Peanut Response to Planting Pattern, Row Spacing, and Irrigation

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ABSTRACT

Experiments were conducted from 1999 through 2002 in North Carolina to compare interactions of planting pattern, plant population, and irrigation on peanut (*Arachis hypogaea* L.) pod yield and market grade characteristics. In additional experiments, pod yield and severity of tomato spotted wilt tospovirus associated with the cultivars NC-V 11, NC 12C, VA 98R, and Perry were compared in single row (rows spaced 91 cm apart) and standard twin row (two rows spaced 18 cm apart on 91-cm centers) planting patterns when peanut was dug and vines inverted on two digging dates spaced 10 to 16 d apart. In a third set of experiments, pod yield, market grade characteristics, and severity of tomato spotted wilt tospovirus were compared when the cultivars NC-V 11 and Perry were planted in single row, standard twin row, and narrow twin row (two rows spaced 18 cm apart on 46-cm centers) planting patterns. Peanut pod yield was higher in standard twin row planting patterns than when grown in single row planting patterns in some but not all experiments. Planting peanut in the narrow twin row pattern did not increase peanut pod yield over the standard twin row planting pattern. Less tomato spotted wilt was observed in standard or narrow twin row planting patterns compared with single row planting patterns. Planting peanut in single rows spaced 46 cm apart did not improve yield over peanut planted in single rows spaced 91 cm apart or the standard twin row planting pattern, regardless of irrigation treatment.

Altering plant population and row pattern can affect crop yield, quality factors, and pest development in peanut. Pod yield of bunch-type peanut was 16% higher when peanut was seeded in rows spaced 46 cm apart compared with 91 cm (Norden and Lipscomb, 1974). Duke and Alexander (1964) reported pod yield that was 14% higher in narrow row plantings compared with traditional wider row patterns using large-seeded Virginia bunch-type peanut. Spanish market type peanut planted in 46-cm rows yielded higher than peanut planted in rows spaced 61, 76, 91, or 107 cm apart at similar in-row plant populations (Parham, 1942). Cox and Reid (1965) reported that increasing plant populations by increasing in-row seeding rate or by decreasing row width increased pod yield.

Although the majority of peanut in the USA is seeded in single rows spaced 91 to 102 cm apart, research suggests that seeding peanut in standard twin row patterns (rows spaced approximately 18 cm apart with centers of these rows spaced 91 to 102 cm apart) can increase yield, improve some market grade characteristics, and decrease incidence of tomato spotted wilt tospovirus (TSWV) (Baldwin and Williams, 2002; Hurt et al., 2003). However, row visibility during the digging and inversion process in narrow row planting patterns or in standard twin row planting patterns can be lower compared with planting peanut in standard single row patterns (Beasley, 1970; Henning et al., 1982).

Crop response to seeding rate and planting pattern can be affected by cultivar selection (Costa et al., 1980; Ablett et al., 1984; Beuerlein, 1988; Nafziger, 1994; Porter et al., 1997). In peanut, Sullivan (1991) reported differences in pod yield among four Virginia market type peanut cultivars when comparing single and twin row planting patterns. Mozingo and Swann (2000) reported that the cultivar VA 98R yielded higher when seeded in standard twin row planting patterns compared with planting in standard single row planting patterns when plant population was similar or higher in the twin row planting pattern. Baldwin and Williams (2002) and Marios and Wright (2003) reported differential response of runner market type cultivars to planting pattern.

Interactions of planting pattern and seeding rate with irrigation have been reported for several crops. Irrigation increased corn (*Zea mays* L.) yield when higher plant populations were established compared with lower plant populations when row pattern was held constant (Liang et al., 1992). In contrast, corn yield did not increase when plant population was increased in absence of irrigation (Liang et al., 1992). In soybean [*Glycine max* (L.) Merr.], increasing plant populations and decreasing row width increased yield (Lehman and Lambert, 1960). In cotton (*Gossypium hirsutum* L.), yield increases were noted when seeding rate was increased and row spacing was decreased (Briggs et al., 1967; Heitholt et al., 1992; Hoskinson et al., 1974).

Determining interactions of seeding rate and planting pattern with variables such as cultivar selection and irrigation will assist growers and their advisors in developing efficient production and pest management systems for peanut. Therefore, research was conducted to compare peanut pod yield, market grade characteristics, and TSWV severity when peanut was seeded in various planting patterns, seeding rates, and cultural practices.

MATERIALS AND METHODS

Peanut Response to Planting Pattern, Row Spacing, and Irrigation

Experiments were conducted during 1999 and 2000 in North Carolina at the Peanut Belt Research Station located near Lewiston-Woodville on a Norfolk sandy loam (fine-loamy,

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Abbreviations: %ELK, percentage of extra large kernels; %OK, percentage of other kernels; %TSMK, percentage of total sound mature kernels; TSWV, tomato spotted wilt tospovirus.

siliceous, thermic, Typic Paleudults) with pH 6.1 and 2.3% organic matter. Peanut cultivars NC 10C (1999) and VA 98R (2000) were planted in mid-May on flat ground in conventionally tilled seedbeds. Plot size was 2 by 15 m. Corn was the previous crop during both years.

Treatments consisted of a single row planting pattern spaced 91 cm apart with in-row plant population of 12 seed m^{-1}, a standard twin row planting pattern with rows spaced 18 cm apart on 91-cm centers with in-row plant population of 15 seed m^{-1} (combination of the two twin rows), single row planting patterns with rows spaced 46 cm apart with in-row plant populations of 8 and 12 plants m^{-1}, and narrow twin row planting patterns with rows spaced 18 cm apart on centers spaced 46 cm apart with in-row plant populations of 4, 8, and 12 plants m^{-1} (combination of the two twin rows) (Fig. 1). Peanut established in these planting patterns and seed spacings was grown with and without overhead sprinkler irrigation. The amount of total irrigation was 570 mm in 1999 (three irrigation events) and 380 mm in 2000 (two irrigation events). These irrigation treatments were applied in July when peanut foliage showed visible signs of wilting. No attempt was made to further quantify soil moisture status or plant stress. Rainfall was sufficient throughout the remainder of the season to prevent plant wilting and the need for irrigation. Aldicarb (*O*, *S*-dimethylacetylphosphoramidothioate) was applied in the seed furrow for each row at 7.8 kg a.i. ha^{-1}. Production and pest management practices other than row pattern, seeding rate, and irrigation were held constant over the entire test area and were based on North Carolina Cooperative Extension Service recommendations. Foliar and soil borne diseases were controlled with biweekly applications of fungicides. Chlorothalonil (tetrachloroisophthalonitrile) at 1.2 kg a.i. ha^{-1} was applied in early July followed by three applications of tebuconazole {α-[2-(4-chlorophenyl)-ethyl]-α-(1,1-dimethylethyl)} at 0.22 kg a.i. ha^{-1} each through late July and August. Chlorothalonil was also applied in early September. The experimental design was a split plot with irrigation system serving as whole plot units and planting pattern/seed spacing combinations serving as subplots. Treatments were replicated four times. Peanut was dug and vines inverted in early October of both years. No attempt was made to determine pod maturity among treatments using pod mesocarp color determination (Williams and Drexler, 1981). Peanut pods were harvested after pods and vines were allowed to air dry for approximately 1 wk. The entire 2-m width of each plot was dug and inverted using a standard two-row digger with a bar attached to both blades to allow efficient digging of the narrow rows. A 1-kg sample of pods was collected at harvest from each plot to determine percentages of fancy pods (%FP), extra large kernels (%ELK), and total sound mature kernels (%TSMK) using Cooperative Grading Service criteria (USDA, 1998).

Data for pod yield, %FP, %ELK, and %TSMK were subjected to analysis of variance appropriate for the two (year) × two (irrigation system) × seven (planting pattern/plant population combination) factorial arrangement of treatments. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$ using appropriate error terms for fixed and random effects (McIntosh, 1982).

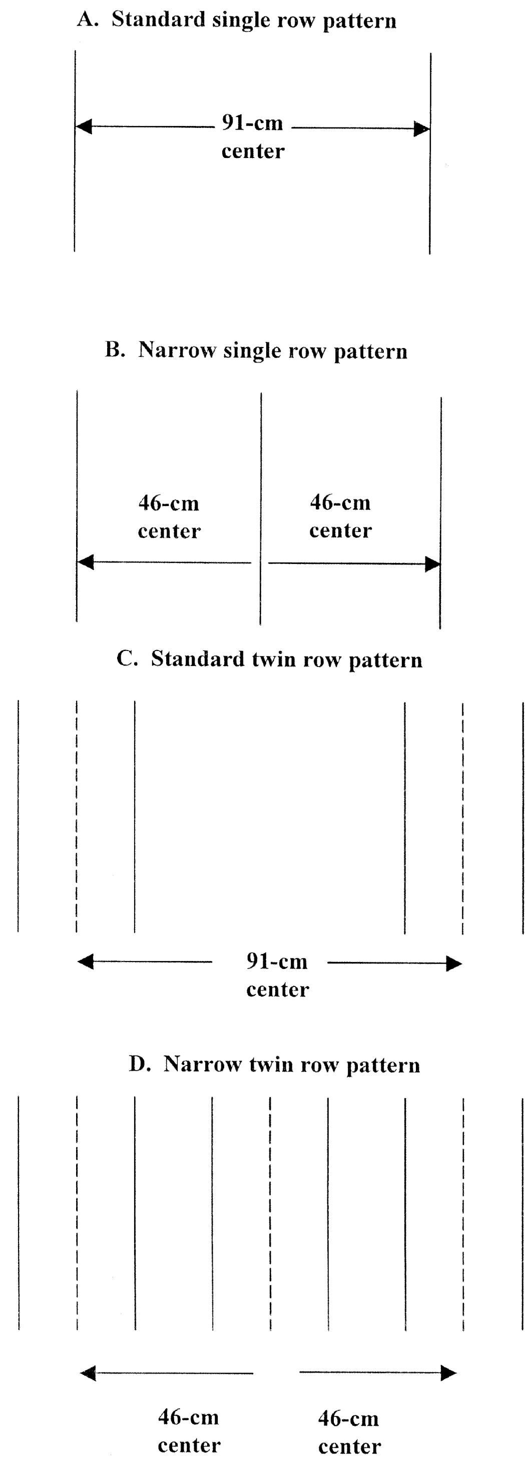

Fig. 1. Diagram of row patterns consisting of: (A) single row planting pattern with rows spaced 91 cm apart, (B) narrow single row planting pattern with rows spaced 46 cm apart, (C) standard twin row planting pattern with rows spaced 18 cm apart on 91-cm centers, and (D) narrow twin row planting pattern with rows spaced 18 cm apart on 46-cm centers. Solid lines indicate a row of peanut.

Peanut Cultivar Response to Planting Pattern and Digging Date

The experiment was conducted during 2000 in North Carolina on private farms located near Gatesville and Williamston and at the Peanut Belt Research Station located near Lewiston-Woodsville. The experiment was also conducted during 2001 and 2002 at the Peanut Belt Research Station (Lewiston-Woodville) and at the Upper Coastal Plain Research Station (Rocky Mount). Soil at Gatesville was a Wanda fine sand (loamy sand, siliceous, thermic, Typic Udipsamments) with 1.1% organic matter and pH 5.9. Soil at Lewiston-Woodville during all years was a Norfolk sandy loam with organic matter ranging from 1.5 to 2.3% and pH 5.9 to 6.1. Soil at Williamston was a Conetoe loamy sand (loamy, mixed, thermic, Arenic Hapludults) with 1.8% organic matter and pH 5.9. Soil at Rocky Mount was a Goldsboro sandy loam (fine-loamy, siliceous, thermic Aquic Paleudults) with 2.4% organic matter and pH 5.9. Peanut was seeded in conventionally tilled seedbeds on 91-cm beds. Plot size was 2 rows by 12 m (Gatesville, Williamston, and Rocky Mount) or 9 m (Lewiston-Woodville). The previous crop at Gatesville, Rocky Mount, and Lewiston-Woodville (2000) was cotton. The previous crop at Williamston was tobacco (*Nicosia tobaccum* L.). Corn was the previous crop at Lewiston-Woodville during 2001 and 2002.

Treatments consisted of the cultivars NC-V 11, NC 12C, VA 98R, and Perry seeded in single rows spaced 91 cm apart or in standard twin rows spaced 18 cm apart on 91-cm centers. In-row plant population was 12 and 15 seed m^{-1} in the single row and standard twin row planting patterns, respectively. Aldicarb was applied in the seed furrow as described previously. Peanut for all combinations of cultivars and row patterns were dug in late September and early October, spaced 10 to 16 d apart. These respective digging dates correspond to 130 to 140 and 145 to 160 d after planting. The number of days required for the cultivars in this study to reach optimum maturity ranges from 148 to 160 d after planting (Jordan, 2003). However, peanut in North Carolina are often dug before optimum maturity because of possible freeze damage and concerns about excessive rainfall associated with hurricanes, which could prevent efficient digging and harvest (Jordan, 2003). All other production and pest management inputs were common across the entire test area and were based on North Carolina Cooperative Extension Service recommendations. Foliar and soil-borne diseases were controlled using the fungicide application schedule described previously. Fields were fumigated with metam sodium 2 wk before planting using a subsoiler designed to establish the point of application 18 to 25 cm below seed placement at Gatesville, Lewiston-Woodville, and Williamston.

The experimental design was a randomized complete block with a split plot arrangement of treatments. Digging date served as whole plot units with cultivars and planting pattern combinations serving as subplots. Treatments were replicated four times. Severity of TSWV was determined in mid September using a scale of 0 (no symptoms) to 100 (the entire foliage of the plot expressing symptoms) for the experiments conducted in 2001 and 2002 (Bailey, 2001). This disease was not present at a visually measurable level at any location in 2000. Chlorosis, plant stunting, and dead plants were considered when making the visual estimates. Peanut was combined after pods and vines were allowed to air dry for approximately 1 wk.

Data for pod yield were subjected to analysis of variance appropriate for a seven (experiment) × two (digging date) × four (cultivar) × two (planting pattern/plant population) factorial treatment arrangement. Data for TSWV were subjected to analysis of variance appropriate for a four (location) × four (cultivar) × two (planting pattern) factorial treatment arrangement pooled over digging dates. Data associated with digging treatments were removed from the analysis because visual estimates of TSWV were recorded before the first digging. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$.

Peanut Cultivar Response to Planting Pattern

Experiments were conducted during 2001 and 2002 in North Carolina at the Peanut Belt Research Station on the Norfolk sandy loam soil described previously. Peanut was planted in conventionally tilled seedbeds on flat ground. Plot size was 2 by 9 m. The previous crop was corn.

Treatments consisted of the cultivars NC-V 11 and Perry seeded in single rows spaced 91 cm apart (in-row plant population of 12 plants m^{-1}), standard twin row panting pattern (twin rows spaced 18 cm apart on 91-cm centers with in-row plant population of 15 seed m^{-1}), and narrow twin row planting patterns (twin rows spaced approximately 18 cm apart on centers spaced 46 cm apart with in-row plant population of 15 plants m^{-1} for the combined twin rows). Aldicarb was applied as described previously. All other production and pest management inputs were common across the entire test area and were based on North Carolina Cooperative Extension Service recommendations. Foliar and soil borne diseases were controlled using the fungicide application schedule described previously.

The experimental design was a randomized complete block with treatments replicated four times. Peanut canopy development was determined using a Sony DKC-ID1 digital camera (Sony Corp. of America, New York) with a spatial resolution of 768 × 561 pixels. Digital images were recorded approximately biweekly beginning approximately 40 d after planting through 85 d after planting. The camera was mounted 2.13 m above the soil surface in the center of an aluminum camera stand transversing two 91-cm peanut rows. The camera lens was perpendicular to the ground, and the field of view was adjusted similarly for all plots. Three images were taken at random within the plot using a built-in supplemental flash. The images were automatically numbered in sequence and stored in the camera in JPEG (joint photographic experts group) image format. Images were then transferred to a computer via memory card reader and stored. Images were analyzed using Adobe Photoshop 4.0 software, which converted the color images into black and white. Images were then analyzed by PixelCounter 1.0 (North Carolina State Univ., Raleigh) to determine the amount of black and white pixels for each image by dividing the number of black pixels (representing peanut leaflets) by the total number of pixels in the image. The percentage of black pixels was termed percent ground cover by peanut. The percent canopy cover for each plot was obtained by averaging the three values for images taken within individual plots.

Pod yield and severity of TSWV were determined as described previously. A 1-kg sample of pods was collected at harvest from each plot to determine %FP, %ELK, and %TSMK using a Cooperative Grading Service criteria (USDA, 1998).

Data for TSWV, percent canopy closure, peanut pod yield, and market grade factors were subjected to analysis of variance appropriate for a two (year) × two (cultivar) × three (planting pattern) factorial treatment arrangement. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$. Regression procedures were used to test linear and quadratic functions for canopy closure vs. days after planting ($p \leq 0.05$), based on results from the factorial analysis.

RESULTS AND DISCUSSION

Peanut Response to Planting Pattern, Row Spacing, and Irrigation

Interactions of year × planting pattern ($p = 0.0184$) and irrigation × planting pattern ($p = 0.0039$) were significant for pod yield. However, the interaction of year × irrigation × planting pattern was not significant ($p = 0.8105$). In 1999, pod yield of peanut seeded in the standard twin row planting pattern exceeded that of peanut planted in the single row planting pattern regardless of row spacing (46- or 91-cm spacings) (Table 1). Additionally, yield with the standard twin row planting pattern exceeded that of the narrow twin row planting pattern when peanut was seeded at an in-row population of 4 plants m^{-1}. Yield was similar when comparing the standard twin row planting pattern with the narrow row planting pattern at in-row populations of 8 and 12 plants m^{-1}. In 2000, trends were similar to the 1999 when comparing pod yield of peanut seeded in the standard twin row planting pattern with the single row pattern either when the row spacing was 46 or 91 cm (Table 1). However, pod yield was similar when comparing the standard twin row planting pattern with the narrow twin row planting pattern regardless of in-row plant population. Peanut yield in the narrow and twin row planting pattern exceeded yield in the single row planting patterns. These data suggest that planting peanut in narrow rows, either as twin rows or single rows, offers no advantage over planting in standard twin row patterns. Lemon et al. (2001) reported similar yields when comparing standard twin row planting patterns with narrow row planting patterns.

When pooled over years, pod yield was similar when peanut was seeded in standard and narrow twin row planting patterns, regardless of plant population, when peanut was not irrigated (Table 1). In contrast, pod yield was higher when peanut was seeded in the standard twin row planting pattern than when seeded in the narrow twin row planting pattern at in-row populations of 4 and 12 plants m^{-1} under overhead sprinkler irrigation. Additionally, pod yield in the standard twin row planting pattern exceeded that of both row spacings and in-row plant populations in single row planting patterns when peanut was irrigated.

With the exception of the main effect of year, all other main effects and interactions were not significant for %ELK or %TSMK. When pooled over treatment factors other than year, the %ELK was 19% in 1999 and 36% in 2000 (data not presented). The cultivars NC 10C and VA 98R were planted in 1999 and 2000, respectively. These respective cultivars, on average, yield %ELK of 23 and 43% (Jordan, 2001). The percentage of TSMK for 1999 and 2000 was 70% and 69%, respectively (data not shown). Jordan (2001) reported %TSMK values of 67 and 69% for these respective cultivars. Main effects and interactions of year, irrigation, and plant population for %FP were not significant.

Table 1. Pod yield as influenced by year, planting pattern, population, and irrigation system.

Planting pattern	Row spacing centers	In-row population	Year† 1999	Year† 2000	Irrigation‡ None	Irrigation‡ Yes
	cm	plants m^{-1}				
Single	96	12	4030b	4460e	4280c	4200cde
Twin§	96	15	4350a	4980ab	4450abc	4880a
Single	48	12	4040b	4480e	4430abc	4090cde
Single	48	8	4010b	4310e	4340c	3980e
Twin§	48	12	4060ab	4970abc	4690a	4340bcd
Twin§	48	8	4150ab	5060a	4600ab	4620ab
Twin§	48	4	4060b	4850a–d	4540abc	4370bc

† Means within a year followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.05$. Data are pooled over irrigation systems.
‡ Means within an irrigation system followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P \leq 0.05$). Data are pooled over years.
§ Standard twin row pattern consisted of two rows spaced 18 cm apart on 91-cm centers. Narrow twin row pattern consisted of two rows spaced 18 cm apart on 46-cm centers.

Peanut Cultivar Response to Planting Pattern and Digging Date

The interaction of experiment × digging date × cultivar was significant for peanut pod yield ($p = 0.0252$). However, interactions of experiment × planting pattern × cultivar ($p = 0.5679$) and experiment × digging date × planting pattern ($p = 0.1112$) were not significant. Although the interaction of planting pattern × cultivar was not significant ($p = 0.3437$), the main effect of planting pattern was significant ($p = 0.0029$). When pooled over experiments, cultivars, and digging dates, pod yield increased from 4620 to 4770 kg ha^{-1} when peanut was seeded in the standard twin row planting pattern compared with planting in single rows (data not presented). Previous research (Baldwin and Williams, 2002; Mozingo and Swann, 2000; Sullivan, 1991) reported higher yields when peanut was seeded in standard twin row planting patterns compared with single row planting patterns.

The interaction of experiment × cultivar × digging date ($p = 0.0252$) was expected. Previous research (Jordan et al., 1998; Mozingo 1991, 1996; Sholar et al., 1995) indicated that pod yield and market grades can vary considerably among digging dates and environmental and edaphic conditions. At both Gatesville and Williamston in 2000, pod yield of the cultivars NC-V 11 and NC 12C increased when digging was delayed (Table 2). At Gatesville, pod yield of the cultivars VA 98R and Perry was similar at both digging dates. In contrast, delaying digging increased yield of these cultivars at Williamston. In contrast to these results, delaying digging resulted in lower yield for the cultivars NC-V 11 (2000 and 2002) and VA 98R (2000) at Lewiston-Woodville (Table 3). There were no differences in pod yield when comparing digging dates for a particular cultivar in 2001. At Rocky Mount, yield of Perry was lower when digging was delayed in 2001 (Table 4). However, there was no difference in yield between digging dates for the other cultivars in 2001 or for any cultivar in 2002.

Table 2. Pod yield as influenced by location, cultivar, and digging date at Gatesville and Williamston during 2000.

Cultivar	Pod yield: Gatesville Early dig	Gatesville Late dig	Williamston Early dig	Williamston Late dig
	kg ha^{-1}			
NC-V 11	4490	5060*	4540	5160*
NC 12C	5160	6310*	4500	5320*
VA 98R	4180	4080	4300	5310*
Perry	4530	4630	5230	5760

* Indicates a significant difference at $p \leq 0.05$ between digging dates when comparing within locations and cultivars. Data are pooled over planting patterns.

Table 3. Pod yield as influenced by year, cultivar, and digging date at Lewiston-Woodville from 2000 through 2002.

	Pod yield					
	2000		2001		2002	
Cultivar	Early dig	Late dig	Early dig	Late dig	Early dig	Late dig
	kg ha^{-1}					
NC-V 11	4710	4130*	4300	4060	4070	3420*
NC 12C	4920	5360	4130	4250	3980	3800
VA 98R	4700	4160*	3800	3700	3840	3420
Perry	5080	5350	4110	4090	4240	4160

* Indicates significant difference at $p \leq 0.05$ between digging dates when comparing within cultivars and years. Data are pooled over planting patterns.

Severity of TSWV was compared using data from 2001 and 2002 only because visual symptoms of TSWV were not present in 2000. The interaction of experiment × planting pattern × cultivar was not significant for TSWV ($p = 0.7149$) or pod yield ($p = 0.2512$). However, the main effect of planting pattern was significant for these respective parameters ($p = 0.0001$ and 0.0007, respectively). Interactions of planting pattern × cultivar and experiment × planting pattern were not significant for these parameters. The main effect of cultivar and the interaction of experiment × cultivar were not significant for pod yield; however, they were significant for %TSWV. When pooled over experiments and cultivars, TSWV severity was 10% in the twin row planting pattern compared with 17% in the single row planting pattern (data not presented). Pod yield in these respective planting patterns was 4010 and 4250 kg ha^{-1} (data not presented). Previous research (Baldwin and Williams, 2002; Johnson et al., 2001; Hurt et al., 2003) indicated that severity of TSWV can be reduced when peanut is seeded in twin row planting patterns compared with single row planting patterns. While the yield increase of 240 kg ha^{-1} may have been partially attributed to lower severity of TSWV, lack of an experiment × planting pattern interaction for pod yield in the analysis including all years and locations suggests that benefits of seeding in twin row planting patterns is associated at least in part with factors other than TSWV management. This was also demonstrated in the experiment involving irrigation and planting pattern/in-row plant populations. In that study, pod yield was higher in the standard twin row planting pattern compared with seeding peanut in the single row planting pattern in the absence of TSWV (Table 1). In both studies, plant population per hectare

Table 4. Pod yield as influenced by year, cultivar, and digging date at Rocky Mount during 2001 and 2002.

	Pod yield			
	2001		2002	
Cultivar	Early dig	Late dig	Early dig	Late dig
	kg ha^{-1}			
NC-V 11	4350	4200	2950	2640
NC 12C	4150	4040	2750	2430
VA 98R	4410	3840	2830	2460
Perry	4520	3580*	2980	2590

* Indicates significant difference at $p \leq 0.05$ between digging dates when comparing within cultivars and years. Data are pooled over planting patterns.

Table 5. Percentage of tomato spotted wilt virus as influenced by cultivar and year.†

	Lewiston-Woodville		Rocky Mount	
Cultivar	2001	2002	2001	2002
	%			
NC-V 11	6c	10a	0c	11b
NC 12C	17b	12a	10a	24a
VA 98R	18b	11a	3bc	23a
Perry	27a	16a	8ab	17ab

† Means within a year and location followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.05$. Data are pooled over planting patterns.

was increased by approximately 20% in the twin row planting pattern compared with the single row planting pattern. However, yield increases in twin row planting patterns compared with single row planting patterns have been noted when the plant population per hectare was held constant or when the in-row seed spacing was increased in the twin row planting patterns (Baldwin and Williams, 2002; Mozingo and Swann, 2000).

The severity of TSWV varied by experiment and cultivar ($p = 0.0064$, Table 5). With the exception of Lewiston-Woodville in 2002, where no difference in TSWV severity was noted among cultivars, the cultivar NC-V 11 had lower levels of TSWV than all cultivars at Lewiston-Woodville in 2001, NC 12C and Perry at Rocky Mount in 2001, and NC 12C and VA 98R at Rocky Mount in 2002. Although variation in cultivar susceptibility often occurs, NC-V 11 is generally more tolerant of TSWV than NC 12C, VA 98R, or Perry (Shew, 2003). The cultivars NC 12C and Perry are assigned similar rankings in an advisory designed to assist in managing TSWV for Virginia market type cultivars (Hurt et al., 2003). In this advisory, the ranking of VA 98R relative to TSWV susceptibility is intermediate between NC-V 11 and the ranking for NC 12C and Perry.

Peanut Cultivar Response to Planting Pattern and Row Spacing

The interaction of year × culivar × plant population was not significant for TSWV severity ($p = 0.2915$) or pod yield ($p = 0.7359$). However, the interaction of cultivar × planting pattern was significant for TSWV severity ($p = 0.0101$) but not for pod yield ($p = 0.3309$). The main effect of planting pattern was significant for pod yield ($p = 0.0004$), although the main effect of cultivar was not significant ($p = 0.1995$).

When pooled over years, TSWV severity ranged from 3 to 9% for the cultivar NC-V 11, and there was no difference among planting patterns (Table 6). In contrast, 18 to 23% TSWV was noted when peanut was seeded in single or standard twin row planting patterns for the cultivar Perry. Seeding peanut in the narrow twin row planting pattern reduced severity of TSWV to 4% for the cultivar Perry. These data are consistent with previous research showing greater tolerance of the cultivar NC-V 11 to TSWV compared with Perry (Hurt et al., 2003; Shew, 2003). Hurt et al. (2003) also reported that increasing the seeding rate and/or planting the cultivar

Table 6. Severity of tomato spotted wilt virus, pod yield, and percentages total sound mature kernels (%TSMK) as influenced by cultivar and planting pattern.

Row spacing center	Row pattern	Tomato spotted wilt virus NC-V 11	Perry	Pod yield†	%TSMK†
cm		%		kg ha^{-1}	%
91	single rows	9b‡	23a	4470b	67b
91	twin rows§	4b	18a	5170a	69a
46	twin rows¶	3b	4b	5190a	67b

† Means followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.05$. Data are pooled over years and cultivar.
‡ Means followed by the same letter are not significant according to Fisher's Protected LSD test at $p \leq 0.05$. Data are pooled over years.
§ Standard twin row pattern consisted of two rows spaced 18 cm apart on 91-cm centers.
¶ Narrow twin row pattern consisted of two rows spaced 18 cm apart on 46-cm centers.

NC-V 11 decreased severity of TSWV when compared with lower seeding rates or planting the cultivar Perry.

As was noted in the previous two studies, pod yield increased when peanut was seeded in standard twin row planting patterns compared with seeding in the single row planting pattern. However, there was no advantage of seeding peanut in the narrow twin row planting pattern compared with the standard twin row planting pattern with respect to yield. While cultivar and planting pattern did not affect %ELK, planting pattern did affect %TSMK ($p = 0.0213$). Interactions of planting pattern with year and cultivar were not significant for %TSMK. The %TSMK was higher when peanut was seeded in the standard twin row pattern compared with seeding in single rows or the narrow twin row planting patterns (Table 6). Baldwin and Williams (2002) reported increased %TSMK when runner market type cultivars were seeded in twin row planting patterns compared with single row planting patterns. However, in the planting pattern/in-row plant population study that included irrigation, no difference in %TSMK was noted between standard and narrow twin row planting patterns ($p = 0.0734$).

The %FP was affected by the interaction of year, cultivar, and planting pattern ($p = 0.0238$). The %FP was similar for the cultivar NC-V 11 regardless of planting pattern in 2001 (Table 7). The %FP was higher when peanut was seeded in the standard twin row planting pattern for the cultivar Perry compared with seeding this cultivar in the single row planting pattern. In 2002, the %FP was lower in the narrow row planting pattern compared with single and standard twin row planting patterns regardless of cultivar.

Canopy closure, as measured by digital imaging, was affected by year × days after planting ($p = 0.0001$) and cultivar × days after planting ($p = 0.0235$). It was expected, based on visual observations, that planting pattern would have influenced canopy closure as measured by digital analysis. However, this was not the case ($p = 0.8999$). When pooled over cultivars and planting patterns, the linear function of canopy closure vs. days after planting, measured as percentage of ground cover, was significant for 2001 ($y = 1.284x - 0.005x^2 + 0.782$, $r^2 = 0.70$) and 2002 ($y = 1.492x - 41.5$, $r^2 = 0.87$) (Table 8). Canopy closure in 2002 was 93% by 85 d after planting. However, by this point in the 2001, canopy closure had reached only 74%. Rainfall was limiting during both years of the experiment throughout most of the growing season. However, peanut was irrigated during the 2002 growing season beginning approximately 50 d after planting. In contrast, peanut was not irrigated in 2001, and this may explain partially lack of canopy closure during that year. The higher level of canopy closure early in the season during 2001 compared with 2002 is more difficult to explain. Rainfall was more plentiful during May and early June 2001, within the first 40 d after planting, whereas rainfall was more limiting early in the season during 2002. This may explain more rapid canopy development early in the season during 2001 compared with 2002. Irrigation, which was needed during both years but only supplied during 2002, increased the rate of canopy development later in the season for 2002 compared with 2001.

Lateral branches from adjacent rows in the narrow twin row planting touched approximately 50 d after planting, whereas lateral branches from adjacent rows in single and standard twin row planting patterns touched approximately 15 to 25 d later based on casual visual observations. Canopy development in narrow rows would have been greater than peanut in twin rows or single rows; however, results from digital imaging showed no difference among planting patterns. Digital imagery may not be effective in quantifying canopy closure in peanut, and other methods may be needed to determine canopy closure of peanut more accurately. The interaction of cultivar × days after planting was also significant

Table 7. Percentage of fancy pods influenced by year, planting pattern, and cultivar.

Row spacing centers	Planting pattern	Fancy pods 2001 NC-V 11	2001 Perry	2002 NC-V 11	2002 Perry
cm		%			
91	single rows†	68a	63b	71a	63c
91	twin rows‡	68a	74a	72a	62c
46	twin rows§	69a	68ab	62c	67b

† Means within a year followed by the same letter are not significant according to Fisher's Protected LSD test at $p \leq 0.05$.
‡ Standard twin row pattern consisted of two rows spaced 18 cm apart on 91-cm centers.
§ Narrow twin row pattern consisted of two rows spaced 18 cm apart on 46-cm centers.

Table 8. Parameter estimates for peanut canopy closure using digital imaging as influenced by year and cultivar.

Days after planting	Parameter estimates for peanut canopy closure† Year 2001	Year 2002	Cultivar NC-V 11	Cultivar Perry
	%			
40	45	18	31	30
55	57	41	44	43
70	66	63	58	57
85	74	93	72	71

† Peanut canopy development was determined using a digital camera mounted 2.13 m above the soil surface of each plot. The percentage of black pixels was termed percent ground cover by peanut.

for canopy closure ($p = 0.0235$). This response was not expected, simply based on casual visual observations. Although the apparent rate of canopy closure appeared to be similar for the two cultivars, the cultivar NC-V 11 ($y = 0.91x - 5.62$, $r^2 = 0.70$) reached a higher level of canopy closure than did the cultivar Perry ($y = 0.895x - 5.62$, $r^2 = 0.61$), and this advantage was maintained throughout the monitoring period (Table 8).

SUMMARY

Collectively, these data indicate that peanut yield will often be higher when peanut is seeded in standard twin row planting patterns compared with singe row planting patterns. These data also indicate that there is no advantage to growing peanut in narrow twin row planting patterns compared with standard twin row planting patterns already in practice. However, comparisons of narrow twin row planting patterns with single or standard twin row planting patterns were conducted under weed-free conditions, and more rapid canopy closure in narrow twin row planting patterns may improve weed control. Severity of TSWV differed among planting patterns, with lower severity observed in standard or narrow twin row planting patterns compared with single row planting patterns. Positive benefits relative to TSWV management and pod yield in standard twin row planting patterns compared with single row planting patterns were generally noted, irrespective of cultivar.

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REFERENCES

Ablett, G.R., J.C. Schleihauf, and A.D. McLaren. 1984. Effect of row width and population on soybean yield in southwestern Ontario. Can. J. Plant Sci. 64:9–15.

Bailey, J.E. 2001. Peanut disease management. p. 85–104. *In* 2001 Peanut information. Publ. AG-331. North Carolina Coop. Ext. Serv., Raleigh.

Baldwin, J., and J. Williams. 2002. Effects of twin rows on yield and grade. The Peanut Grower 14:28–29.

Beasely, E.O. 1970. Field losses of peanuts in North Carolina. J. Am. Peanut Res. Educ. Assoc. 2:78–86.

Beuerlein, J.E. 1988. Yield of indeterminate and determinate semi-dwarf soybean for several planting dates, row spacings, and seeding rates. J. Prod. Agric. 1:300–303.

Briggs, R.E., L.L. Patterson, and G.D. Massey. 1967. Within- and between-row spacing of cotton. Arizona, Agric. Ext. Serv. Annual Rep. p. 6–7. Univ. of Arizona, Tuscon.

Costa, J.A., E.S. Oplinger, and J.W. Pendleton. 1980. Response of soybean cultivars to planting patterns. Agron. J. 72:153–156.

Cox, R.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.

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

Heitholt, J.J., W.T. Pettigrew, and W.R. Meredith, Jr. 1992. Light interception and lint yield of narrow-row cotton. Crop Sci. 32: 718–733.

Henning, R.J., A.H. Allison, and L.D. Tripp. 1982. Culture practices. p. 123–138. *In* H.E. Pattee and C.T. Young (ed.) Peanut science and technology. Am. Peanut Res. and Educ. Soc., Yoakum, TX.

Hoskinson, P.E., J.A. Mullins, and T. McCutchen. 1974. Narrow row cotton in Tennessee. Bull 535. The Univ. of Tennessee Agric. Exp. Stn.

Hurt, C., R. Brandenburg, D. Jordan, B. Shew, T. Isleib, M. Linker, A. Herbert, P. Phipps, C. Swann, and W. Mozingo. 2003. Managing tomato spotted wilt virus in peanuts in North Carolina and Virginia. North Carolina Coop. Ext. Ser. Publ. AG-638.

Johnson III, W.C., T.B. Brenneman, S.H. Baker, A.W. Johnson, D.R. Sumner, and B.G. Mullinix, Jr. 2001. Tillage and pest management considerations in a peanut–cotton rotation in the southeastern Coastal Plain. Agron. J. 93:570–576.

Jordan, D.L. 2001. Peanut production practices. p. 10–29. *In* 2001 Peanut information. Publ. AG-331. North Carolina Coop. Ext. Serv., Raleigh.

Jordan, D.L. 2003. Peanut production practices. p. 9–25. *In* 2003 Peanut information. Publ. AG-331. North Carolina Coop. Ext. Serv., Raleigh.

Jordan, D.L., J.F. Spears, and G.A. Sullivan. 1998. Influence of digging date on yield and gross return of Virginia-type peanut cultivars in North Carolina. Peanut Sci. 25:45–50.

Lehman, W.F., and J.W. Lambert. 1960. Effects of spacing of soybean plants between and with-in rows on yield and its components. Agron. J. 52:84–86.

Lemon, R.G., B.A. Besler, W.J. Grichar, D.J. Pigg, and K. Brewer. 2001. Effects of narrow and twin row systems on peanut production in Texas. Proc. Am. Peanut. Res. Educ. Soc. 33:40–41.

Liang, B.C., M. Remillard, and A.F. Mackenzie. 1992. Effects of hybrids, population densities, fertilization and irrigation on grain corn (*Zea mays* L.) in Quebec. Can. J. Plant Sci. 72:1163–1170.

Marios, J.J., and D.L. Wright. 2003. Effect of tillage system, phorate, cultivar on tomato spotted wilt of peanut. Agron. J. 95:386–389.

McIntosh, M.S. 1982. Analysis of combined experiments. Agron. J. 75:153–155.

Mozingo, R.W. 1991. Peanut variety and quality evaluation results 1991: I. Agronomic and yield data. Tidewater Agric. Exp. Stn. Inf. Ser. 292. Virginia Polytechnic Inst. and State Univ., Blacksburg, VA.

Mozingo, R.W. 1996. Peanut variety and quality evaluation results 1991: I. Agronomic and yield data. Tidewater Agric. Exp. Stn. Inf. Ser. 380. Virginia Polytechnic Inst. and State Univ., Blacksburg, VA.

Mozingo, R.W., and C.W. Swann. 2000. Response of VA98R peanut to twin versus single row planting patterns. Proc. Am. Peanut Res. Educ. Soc. 32:43.

Nafziger, E.D. 1994. Corn planting date and plant population. J. Prod. Agric. 7:59–62.

Norden, A.J., and R.W. Lipscomb. 1974. Influence of plant growth habit on peanut production in narrow rows. Crop Sci. 14:454–457.

Parham, S.A. 1942. Peanut production in the Coastal Plain of Georgia. Georgia Coastal Plain Exp. Stn. Bull. 34.

Porter, P.M., D.R. Hicks, W.E. Lueschen, J.H. Ford, D.D. Warnes, and T. Hoverstad. 1997. Corn response to row width and plant population in the Northern Corn Belt. J. Prod. Agric. 10:293–300.

Shew, B. 2003. Peanut disease management. p. 75–98. *In* 2003 Peanut information. Publ. AG-331. North Carolina Coop. Ext. Serv., Raleigh.

Sholar, J.R., R.W. Mozingo, and J.P. Beasley, Jr. 1995. Peanut cultural practices. p. 354–382. *In* H.E. Pattee and H.T. Stalker (ed.) Advances in peanut science. Am. Peanut Res. Educ. Soc., Stillwater, OK.

Sullivan, G.A. 1991. Cultivar response to twin row planting. Proc. Am. Peanut Res. Educ. Soc. 23:36.

U.S. Department of Agriculture. 1998. Farmers' stock peanuts inspection instructions. USDA, Washington, DC.

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