results are reported separately by year and location (Table 4). In 2003, peanut in the twin row planting pattern yielded an average of 300 kg/ha better than peanut in single row and diamond planting patterns at the Payne farm. Twin row and diamond pattern planted peanut produced an average of 510 kg/ha more than single row peanut at the Payne farm in 2004. At the Fiveash farm, peanut in twin row and diamond planting patterns produced an average of 925 and 890 kg/ha more peanuts than single rows in 2002 and 2003, respectively. There was a significant interaction between location, fungicide regime, and years for pod yield (Table 5). In four of six trials, peanut yields were similar for the three fungicide regimes. In 2003, the advisory program using MDST reduced yield by 250 to 360 kg/ha compared to the calendar schedule and the advisory program alone at the Payne Farm. Peanut treated with the block calendar program at the Fiveash Farm in 2002 produced an average of 400 kg/ha more yield than peanut under both advisory fungicide programs. There was a significant planting pattern by location interaction for grade, so locations were analyzed separately. Planting pattern did not affect grade of peanut grown at the Fiveash Farm (data not shown). Peanut in diamond and twin row planting patterns at the Payne Farm graded significantly higher than peanut in single rows over the 3 years of this study, 74.2 and 73.6, respectively.

At the Fiveash farm, the peanut in twin row and diamond planting patterns out performed single row planted peanut in each year by an average of $265/ha (Table 6). At the Payne farm in 2002, peanut in all 3 planting patterns produced similar net return. Peanut planted in twin rows was most profitable in 2003 by an average of $125/ha compared to peanut planted in single or diamond planting patterns. The 2004 crop showed an

Table 2. Leaf spot rating at harvest for two locations near Dawson, Georgia 2002–2004.[a]

	Payne Farm			Fiveash Farm		
Fungicide schedule	2002	2003	2004	2002	2003	2004
	Leaf spot intensity (Florida 1–10 scale)					
Calendar	3.9 b	1.9 b	3.9 a	-	2.3 a	-
AU-Pnuts	5.2 c	3.4 a	3.2 a	-	2.5 a	-
AU-Pnuts plus MDST	1.3 a	2.8 a	4.3 a	-	2.8 a	-

[a]Means followed by the same letter within a location and year are not statistically different according to Fisher's Protected LSD at $\alpha = 0.05$. Data are pooled over planting patterns.

Table 3. List of applications, product selection, and total cost for disease control programs near Dawson, Georgia in 2002 to 2004. Total program cost includes fungicide and application costs.[a]

Location	Year	Program	Fungicide applications: Chlorothalonil	Fungicide applications: Tebuconazole	Total program cost
			No. of sprays		$/ha
Fiveash	2002	Calendar	4	4	$267.18
Fiveash	2003	Calendar	3	3	$200.38
Fiveash	2004	Calendar	3	4	$242.93
Payne	2002	Calendar	3	4	$242.93
Payne	2003	Calendar	3	3	$200.38
Payne	2004	Calendar	3	4	$242.93
Fiveash	2002	Advisory	3	4	$242.93
Fiveash	2003	Advisory	3	3	$200.38
Fiveash	2004	Advisory	4	3	$224.69
Payne	2002	Advisory	2	4	$218.68
Payne	2003	Advisory	4	2	$182.08
Payne	2004	Advisory	4	3	$224.69
Fiveash	2002	Ad. plus MDST	5	2	$206.33
Fiveash	2003	Ad. plus MDST	4	2	$182.08
Fiveash	2004	Ad. plus MDST	2	5	$261.23
Payne	2002	Ad. plus MDST	5	1	$163.78
Payne	2003	Ad. plus MDST	5	1	$163.78
Payne	2004	Ad. plus MDST	2	5	$261.23

[a]Advisory, fungicide applications were based on the AU-Pnuts advisory based decision model that calls for fungicide application based on rainfall events, weather forecast, and crop age; Ad. Plus MDST, fungicide application timing was based on the AU-Pnuts model and fungicide selection was based on mean daily soil temperature (MDST) where tebuconazole was selected at MDST below 21.1°C and above 23.9°C and chlorothalonil was used otherwise.

average net return advantage for peanut in twin row and diamond planting patterns of $210 over single row planted peanuts at the Payne farm. Crop value minus the cost of fungicide programs produced similar net return in 5 of 6 trials (Table 7). In 2003, at the Payne farm, the calendar block and advisory program outperformed the advisory program using MDST by $100/ha.

Discussion

The 41% reduction in stem rot incidence for peanut planted in diamond planting patterns compared to peanut in single row planting patterns may be attributable to the increased distance between plants and comparable to results with peg, pod, and limb rot found by Sorensen *et al.* (2004). The fact that stem rot disease index for peanut in a twin row pattern was intermediate between diamond and single row planting patterns in the current study leads to further evidence that plant spacing may affect disease spread among neighboring plants. Butzler *et al.* (1998) stated that plant-to-plant infection of Sclerotinia blight of peanut (*Sclerotinia minor* Jagger) occurs after canopy closure and concluded that further spread of the disease could successfully be reduced by mowing excess foliage after disease pressure was evident.

Table 4. Pod yield as affected by planting pattern at two locations near Dawson, Georgia 2002–2004.[a]

Planting pattern	Payne Farm 2002	Payne Farm 2003	Payne Farm 2004	Fiveash Farm 2002	Fiveash Farm 2003	Fiveash Farm 2004
	kg/ha					
Single row	4680 a	4290 b	4450 b	2610 b	2900 b	3150 a
Twin row	4030 a	4600 a	4940 a	3640 a	3830 a	3500 a
Diamond	4380 a	4310 b	4980 a	3430 a	3750 a	3420 a

[a]Means followed by the same letter within a location and year are not statisticallydifferent according to Fisher's Protected LSD at $\alpha = 0.05$. Data are pooled over fungicide programs.

Table 5. Pod yield as affected by fungicide scheduling method at two locations near Dawson, Georgia 2002–2004.[a]

Fungicide schedule	Payne Farm			Fiveash Farm		
	2002	2003	2004	2002	2003	2004
	kg/ha					
Calendar	4770 a	4560 a	4980 a	3490 a	3750 a	3260 a
AU-Pnuts	4780 a	4450 a	4640 a	3140 b	3250 a	3570 a
AU-Pnuts plus MDST	4670 a	4200 b	4750 a	3040 b	3470 a	3290 a

[a]Means followed by the same letter within a location and year are not statistically different according to Fisher's Protected LSD at $\alpha = 0.05$. Data are pooled over planting patterns.

A fungicide program with a block calendar schedule provided the most consistent control of leaf spot and peg, pod, and limb rot, although none of the disease management schedules tested allowed high soil-borne disease infestation in the years tested. None of the fungicide programs had leaf spot rating averages below 3.0 in 2004; this may be due to higher levels of leaf spot incidence in 2004 (Pearce, 2005) or possible development of tebuconazole resistance in local leaf spot populations. The results of disease ratings at these locations in 2002–2004, show low disease pressure, or at least relatively good control of the pathogens with the three fungicide regimes used.

Digging and inverting diamond planted peanuts is best with adequate soil moisture. Heavy soils that are dry are more of a problem because clods are more tightly held among plants in a diamond pattern. Plants in diamond pattern plots did not invert uniformly when plants were small and did not have intertwined vines as is common with runner market type peanuts grown in single or twin rows.

The strongest effects found in this study were those associated with planting patterns. At a constant population, peanut in a twin row planting pattern had a yield advantage over peanut in single row patterns in most experiments and the diamond planted peanuts had a yield advantage over single row peanuts in half of the experiments. Mozingo and Coffelt (1984) reported variable responses for two Virginia market type peanut cultivars planted in twin row patterns. Although the calendar program required the most input over the 3 years, it was the most consistent in controlling disease and did not have negative effect on crop value. Using MDST as part of an advisory program shows some positive features, but lacked consistency. Perhaps other factors should be included with models using MDST, such as maximum or average soil temperature, which are necessary to calculate MDST. Models based on multiple factors including soil temperature thresholds have been successfully adapted in decision based models for controlling Sclerotinia blight of peanut (Langston *et al.*, 2002).

In this study, net return was most affected by yield. Although there were differences in input costs between fungicide programs and some differences in disease control, disease incidence was not a large factor in determining net return. Peanut planted in twin rows produced better pod yield than peanut in single rows in 4 of 6 trials.

Table 6. Net return as affected by peanut planting pattern for two locations near Dawson, Georgia 2002–2004.[a,b,c]

Planting pattern[c]	Payne Farm			Fiveash Farm
	2002	2003	2004	2002–2004
	$/ha			
Single row	$1,710 a	$1,500 b	$1,550 b	$890 b
Twin row	$1,700 a	$1,630 a	$1,750 a	$1,180 a
Diamond	$1,840 a	$1,510 b	$1,770 a	$1,130 a

[a]Net return is calculated as crop value less the cost of fungicide programs assuming that all other production costs are equal among other treatment factors.

[b]Means within a location and year followed by the same letter are not statistically different according to Fisher's Protected LSD at $\alpha = 0.05$. Data for each year at the Payne farm are pooled over fungicide programs. Data at the Fiveash farm are pooled over fungicide programs and years.

[c]The single row planting pattern places seed in one row 91 cm apart. The twin row planting pattern places seed in two rows 23 cm apart on 91 cm beds. The diamond row pattern places seed in four rows 15 cm apart on 91 cm beds. All seeding rates were equivalent per unit area.

Table 7. Net return as affected by disease control program for two locations near Dawson, Georgia 2002–2004.[a,b]

Planting pattern	Payne Farm 2002	Payne Farm 2003	Payne Farm 2004	Fiveash Farm 2002–2004
	$/ha			
Calendar	$1,740 a	$1,580 a	$1,770 a	$1,110 a
AU-Pnuts	$1,750 a	$1,580 a	$1,640 a	$1,060 a
AU-Pnuts plus MDST	$1,750 a	$1,480 b	$1,660 a	$1,050 a

[a]Net return is calculated as crop value less the cost of fungicide programs assuming that all other production costs are equal among other treatment factors.

[b]Means followed by the same letter within a location and year are not statistically different according to Fisher's Protected LSD at $\alpha = 0.05$. Data for each year at the Payne farm are pooled over planting patterns. Data at the Fiveash farm are pooled over planting patterns and years.

Diamond planted peanut produced more than single row peanut 50% of the time and yielded less than twin row peanut in 1 year. In studies with Virginia market type peanut cultivars, Lanier et al. (2004) concluded that the cultivars tested produced superior yield when planted in twin rows compared to a single row pattern. Lanier *et al.* (2004) also reported that increasing the number of planted rows beyond two did not improve pod yield compared to peanut in twin rows. It may be possible that peanuts in a diamond planting pattern initiate fruit either earlier or later than peanuts in crowded single or twin row patterns. This point will have to be addressed by further research with these variable planting patterns. In this study, all plots were dug and harvested on the same dates, so determining effect of row pattern on maturity was not possible.

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