Abstract

Lanier, James Edward. Peanut (*Arachis hypogaea*) Response to Cultural Practices Related to Planting Pattern, Irrigation, and Fertility. (Under direction of David L. Jordan and Randy Wells).

Experiments were conducted during 2001 and 2002 at the Peanut Belt Research Station near Lewiston-Woodville in North Carolina to compare development of early leaf spot (*Cercospora arachidicola* Hori), pod yield, and market grade characteristics when peanut was grown under overhead sprinkler irrigation (OSI) and subsurface drip irrigation (SDI) with and without fungicides. Incidence of early leaf spot was lower when peanut was grown under SDI compared with OSI when fungicides were not applied, and fewer fungicide applications were needed when applications were based on weather advisories rather than when applied bi-weekly. There was no difference in early leaf spot control or leaf defoliation resulting from disease when fungicides were applied regardless of irrigation system or fungicide application approach nor was there a difference in yield when fungicides were applied, regardless of irrigation system. The percentage of extra large kernels (%ELK) was lower in one of two years under SDI compared with OSI. The percentage of total sound mature kernels (%TSMK) was higher when fungicides were applied compared with non-treated peanut. There were no differences in percentages of fancy pods (%FP), sound splits (%SS), and other kernels (%OK) among irrigation systems and fungicide programs. In a separate experiment where fungicides were applied bi-weekly, pod yield, %FP, %ELK, and %OK were similar under SDI and OSI but greater than non-irrigated peanut.

Experiments were conducted from 1999 through 2002 in North Carolina to compare interactions of planting pattern, plant population, and irrigation on peanut pod yield and market grade characteristics. Peanut pod yield was higher in standard twin row planting patterns (rows spaced 18 cm apart on 91-cm centers) than when grown in single row planting patterns (rows spaced 91 cm apart) in some but not all experiments. Planting peanut in the narrow twin row pattern (rows spaced 18 cm apart on 46-cm centers) did not increase peanut pod yield over the standard twin row planting pattern. Less tomato spotted wilt virus was observed in standard or narrow twin row planting patterns compared with single row planting patterns. Sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby] control was higher when peanut was seeded in standard twin row planting pattern compared with peanut planted in the single-row planting pattern irrespective of preemergence or postemergence herbicide treatment. Irrigation and planting peanut in single rows spaced 46 cm apart did not improve yield over non-irrigated peanut or single rows spaced 91 cm apart, respectively. The interaction of cultivar by planting pattern was not significant for pod yield, market grade characteristics, or severity of tomato spotted wilt virus, suggesting that response to these variables will be independent.

Experiments were conducted from 2000 through 2002 in North Carolina to compare peanut response to inoculation with Brady rhizobia and ammonium sulfate. Peanut pod yield was higher following application of inoculant in 7 of 17 experiments. Ammonium sulfate increased pod yield in 3 of 6 experiments, although the rate of ammonium sulfate needed to optimize yield varied by experiment. Inoculating both rows of peanut seeded in twin row patterns yield higher in 2 of 4 experiments than when one of the twin rows was inoculated or when inoculant was not included. Fumigation with metam sodium did not affect pod yield, regardless of inoculation treatment.

Peanut (*Arachis hypogea*) Response to Cultural Practices Related to Planting Pattern, Irrigation, and Fertility

BY

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DEDICATION

This thesis is dedicated to my parents, Keith and Kim Lanier, grandparents and the rest of my family for their wonderful support, example, and love extended to help me reach all my goals and for where I am now.

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I would like to extend appreciation to the following individuals and organizations for the support and inspiration that I needed to complete this degree.

My eagerness to learn was instilled at an early age on the farm learning from my father, and this eagerness continues to be driven by influential leaders in my life. I would like to thank various high school teachers, professors, and colleagues for their positive influences and confidence in me.

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VITA

James Edward Lanier was born to Keith and Kim Lanier on February 20, 1979 in Kinston, North Carolina three months premature. His parent's claim that he was fast to get into the world and has not slowed down to this day. He was raised on a family farm where hard work was instilled into him at an early age. Local neighbors and community members claimed that he was to young to be on a tractor because he had to sit on a home made-stool to reach the pedals and steering wheel. He has two younger brothers, Gerren and Joshua, and a close cousin, Jeremiah Jones, that have been an inspiration during his youth and early adulthood. He graduated from East Duplin High School in May of 1997 where FFA was an extremely important part in his life. He received his Bachelor of Science degree in Agronomy from North Carolina State University in May of 2001. In the four years of his undergraduate program he was dedicated to going home to the family farm on weekends and holidays to help run the farm. During his studies at North Carolina State University he suffered two devastating family medical problems, where both parents had tragic strokes within two years of each other resulting in loss of the family farm. This loss of the family farm and hardship that was placed on the family inspired him to further his education by starting the Master of Science program in Crop Science in June of 2001. James is currently employed in the Crop Science Department under Dr. Keith Edmisten's direction. And resides in Raleigh, North Carolina.

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INTRODUCTION

Irrigation has been an important management tool to increase crop yields across the world. Today there are approximately 195,618 ha of irrigated peanut (*Arachis hypogea* L.) in the southeastern U.S (Lamb et al., 1997). This represents an increase from less than 10% of the total peanut acreage in the 1970s to over 49% in the 1990s (Lamb et al., 1997). Important requirements for optimum peanut production include proper soil and climatic conditions, crop rotation, land preparation and planting conditions, fertilization, cultivar selection, weed and pest control, and adequate rainfall or irrigation. Main methods of irrigation of peanut include overhead application of water to the crops with such equipment as center-pivot, traveling guns, or stationary systems. More recently subsurface drip irrigation (SDI) has provided alternatives to traditional irrigation and offers several advantages for example. SDI can conserve water while maintaining or increasing crop yield (Puppala et al., 2000). Increasing soil moisture with overhead irrigation also increases humidity in the crop canopy. Higher humidity in the crop canopy increase potential for disease to develop. SDI can provide a solution to this problem by irrigating the crop directly in the root zone. By lowering the potential of an increased humidity in the crop canopy, disease incidence may be lower with the SDI compared to overhead irrigation.

Planting patterns can influence crop growth, weed control, disease incidence, and yields for many crops. The use of narrower rows and plant population is a contributing factor in this increase in yield. Using twin row planting pattern in peanut instead of the standard single row configuration is the leading way to manipulate planting pattern. Recent reports from the Southeast demonstrate that twin rows possess yield and grade advantages over single row planting pattern row and lower incidence to TSWV (Baldwin and Williams, 2002). Row spacings narrower than the standard twin row configuration has not increased pod yield (Baldwin and Williams, 2002). Peanut cultivars differ in vine growth, disease resistance, and yield under different growing condition and planting patterns. Twin row pod yields for the Virginia market type cultivars NC 7, NC 9, NC-V 11, and NC 10C averaged 310, 290, 170, and 30 kg ha^{-1} higher, respectively, than that for single rows (Sullivan, 1991). Planting patterns have been found to greatly effect weed control for crops due to increased crop competition for resources with weeds. In peanut, twin row enhanced peanut yield, suppressed weeds and decreased incidence of tomato spotted wilt (Baldwin and Williams, 2002; Colvin et al., 1985).

Nitrogen is critical for a peanut crop to produce optimum yields. Most of the nitrogen needed by peanut is obtain by biological nitrogen fixation. This is insured by applying inoculant at planting to increase the amount of *Rhizobium* in the soil. Although positive response to inoculant was observed for peanut (Schiffman and Alper, 1968; Shimshi et al., 1967), yield response are typically not observed when peanut is planted in fields that have been rotated regularly with peanut (Reid and Cox, 1973; Walker et al., 1976). To compensate for poor inoculation, nitrogen-containing fertilizer can been applied to meet the nitrogen requirement of peanut. The most consistent responses to nitrogen fertilization have been obtained in studies where the soil conditions were not suitable for nodulation of peanut (Reid and Cox, 1973).

Use of non-selective fumigation to control plant pathogens at planting is an important disease management practice. Concern about negative effects of fumigation on rhizobium has been expressed. There for determining interactions of inoculation with fumigants and peanut response to application of ammonium sulfate will assist growers and their advisors enhance or improve efficient production practices for peanut. Also, determining yield advantages occur of applying in-furrow inoculant to fields that have had peanuts previously could help reduce production cost by defining which fields need inoculation.

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Disease Management in Overhead Sprinkler and Subsurface Drip Irrigation Systems for Peanut

ABSTRACT

Experiments were conducted during 2001 and 2002 at the same location in North Carolina to compare development of early leaf spot (*Cercospora arachidicola* Hori), pod yield, and market grade characteristics when peanut was grown under overhead sprinkler irrigation (OSI) and subsurface drip irrigation (SDI) when fungicides were not applied or when fungicides were applied bi-weekly or based on weather advisories. Incidence of early leaf spot was lower when peanut was grown under SDI compared with OSI when fungicides were not applied. Fewer fungicide applications were needed when applications were based on weather advisories rather than when applied bi-weekly. There was however, no difference in early leaf spot control or leaf defoliation resulting from disease when fungicides were applied regardless of irrigation system or fungicide application approach. Pod yield was higher in 2001 under SDI compared with OSI when fungicides were not applied; pod yield was similar in 2002. Disease severity was much higher in 2001 than in 2002 and most likely explains differences in pod yield between years. No difference in yield was noted when fungicides were applied, regardless of irrigation system. However, the percentage of extra large kernels (%ELK) was lower in one of two years under SDI compared with OSI. The percentage of total sound mature kernels (%TSMK) was higher when fungicides were applied compared with non-treated peanut. There were no differences in percentages of fancy pods (%FP), sound splits (%SS), and other kernels (%OK) among irrigation systems and fungicide programs. In a separate experiment where

fungicides were applied bi-weekly, pod yield, %FP, %ELK, and %OK were similar under SDI and OSI but greater than non-irrigated peanut.

Abbreviations: SDI, subsurface drip irrigation; OSI, overhead sprinkler irrigation; %ELK, percentage of extra large kernels; %OK, percentage of other kernels; %SS, percentage of sound splits; %TSMK, percentage of total sound mature kernels.

INTRODUCTION

There are approximately 195,615 ha of irrigated peanut (*Arachis hypogea* L.) in the southeastern United States (Lamb et al., 1997). The percentage of irrigation has increased from less than 10% in the 1970s to over 49% in the 1990s (Lamb et al., 1997). In North Carolina, however, less than 20% of peanut acreage is irrigated (Jordan, 2003). While in the southwestern United States, 44% of peanut acreage is irrigated (Bosch et al., 1998). Overhead sprinkler irrigation is the primary method irrigation method in these regions (O'Brien et al., 1998). Irrigation generally increases peanut yield when disease is controlled (Porter and Wright, 1987). However, disease incidence often increases under irrigation, and benefits of increased yield can be minimized due to increased incidence of non-controlled disease (Rotem and Palti, 1969; Wright et al., 1986). Increased moisture on the soil surface and humidity in the peanut canopy following overhead irrigation has been shown to increase incidence of Sclerotinia blight (*Sclerotinia minor*), pod rot (*Pythium myriotylum*), and leafspots (*Cercospora arachidicola* and *Cercosporidium personatum*) (Wright et al., 1986).

Subsurface drip irrigation (SDI) has been evaluated in a variety of agronomic and horticultural crops (O'Brien et al., 1998). SDI was found to conserve water while maintaining or increasing peanut yield (Puppala et al., 2000). It is suspected disease incidence in peanut would be lower under SDI compared with OSI because a decrease in the amount and duration of moisture in the canopy under SDI would lessen the likelihood of disease development. Cost of installation of SDI and OSI is dependant upon field size, topography, and cropping systems (Bosch et al., 1992; O'Brien et al., 1998). Initial and long-term investment in either system is however, similar (O'Brien et al., 1992). Less disease and more efficient water use make SDI an attractive alternative to OSI. In North Carolina, peanut is grown on relatively small and irregular shaped fields that limit efficient use of OSI.

Peanut producers in the United States apply a wide range of fungicides to control foliar and soil-borne diseases (Shew, 2003). Although many peanut producers apply fungicides bi-weekly, advisories have been developed to more precisely time applications (Bailey, 1999). This approach to disease management uses temperature and relative humidity to establish a threshold for development of early leaf spot and other diseases (Bailey, 1994, 1999). Using weather-based advisories to target fungicides for early leaf spot control can reduce the number of fungicides sprays needed for adequate disease control (Bailey, 1999; Damicone et al., 1994; Jordan et al., 1999).

Although the majority of peanut in the United State is seeded in single rows spaced 91 to 100 cm apart, research suggests that seeding peanut in twin row patterns (rows spaced approximately 18 cm apart with centers between the twin rows spaced 91 to 100 cm apart) can increase yield, improve some market grade characteristics, and decrease incidence of tomato spotted wilt tospovirus (Baldwin and Williams, 2002). However, increased incidence of other diseases and poor row visibility at the time of digging and inversion of peanut vines has been observed in twin row planting patterns (Beasley, 1970; Henning et al., 1982).

Determining interactions among irrigation systems and disease management programs will assist in enhancing efficient production and pest management systems for peanut. Research was conducted to compare early leaf spot control, peanut pod yield, and market grade characteristics when peanut was grown under SDI and OSI when fungicides were applied bi-weekly or based on weather advisories. Additional research was conducted to compare peanut pod yield and market grade characteristics when peanut was grown under SDI and OSI compared with non-irrigated peanut when fungicides were applied bi-weekly.

MATERIALS AND METHODS

Peanut Response to SDI and OSI Under Various Disease Management Programs

Experiments were conducted in 2001 and 2002 at the Peanut Belt Research Station located near Lewiston-Woodville, NC. Soil type in both years was a Norfolk sandy loam (fine-loamy, siliceous, thermic, Typic Paleudults) with pH 6.1 and 2.3% organic matter. In early April 2001, soil was disked twice and cultivated to prepare the field for installation of drip irrigation lines. Irrigation lines were installed with a ripper-bedder at a depth of 25 cm in rows spaced 91 cm apart. Corn (*Zea mays* L.) was planted the previous year. Irrigation lines were also installed adjacent to the experiment with cotton (*Gossypium hirsutum* L.) to allow for a crop rotation. Beds in the SDI area of the field were reestablished in 2002 using a bedder without ripper shanks. Water was pumped from an irrigation pond to a reservoir tank to supply the SDI plots with irrigation. Water from the reservoir tank was supplied with a centrifugal propeller water pump [Challenger 1.5 kW Water Pump, Model 35-5460, Pentair Pool Products, St. Paul, MN) to a sand filter system (Flow Guard Sand Filter System, Model 215S, Flow Guard Filtration Products Selma, CA), then to disk filtration system [ARKAL Disk Filter (140 mesh by 100 micron), Netafim, Tel Aviv, Israel] to remove fine particles from irrigation water. Water then flowed to an irrigation manifold which supplied water to specific plots. Irrigation water scheduling to plots was controlled by an electric water control console and electric solenoids (Orbit Electric Water Control, Model 57540, Orbit Irrigation Products Inc., Bountiful, UT). Flow meters (ABA Flow Meters, 16 mm by 19 mm, Model 98604940, Sennniger Irrigation, Inc., Orlando, FL) were used to measure flow rates. Pressure regulators followed the flow meters to reduce pressure to 69 kPa. Irrigation water then flowed in 25 mm supply lines buried 25 cm below the ground surface. The water then flowed through drip tape (TSX2 510-12-450 T-Tape, T-Systems Inc., Queensland, Australia) with emitters spaced 30 cm apart delivering 102 L m^{-1}. SDI was calibrated to supply 5 mm d^{-1}, a rate for SDI established previously for peanut (Stansell et al., 1976). OSI irrigation system consisted of 6 irrigation heads spaced 6.1 m apart (OSI System 20H, Nelson Irrigation Sprinkler Heads, Walla Walla, WA) established on a single irrigation line placed down the middle of the OSI. Irrigation of 18 mm of water was applied over 45 minutes from the same water source used for SDI. Frequency and amount of irrigation was based on recommendations from the Irrigator Pro model (Davidson et al., 1998). This system uses thermal data from probes established 5 cm below the soil surface to initiate irrigation. OSL was supplied as sequential applications of 18 mm on consecutive days. Irrigation was applied during the morning when wind speed was low to avoid movement to adjacent plots. Beds were established during both years in OSI with a ripper shanks included (ripping depth of 25 cm). The amount of rainfall and total irrigation for both SDI and OSI are presented in Figure 1. A total of 156 mm and 155 mm of water in OSI was provided in 2001 and 2002, respectively. In these respective years, 153 mm and 154 mm of water in SDI was provided during the season. Average daily air temperature and relative humidity were recorded from a stationary weather station 1.5 m above ground located 200 m from the test site (Figures 2 and 3). OSI was applied each day from Monday though Friday at a rate of 2 mm d^{-1}. OSI was reinitiated 4 d after rainfall in excess of 18 mm. OSI was continued when rainfall was less than 18 mm.

Within irrigation systems, three approaches to disease management were incorporated: no fungicides in a single row seeding pattern; fungicides applied based on weather advisories (Bailey, 1999) for early leaf spot control in a single row seeding pattern; and fungicides applied bi-weekly in both single row and twin row seeding patterns. The Weather-based advisories used temperature and relative humidity to determine if conditions are favorable for early leaf spot development (Bailey, 1994, 1999). Fungicides and rates as well as dates of application are presented in Tables 1 and 2. Fungicide applications were initiated in late June and were continued through early September. The twin row-seeding pattern consisted of two rows spaced 18 cm apart on 91-cm centers. The cultivar Perry was seeded at 140 kg ha^{-1} in single rows and 170 kg ha^{-1} in the twin row seeding pattern. These seeding rates were designed to establish 14 and 18 plants per linear m of row, respectively (Jordan, 2003). Aldicarb (*O*,*S*-dimethylacetylphosphoramidothioate) was applied in the seed furrow at 7.8 kg ai ha^{-1} to control early season pest. With the exception of fungicides applied for disease control and irrigation, all other production and pest management inputs were common across the entire test area and were based on North Carolina Cooperative Extension Service recommendations.

The experimental design was a randomized complete block with treatments arranged in a split plot design. Irrigation system served as whole plot units with disease management strategies and seeding pattern serving as split plot units. Plot size for the experimental unit was 4 rows (spaced 91 cm apart) by 9 m. Split plot units were replicated four times.

The percentage of peanut leaflets with early leaf spot lesions present in mid September were recorded on a scale of 0 to 100% where 0 = no lesions and 100 = all leaflets with at least one lesion present. The percentage of the peanut canopy defoliated by early leaf spot was determined in late September using a scale of 0 to 100% where 0 = no defoliation and 100 = complete defoliation of the peanut canopy. Percentage of plants exhibiting symptoms characteristic for tomato spotted wilt virus (Shew, 2003) were determined using a scale of 0 (no symptoms) to 100 (each 30-cm section of row exhibiting symptoms). Peanut digging date was based on pod mesocarp color determination (Williams and Drexler, 1981) and pod maturity was similar under both irrigation systems, allowing digging of peanut for both irrigation systems to occur on the same day. Peanut was combined after pods and vines were allowed to air dry for approximately 1 wk. A 1-kg sample of pods was collected at harvest from each plot to determine percentages of fancy pods (%FP), extra large kernels (%ELK), sound splits (%SS), total sound mature kernels (%TSMK), and other kernels (%OK) using Cooperative Grading Service criteria (Peanut Loan Schedule, 1997-2001, USDA-FSA-1014-3).

Data were subjected to analysis of variance appropriate for a two (year) by two (irrigation system) by four (disease management program) factorial treatment arrangement. 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 for the split plot treatment arrangement (McIntosh, 1982).

Comparison of Irrigated and Non-irrigated Systems

The experiment was conducted during 2001 and 2002 at Lewiston-Woodville in the same field described previously. Irrigation systems for SDI and OSI as described previously. The peanut cultivar Perry was seeded in single rows at a spacing of 91 cm and a seeding rate of 140 kg ha^{-1}. In addition to SDI and OSI irrigation, a no-irrigation control was included. Fungicides were applied bi-weekly as described previously to maintain peanut free of early leaf spot (Tables 1 and 2). Irrigated and non-irrigated peanut was dug and vines inverted on the same day in 2001, based on pod mesocarp color determination. In 2002, however, peanut was dug and vines inverted 1 wk earlier under SDI and OSI than non-irrigated peanut based on pod mesocarp color determination.

The experimental design was a randomized complete block with irrigation treatments replicated 4 times. Data for pod yield and market grade characteristics were subjected to analysis of variance. Means were separated using Fisher's Protected LSD test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Peanut Response to SDI and OSI Under Various Disease Management Programs

The interaction of year by irrigation system by disease management program was significant for early leaf spot incidence (Table 3). When analyzed by year, the interaction of irrigation by disease management program was significant during both years (Table 4). This interaction was most likely caused by differences in severity of early leaf spot for the two years as observed in the no-fungicide controls for both irrigation systems (Table 5). It is suspected that higher rainfall in 2001, especially earlier in the season, may have contributed to greater incidence of early leaf spot during 2001 compared with 2002 (Figure 1). Irrigation was generally applied early in the morning, giving foliage ample time to dry during the day. Although not clearly established in the climatic data, high temperature and somewhat low relative humidity in general may have contributed to less early leaf spot in 2002 compared with 2001 when fungicides were not applied (Table 5 and Figures 2 and 3).

Incidence of early leaf spot was greater when peanut was grown under OSI compared with SDI when fungicides were not applied (Table 5). Early leaf spot incidence in 2001 was 64% in SDI compared with 95% with OSI when fungicides were not applied. In contrast, incidence was 10 and 20% with these respective irrigation systems in 2002. Differences in early leaf spot incidence in 2001 translated into similar differences among fungicide treatments in leaf defoliation (Table 5). In contrast, there was no difference in defoliation among irrigation systems in 2002 when fungicides were not applied. When fungicides were applied bi-weekly (single and twin row seeding patterns) or based on weather advisories, early leaf spot incidence and peanut defoliation were similar. These data suggest that early leaf spot incidence may be lower when peanut is grown under SDI rather than OSI. However, development of early leaf spot and subsequent peanut foliage defoliation may not differ among irrigation systems, depending upon weather conditions that influence development and severity of incidence.

In both SDI and OSI, six fungicide treatments were applied in the bi-weekly approach (Tables 1 and 2). In contrast, four fungicide applications were made when fungicide applications were based on weather advisories under SDI (Tables 1 and 2). These data reinforce previous research showing that early leaf spot control using weather advisories to target fungicide applications are as effective as fungicides applied bi-weekly, and in some instances the number of fungicide applications can be reduced without sacrificing disease control (Bailey, 1994, 1999; Damicone et al., 1994; Jordan et al., 1999).

Incidence of tomato spotted wilt tospovirus varied by year and irrigation system (Table 3). Incidence was 3% or less in 2001, and there were no differences among irrigation systems or disease management programs (Table 6). In contrast, incidence of tomato spotted wilt tospovirus was much higher in 2002. When pooled over disease management programs, tomato spotted wilt virus incidence was 20% under SDI and 12% under OSI. Tomato spotted wilt tospovirus did not differ among disease management programs ($p = 0.6204$, Table 3). Tomato spotted wilt tospovirus is transmitted by thrips (*Frankliniella* spp.) generally early in the growing season (Johnson et al., 2001). In our experiment, irrigation and fungicide treatments did not differ until late June after the majority of transmission of virus would have occurred. Additional research is needed to determine the consistency of tomato spotted wilt incidence under various irrigation systems.

When comparing incidence of tomato spotted wilt tospovirus between single and twin row planting patterns, 21 and 19% tomato spotted wilt tospovirus occurred in these respective planting patterns under SDI (data not presented). Under OSI, incidence of tomato spotted wilt tospovirus was 13 and 5% with these respective planting patterns (data not presented). While not significantly different in these experiments, incidence of tomato spotted wilt tospovirus in peanut is generally lower when seeding peanut in twin row planting patterns rather than single row planting patterns (Brown et al., 1999).

The interaction of year by irrigation system by disease management program was not significant for peanut pod yield (p = 0.9863, Table 3). However, the interaction of year by disease management program was significant (p = 0.0011). In 2001, pod yield was higher when fungicides were applied, regardless of irrigation system or whether or not fungicides were applied bi-weekly or based on weather advisories (Table 7). In contrast, pod yield was similar in 2002 regardless of disease management program/planting pattern combination. Differences in yield most likely were related to differences in leaf defoliation caused by early leaf spot. The main effect of irrigation system (p = 0.1189) and interactions of year by irrigation system (p = 0.5279) and irrigation system by disease management program (p = 0.4593) were not significant. These data suggest that yield under SDI and OSI can be similar. Other research (Puppala et al., 2000) has documented similar yields in SDI and OSI systems.

The main effect of irrigation system was significant for %FP (p = 0.0001, Table 3). However, the interaction of year by irrigation system was not significant for this parameter (p = 0.9999), nor were disease management program (p = 0.6068) and the interaction of irrigation system by disease management program (p = 0.7995) were not significant. When pooled over years and disease management programs, the %FP was 84 and 82 for SDI and OSI systems, respectively (data not presented).

The interaction of year by irrigation system was significant for %ELK (p = 0.0320, Table 3). The main effect of disease management program was also significant (p = 0.0252) for %ELK. However, the main effect of irrigation (p = 0.5366) and the interaction of irrigation system by disease management program (p = 0.3350) were not significant for %ELK. The %ELK was higher under OSI compared to SDI in 2001 (Table 8). However, there was no difference between irrigation systems for this parameter in 2002. Although not substantiated in our experiments, it is suspected that while SDI provided sufficient soil moisture to promote growth of the peanut plant, soil moisture with this irrigation system was limited in the pegging zone. Sorensen et al. (2003) reported difficulty in moving sufficient irrigation water through SDI lines to the pegging zone of peanut. Soil moisture in the pegging zone was more favorable in OSI, and this may have favored greater movement of calcium into the developing pods. Calcium movement into developing pegs and maturing pods is influenced by soil moisture, and lower %ELK values are often associated with suboptimal calcium absorption by these structures (Gashco and Davis, 1995; Jordan et al., 2000). Although not recorded in these experiments, soil temperature may have been cooler in the pegging zone with OSI compared with SDI. Higher temperatures may have been detrimental to pod development and may explain partially why a lower %ELK was noted in SDI compared with OSI in one of two years. Sorenson and Wright (2002) suggested that SDI maintained soil temperatures in the pegging zone below a critical value of 29 C (Davidson et al., 1991) from peanut fruit initiation through crop harvest. However, a ceiling for the critical value for soil temperature has not been established for Virginia market type peanut. Additional research is needed to address this issue.

The %ELK generally increased as disease management intensity increased (Table 9). There was no difference between %ELK for peanut treated bi-weekly when seeded in single or twin row planting patterns. The %ELK was also similar when fungicides were not applied and when they were applied based on weather advisories. However, applying fungicides bi-weekly in the twin row seeding pattern increased %ELK over the no fungicide control when fungicide applications were based on the weather advisory. More intensive disease management often reduces peanut leaf defoliation and subsequent pod shed. This may explain lower %ELK when fungicides were not applied.

The interaction of year by irrigation system by disease management program was significant for %TSMK ($p = 0.0430$, Table 3). Although no difference in %TSMK was noted among irrigation systems and disease management in 2001, %TSMK was higher when fungicides were applied bi-weekly when peanut was seeded in single rows compared with peanut not treated with fungicides, when fungicides were applied based on weather, or when fungicides were applied bi-weekly in OSI (Table 9). While some differences in %SS and %OK were noted among years, disease management, and irrigation systems, a consistent trend was not apparent. Additionally, percentages of these parameters were 2% or less, and most likely are of limited agronomic significance.

Comparison of Irrigated and Non-irrigated Systems

Although the interaction of year by irrigation system was not significant for peanut pod yield, %FP, %ELK, %SS, or %OK, main effects for some of these parameters were significant (Table 10). Additionally, the interaction of year by irrigation systems was significant for %TSMK ($p = 0.0053$). When pooled over years, non-irrigated peanut yielded 1020 and 820 kg ha^{-1} lower than SDI and OSI systems, respectively (Table 11). However, pod yield under SDI and OSI was similar. Previous research has shown higher yield of irrigated peanut when diseases are controlled. Additional research has shown similar yields when peanut is grown under SDI and OSI systems (Lamb et al., 1997; Puppala et al., 2000).

The %FP and %ELK were similar under SDI and OSI but exceeded that for non-irrigated peanut (Table 11). Although not significant, the %ELK was 5% higher under OSI as compared with SDI. As was noted in the disease management study, it is suspected that greater soil moisture in the top few cm under OSI contributed to a higher %ELK due to higher calcium levels in soil water or that soil temperature in the pegging zone was cooler. There were no differences in %TSMK regardless of irrigation system in 2001 (Table 11). The percentage of TSMK was higher when peanut was irrigated in 2002, regardless of the irrigation system. Irrigation did not effect %SS in either year but did affect %OK (Table 11). The %OK was lower when peanut was irrigated regardless of system when compared with non-irrigated peanut.

SUMMARY

Collectively, these data suggest that peanut yield under SDI and OSI systems can be similar. Additionally, when conditions favor development of early leaf spot, incidence may be lower under SDI than OSI, and fewer fungicides applications may be needed to gain acceptable early leaf spot control compared with the number needed under OSI. Although yields were similar under SDI and OSI systems, the %ELK was lower under SDI than under OSI in one of two years. Additional research is needed to address market grade characteristics more critically under these irrigation systems. Results from these studies reinforce results from previous research demonstrating that applying fungicides based on weather advisories can be as effective as bi-weekly fungicide applications.

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Figure 1. Rainfall and irrigation at Lewiston-Woodville during 2001 and 2002.

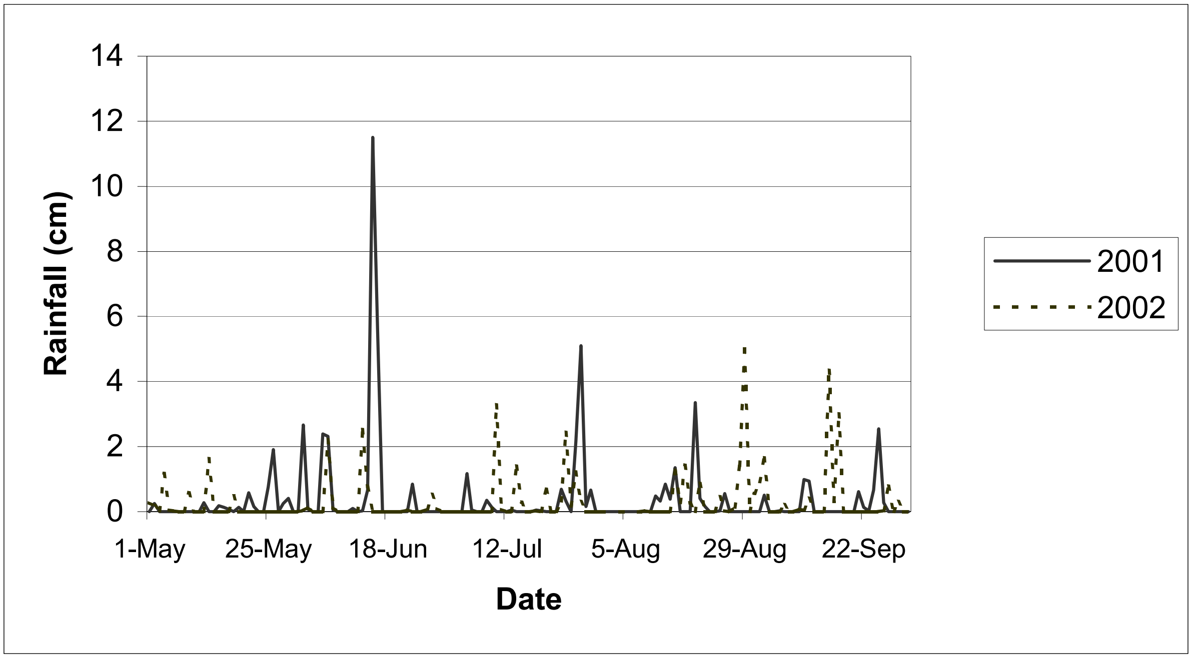

Figure 2. Average daily air temperature from May 1 through October 1 at Lewiston-Woodville during 2001 and 2002.

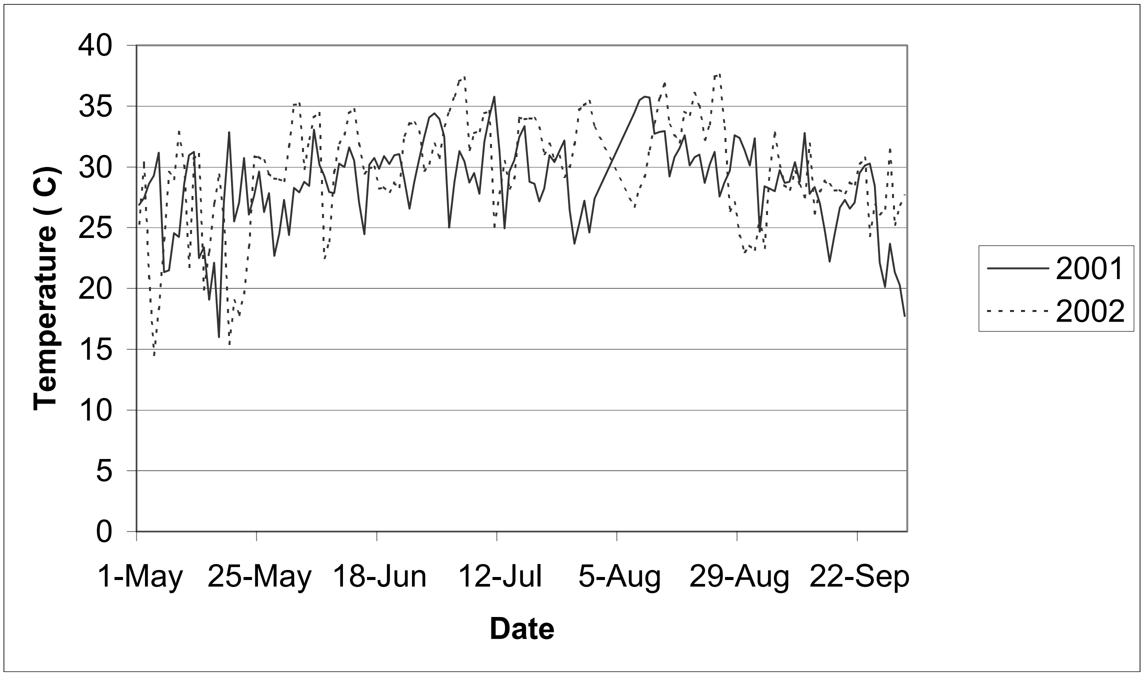

Figure 3. Average daily relative humidity at Lewiston-Woodville during 2001 and 2002.

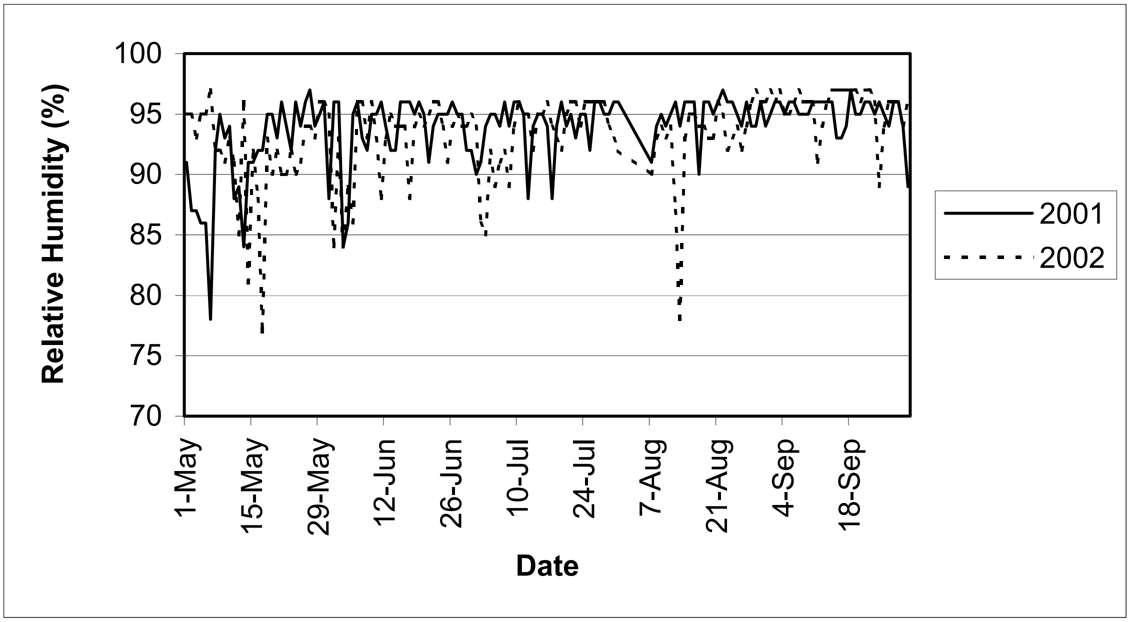

Table 1. Fungicides and rates and dates of fungicide application for bi-weekly and weather-based approaches to fungicide application in OSI and SDI systems during 2001.

Irrigation System*	Fungicide	Fungicide Rate	Date
		kg ai ha^{-1}	
	Fungicides applied bi-weekly		
SDI and OSI	Chlorothalonil	1.2	22 June
SDI and OSI	Chlorothalonil	1.2	9 July
SDI and OSI	Tebuconazole	0.23	26 July
SDI and OSI	Tebuconazole	0.23	9 Aug.
SDI and OSI	Chlorothalonil plus Tebuconazole	0.84 + 0.23	23 Aug.
SDI and OSI	Chlorothalonil	1.2	7 Sep.
	Fungicides applied based on weather advisory		
SDI and OSI	Chlorothalonil	1.2	9 July
OSI	Tebuconazole	0.23	26 July
SDI	Tebuconazole	0.23	1 Aug.
OSI	Tebuconazole	0.23	9 Aug.
SDI and OSI	Chlorothalonil plus Tebuconazole	0.84 + 0.23	23 Aug.
SDI and OSI	Chlorothalonil	1.2	7 Sep.

*Abbreviations: SDI, subsurface drip irrigation; OSI, overhead sprinkler irrigation.

Table 2. Fungicides and rates and dates of fungicide application for bi-weekly and weather-based approaches to fungicide application in OSI and SDI systems during 2002.

Irrigation System*	Fungicide	Fungicide Rate	Date
		kg ai ha^{-1}	
	Fungicides applied bi-weekly		
SDI and OSI	Chlorothalonil	1.2	3 July
SDI and OSI	Chlorothalonil	1.2	15 July
SDI and OSI	Tebuconazole	0.23	30 July
SDI and OSI	Tebuconazole	0.23	13 Aug.
SDI and OSI	Chlorothalonil	1.2	25 Aug.
SDI and OSI	Chlorothalonil	1.2	11 Sep.
	Fungicides applied based on weather advisory		
OSI	Chlorothalonil	1.2	9 July
SDI	Chlorothalonil	1.2	15 July
OSI	Tebuconazole	0.23	26 July
SDI and OSI	Tebuconazole	0.23	6 Aug.
OSI	Chlorothalonil	1.2	25 Aug.
SDI	Chlorothalonil	1.2	27 Aug.
SDI and OSI	Chlorothalonil	1.2	11 Sep.

*Abbreviations: SDI, subsurface drip irrigation; OSI, overhead sprinkler irrigation.

Table 3. Analyses of variance (p values) for early leaf spot; leaf defoliation; tomato spotted wilt incidence; pod yield; and percentages of fancy pods (%FP), extra large kernels (%ELK), total sound mature kernels (%TSMK), sound splits (%SS), and other kernels (%OK).

Source	Early Leaf spot*	Defolia-tion	Tomato spotted wilt virus	Pod yield	%FP	%ELK	%TSMK	%SS	%OK
	p-value								
Year	0.0001	0.0001	0.0440	0.0944	0.0555	0.5559	0.0002	0.0346	0.5489
Irrigation System (IS)	0.2848	0.4735	0.6067	0.1189	0.0001	0.5366	0.5987	0.3913	0.3500
Year*IS	0.0947	0.0086	0.0324	0.5279	0.9999	0.0320	0.0841	0.0736	0.4605
Disease Management (DM)	0.0001	0.0001	0.6204	0.0001	0.6068	0.0252	0.0940	0.2012	0.0769
Year*DM	0.0001	0.0001	0.8040	0.0011	0.8313	0.2061	0.0364	0.0814	0.0615
IS * DM	0.0001	0.0058	0.7285	0.4593	0.7995	0.3350	0.2234	0.1536	0.1245
Year*IS*DM	0.0329	0.0164	0.6586	0.9863	0.7073	0.6337	0.0430	0.0499	0.8360

Table 4. Analyses of variance (p values) for early leaf spot, leaf defoliation, and percentage of total sound mature kernels (%TSMK) for 2001 and 2002.

Source	Early leaf spot		Defoliation		%TSMK	
	2001	2002	2001	2002	2001	2002
	p-value					
Rep	0.3105	0.9553	0.4970	0.2570	0.7127	0.3621
Irrigation System (IS)	0.0080	0.0078	0.0040	0.7887	0.0502	0.6063
Disease Management (DM)	0.0001	0.0001	0.0001	0.0001	0.6679	0.0057
IS * DM	0.0008	0.0025	0.0062	0.9735	0.5580	0.0188

Table 5. Early leaf spot incidence and leaf defoliation as influenced by irrigation system and disease management program during 2001 and 2002.*

Disease management program	Row pattern[†]	Early leaf spot				Leaf defoliation			
		2001		2002		2001		2002	
		SDI[‡]	OSI[‡]	SDI	OSI	SDI	OSI	SDI	OSI
		%							
None	Single	64b	95a	10b	20a	62b	74a	9a	10a
Advisory	Single	4c	4c	2b	3b	4c	5c	0b	0b
Bi-weekly	Single	1c	2c	2b	1b	4c	5c	0b	0b
Bi-weekly	Twin	1c	1c	1b	1b	3c	4c	0b	0b

*Means within a year followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P \leq 0.05$).
†Twin row pattern consisted of two rows spaced 18 cm apart on 91-cm centers.
‡Abbreviations: SDI, subsurface drip irrigation; OSI, overhead sprinkler irrigation.

Table 6. Tomato spotted wilt virus incidence as influenced by irrigation system and year.*

Irrigation system	Tomato spotted wilt virus incidence	
	2001	2002
	%	
Subsurface drip	1a	20a
Overhead sprinkler	3a	12b

*Means within a year followed by the same letter are not significant according to Fisher's Protected LSD test ($P \leq 0.05$). Data are pooled over disease management programs.

Table 7. Pod yield as influenced by year and disease management program.*

Disease management program	Row pattern†	2001	2002
		kg ha^{-1}	
None	Single	2690b	3930a
Advisory	Single	3810a	4110a
Bi-weekly	Single	3920a	4080a
Bi-weekly	Twin	4100a	4120a

*Means within a year followed by the same letter are not significant according to Fisher's Protected LSD test ($P \leq 0.05$). Data are pooled over irrigation systems.

†Twin row pattern consisted of two rows spaced 18 cm apart on 91-cm centers.

Table 8. The percentage of extra large kernels as influenced by irrigation system and year.*

Irrigation system	Extra large kernels	
	2001	2002
	%	
Subsurface drip	49b	50a
Overhead sprinkle	54a	50a

***Means within a year followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P \leq 0.05$). Means are pooled over disease management programs.**

Table 9. Percentages of extra large kernels (ELK), total sound mature kernels (TSMK), and sound splits (SS) as influenced by year, irrigation system, and disease management program.*

Disease Management Program	Row pattern[†]	Extra large kernels	Total sound mature kernels				Sound splits			
			2001		2002		2001		2002	
			SDI[‡]	OSI[‡]	SDI	OSI	SDI	OSI	SDI	OSI
		%								
None	Single	48c	74a	77a	71a	71b	1b	2a	1a	1a
Advisory	Single	50bc	77a	77a	72a	70b	2a	2a	1a	1a
Bi-weekly	Single	53a	75a	77a	73a	77a	2a	1b	1a	0b
Bi-weekly	Twin	52ab	75a	79a	73a	69b	1b	1b	1a	1a

[*]Means within a parameter and year followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P \leq 0.05$).
[†]Twin row pattern consisted of two rows spaced 18 cm apart on 91-cm centers.
[‡]Abbreviations: SDI, subsurface drip irrigation; OSI, overhead sprinkler irrigation.

Table 10. Analyses of variance for peanut pod yield and percentages of fancy pods (%FP), extra large kernels (%ELK), total sound mature kernels (%TSMK), sound splits (%SS), and other kernels (%OK).

Source	Pod yield	%FP	%ELK	%TSMK	%SS	%OK
	p-values					
Year	0.1531	0.0004	0.4413	0.0130	0.0030	0.1000
Irrigation System	0.0001	0.0001	0.0020	0.0072	0.1014	0.0057
Year*Irrigation System	0.4564	0.5748	0.1891	0.0053	0.2621	0.0659

Table 11. Influence of irrigation system on pod yield and percentages of fancy pods (%FP), extra large kernels (%ELK), total sound mature kernels (%TSMK), sound splits (%SS), and other kernels (%OK).*

Irrigation System				%TSMK			
	Pod yield	%FP	%ELK	2001	2002	%SS	%OK
	kg ha^{-1}	%					
Subsurface drip	3560a	83a	51a	75a	73a	1a	2b
Overhead sprinkler	3360a	93a	55a	75a	76a	1a	2b
None	2540b	70b	44b	75a	66b	1a	3a

*Means within a parameter and year followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P \leq 0.05$). Data for %FP, %ELK, %SS, and %OK are pooled over years.

Peanut Response to Planting Pattern, Row Spacing, and Irrigation

ABSTRACT

Experiments were conducted from 1999 through 2002 in North Carolina to compare interactions of planting pattern, plant population, and irrigation on peanut pod yield and market grade characteristics. In additional studies, 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 approximately 10 d apart. In a study, pod yield, market grade characteristics, and severity of tomato spotted wilt tospovirus were compared when peanut was planted in single row, standard twin row, and narrow twin row (two rows spaced 18 cm apart on 46-cm center) planting patterns. In a final set of experiments, sicklepod [*Senna obtusifolia* (L.) Irwin & Barneby] control and peanut pod yield following a variety of preemergence and postemergence herbicides were compared in single and standard twin row 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. However, less tomato spotted wilt was observed in standard or narrow twin row planting patterns compared with single row planting patterns. Sicklepod control was higher

when peanut was seeded in standard twin row planting pattern compared with peanut planted in the single-row planting pattern irrespective of preemergence or postemergence herbicide treatment. Irrigation and planting peanut in single rows spaced 46 cm apart did not improve yield over non-irrigated peanut or single rows spaced 91 cm apart, respectively. The interaction of cultivar by planting pattern was not significant for pod yield, market grade characteristics, and severity of tomato spotted wilt virus, suggesting that response to these variables will be independent.

Abbreviations: HADSS, herbicide application decision support system; %ELK, percentage of extra large kernels; %OK, percentage of other kernels; %TSMK, percentage of total sound mature kernels; TSWV, severity of tomato spotted wilt tospovirus.

INTRODUCTION

Altering plant population and row pattern can affect crop yield, quality factors, and pest development in peanut (*Arachis hypogaea* L.). Pod yield of bunch-type peanut was 16 % higher when peanut was seeded in rows spaced 46 cm apart compared with 91cm (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 (Parham, 1942). In these studies, in-row plant population was held constant. 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 United States 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 the Virginia market type peanut 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 were 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 a range of crops. Irrigation increased corn (*Zea mays* L.) yield when higher plant populations were established compared to 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. 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)

Planting soybean in narrow rows compared with wide-row spacings can increase season-long weed control, and in some cases can reduce the number of herbicides needed to control weeds throughout the season (Weber et al., 1996; Wells et al., 1993). In peanut, Hauser and Buchanan (1981) reported improved weed control when peanut was seeded in narrow rows compared with single row planting patterns. Colvin et al. (1985) reported more effective control of sicklepod {*Senna obtusifolia* (L.) Irwin & Garneby}, Florida beggarweed [*Desmodium tortuosum* (Sw.) DC], and bristly starbur (*Acanthospermum hispidum* DC) in both twin row and narrow row planting patterns compared with control in single row planting patterns. However, enhanced weed control in peanut seeded in twin row planting patterns did not reduce herbicide usage when compared with single row planting patterns (Colvin et al., 1985).

Determining interactions of seeding rate and planting pattern with variables such as cultivar selection, irrigation, and herbicide programs 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 pest management when peanut was planted in various row patterns and seeding rates.

MATERIALS AND METHODS

Peanut Response to Planting Pattern, Row Spacing, and Irrigation

Experiments were conducted during 1999 and 2000 at the Peanut Belt Research Station located near Lewiston-Woodville, NC on a Norfolk sandy loam (fine-loamy, 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. The previous crop during both years was corn.

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 approximately 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) (Figure 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. Rainfall was sufficient throughout the remainder of the season to prevent the need for irrigation. Aldicarb (*O*,*S*-dimethylacetylphosphoramidothioate) was applied in the seed furrow for each row at 7.8 kg ai ha^{-1} for early season pest control. 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 bi-weekly applications of fungicides. Chlorothalonil (tetrachloroisophthalonitrile) at 1.2 kg ai 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 ai ha^{-1} each through late July and August. Chlorothalonil was also applied in early September.

The experimental design was a randomized complete block with treatments arranged in a split plot arrangement with irrigation system serving as whole plot units and planting pattern/seed spacing combinations serving as sub plots. 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. 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. Peanut pods were harvested after pods and vines were allowed to air dry for approximately 1 wk. 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 (Peanut Loan Schedule, 1997-2001, USDA-FSA-1014-3).

Data for pod yield, %FP, %ELK, and %TSMK were subjected to analysis of variance appropriate for the two (year) by two (irrigation system) by 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).

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 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 in 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. 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 disease was controlled using the fungicide application schedule described previously. Fields were fumigated with metam sodium 2 wk prior to 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 sub plots. Treatments were replicated four times. Severity of tomato spotted wilt virus (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) by two (digging date) by four (cultivar) by two (planting pattern-plant population) factorial treatment arrangement. Data for TSWV were subjected to analysis of variance appropriate for a four (location) by four (cultivar) by 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 prior to 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 on 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 4 times. Peanut canopy development was determined using a Sony DKC-ID1 digital camera (Sony Corp. of America, New York, NY) with a spatial resolution of 768x561 pixels. Digital images were recorded approximately bi-weekly 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 to be exactly 97 cm wide by placing a meter stick on the ground for reference. Three images using a built-in supplemental flash were taken at random within the plot. 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 University, 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 (Peanut Loan Schedule, 1997-2001, USDA-FSA-1014-3).

Data for TSWV, percent canopy closure, peanut pod yield, and market grade factors were subjected to analysis of variance appropriate for a two (year) by two (cultivar) by 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 versus days after planting ($p \leq 0.05$), based on results from the factorial analysis.

Weed Management in Peanut Planted in Single and Twin Row Planting Patterns

The experiment was conducted during 2001 and 2002 at the Cherry Farm Unit located near Goldsboro, NC on a Wickham sandy loam (fine-loamy, mixed, semi active, thermic Typic Hapludults) with 1.8 % organic matter and pH 6.2. Plot size was 4 rows (91-cm centers) by 12 m. Herbicide treatments consisted of dimethenamid {(*S*)-2-chloro-*N*-[1-methyl-2-methoxy) ethyl]-*N*-(2,4-dimethyl-thien-3yl)-aceatamide} at 1.1 kg ai ha^{-1} applied preemergence (PRE) or dimethenamid (1.1 kg ha^{-1}) plus diclosulam {*N*-(2,6-dichloropheny)-5-ethoxy-7-fluoro[1,2,4]triazolo-[1,5-c]pyrimidine-2-sulfonamide} at 0.027 kg ai ha^{-1} applied PRE followed by no postemergence herbcicides or postemergence herbicide based on the primary economical recommendation provided by HADSS (Herbicide Application Decision Support System, Ag Renaissance Software LLC, www.hadss.com) (Wilkerson et al., 2002). Imazapic {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid} at 70 g ai ha^{-1} was recommended by the HADSS program. The mixture of acifluorfen {sodium 5-[2-chloro-4(trifluoromehtyl)phenoxy]-2-nitrobenzoate} plus bentazon {3-(1-methylethyl)-*1H*-2,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide} plus paraquat {1,1'-dimethyl-4,4'-bipyridinium dichloride}(0.28 + 0.56 + 0.14 kg ai ha^{-1}, respectively) was applied over the entire test area at the cracking stage of peanut. Nonionic surfactant at 0.125% (v/v) was applied with the mixture of acifluorfen plus bentazon plus paraquat and at 0.25% (v/v) with imazapic. Weed densities were determined in each plot designated to receive herbicides based on the HADSS recommendation 4 wk after planting (3 wk after application of acifluorfen plus bentazon plus paraquat). Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 140 kPa. All herbicide combinations were applied to the cultivar NC-V 11 planted in single rows spaced 91 cm apart or in standard twin rows spaced 18 cm apart with centers spaced 91 cm apart. Aldicarb was applied in the seed furrow 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 except for weed management.

The experimental design was a randomized complete block with four replications. Visual estimates of percent sicklepod control were recorded in early August and early September using a scale of 0 to 100% where 0 = no control and 100 = complete control. Foliar chlorosis, necrosis, plant stunting, and stand reduction were used when making the visual estimates. Peanut pods were dug and harvested as described previously.

Data for percent sicklepod control and pod yield were subjected to analysis of variance appropriate for a two (year) by two (planting pattern) by two (preemergence herbicide) by two (postemergence herbicide) factorial treatment arrangement. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$.

In a separate experiment conducted only in 2002 at the Peanut Belt Research Station, TSWV severity and peanut pod yield were compared when no postemergence herbicides were applied or when acifluorfen (0.28 kg ha^{-1}) plus bentazon (0.56 kg ha^{-1}), acifluorfen (0.28 kg ha^{-1}) plus bentazon (0.56 kg ha^{-1}) plus 2,4-DB (0.22 kg ai ha^{-1}), or imazapic (70 g ha^{-1}) were applied postemergence. The herbicides were applied to the peanut cultivar NC-V 11 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). Pendimethalin {*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine} at 0.84 kg ai ha^{-1} and metolachlor {acetamide, 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl]-,(*S*)} at 0.84 kg ai ha^{-1} were applied over the entire test area. The combination of pendimethalin and metolachlor sufficiently controlled weeds. Therefore, the experiment was weed-free throughout the season. Acephate {*O,S*-dimethyl actyl-phosphoramidothioate} at 1.1 kg ai ha^{-1} was applied postemergence over the entire test area 2 wk after emergence to control tobacco thrips [*Frankliniella fusca* (Hinds)].

The experimental design was a randomized complete block with treatments replicated four times. Data for TSWV severity and pod yield were subjected to analysis of variance appropriate for a five (herbicide) by three (row pattern) factorial treatment arrangement. Means of significant main effects and interactions were separated using Fisher's Protected LSD Test at $p \leq 0.05$

RESULTS AND DISCUSSION

Peanut Response to Planting Pattern, Row Spacing, and Irrigation

Interactions of year X planting pattern ($p = 0.0184$) and irrigation X planting pattern ($p = 0.0039$) were significant for pod yield (Table 1). However, the interaction of year X irrigation X 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 2). 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 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 2). 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 2). 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 (Table 2). 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 (Table 1). 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).

Peanut Cultivar Response to Planting Pattern and Digging Date

The interaction of experiment X digging date X cultivar was significant for peanut pod yield ($p = 0.0252$, Table 3). However, interactions of experiment X planting pattern X cultivar ($p = 0.5679$) and experiment X digging date X planting pattern ($p = 0.1112$) were not significant. Although the interaction of planting pattern by 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 kg ha^{-1} 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 X cultivar X digging date ($p = 0.0252$) was expected (Table 3). 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 4). 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. However, delaying digging resulted in lower yield for the cultivars NC-V 11 (2000 and 2002) and VA 98R (2000) at Lewiston-Woodville (Table 5). 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 6). However, there was no difference in yield between digging dates for the other cultivars in 2001 or for any cultivar in 2002.

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 X planting pattern X cultivar was not significant for TSWV ($p = 0.7149$) or pod yield ($p = 0.2512$)(Table 7). However, the main effect of planting pattern was significant for these respective parameters ($p = 0.0001$ and 0.0007, respectively). Interactions of planting pattern X cultivar and experiment X planting pattern were not significant for these parameters (Table 7). The main effect of cultivar and the interaction of experiment X cultivar were not significant for pod yield, however, they were significant for %TSWV. When pooled over experiments and cultivars, the TSWV severity was 17% in the twin row planting pattern compared with 10% in the single row planting pattern (data not presented). Pod yield in these respective planting patterns was 4010 kg ha^{-1} 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 X planting pattern interaction for pod yield (Table 3) 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 ha 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 ha 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 8). 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 (Table 8). 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 X culivar X plant population was not significant for TSWV severity (p = 0.2915) or pod yield (p = 0.7359)(Table 9). However, the interaction of cultivar by 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 10). In contrast, 18 to 23% TSWV was noted when peanut was seeded in single or standard twin row planting patterns for the cultivar Perry (Table 10). 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 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 independent of year or cultivar (Table 9). 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 10). 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 (Table 1).

The %FP was affected by the interaction of year, cultivar, and planting pattern ($p = 0.0238$)(Table 9). The %FP was similar for the cultivar NC-V 11 regardless of planting pattern in 2001 (Table 11). The %FP was higher when peanut was seeded in the standard twin row planting pattern for the cultivar NC-V 11. In 2002, the %FP was lower in the narrow row planting pattern compared with standard single and twin row planting patterns. There was no difference in %FP for Perry in 2002.

Canopy closure, as measured by digital imaging, was affected by year and days after planting ($p = 0.0001$) and cultivar X days after planting ($p = 0.0235$) (Table 12). 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 ($p = 0.8999$) (Table 12). When pooled over cultivars and planting patterns, the linear function of canopy closure, measured as percent 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 13). 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 peanut growth and row closure more accurately. The interaction of cultivar X days after planting was also significant for canopy closure ($p = 0.0235$) (Table 12). 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.

Weed Management in Single and Twin Row Planting Patterns

The interaction of year X planting pattern X herbicide program was not significant for sicklepod control in early August or early September (Table 14). However, the year X planting pattern was not significant at the early August evaluation ($p = 0.0239$). This interaction was significant at the early September evaluation. When pooled over years and herbicide programs, sicklepod control in early August was 9% higher when peanut was seeded in the standard twin row planting pattern compared with the single row pattern (Table 15). When evaluated in early September, there was no difference in sicklepod control when comparing planting patterns in 2001 (Table 15). However, sicklepod control was 17% higher in the standard twin row planting compared with the single row planting pattern in 2002. The difference in late-season sicklepod control may have been partially attributed to sicklepod density noted between the two years. In 2001, sicklepod density was 2 plants m^{-2} when dimethenamid was applied PRE without additional PRE herbicides or postemergence applications of imazapic while sicklepod density following this herbicide program in 2002 was 40 plants m^{-2}. The competitive advantage of the standard twin row planting pattern compared with the single row planting pattern may have been more pronounced under the higher sicklepod infestation noted in 2002. Other research (Hauser and Buchanan, 1981) reported better control of sicklepod when peanut was seeded in standard twin row planting patterns compared with single row planting patterns. More recently, Yoder et al. (2003) reported that Florida beggarweed control was higher in standard twin row planting pattern compared with single row planting patterns irrespective of herbicide program.

When pooled over herbicide programs, pod yield was higher during 2002 when peanut was seeded in the standard twin row planting pattern compared with seeding in single rows (Table 15). In contrast, pod yield was similar in 2001 when comparing planting patterns. Additionally, yields were lower in 2002 compared with 2001. Lower pod yield in 2002 may have been associated with greater weed interference as a result of the field having a higher population of sicklepod and from extremely dry conditions in 2002 compared with 2001.

Sicklepod control in early August 2001 was higher when dimethenamid was applied with diclosulam (35%) than when dimethenamid was applied alone (5%) when postemergence herbicides were not applied (Table 16). Sicklepod control in early September remained higher when diclosulam was applied with dimethenamid than when dimethanamid was applied alone when imazapic was not applied. Control did not differ among these treatments at either evaluation period in 2002. Previous research (Grey et al., 2003) suggests that PRE applications of diclosulam can suppress but not control sicklepod. Applying imazapic POST increased sicklepod control to at least 90% in 2001 regardless of the soil-applied herbicide program. Previous research (Grey et al., 2003) also suggests that imazapic controls sicklepod effectively. Sicklepod control decreased in early September compared with control in early August. In 2001, pod yield was lower when dimethenamid alone was applied compared to all other herbicide programs, including dimethenamid plus diclosulam (Table 16). In 2002, pod yield was higher following the herbicide program containing dimthenamid plus diclosulam followed by imapzapic than the program of dimethenamid plus dicosulam without imazapic POST or dimethenamid followed by imazapic POST.

In the final study, the interaction of herbicide program X planting pattern was not significant for TSWV severity ($p = 0.9467$) and pod yield ($p = 0.6053$) (data not presented). The main effect of herbicide program was not significant for either parameter. Previous research (Shaikh et. al., 2003) reported that postemergence herbicides did not affect TSWV incidence. In contrast, the main effect of planting pattern was significant for TSWV severity ($p = 0.0001$) and pod yield ($p = 0.0001$). The severity of TSWV differed among planting patterns, and was 28, 12, and 3% lower when peanut was seeded in single rows, the standard twin row planting pattern, or the narrow twin row planting pattern, respectively (data not presented). Pod yield in these respective planting patterns was 3180, 3690, and 3840 kg ha^{-1}. Pod yield for the standard and narrow twin row planting patterns was similar and exceeded yield of peanut seeded in the single row pattern. Results from this experiment, relative to pod yield, are consistent with the previously discussed studies, demonstrating advantages of seeding peanut in a narrow twin row planting pattern compared with the standard twin row planting pattern with respect to reducing TSWV severity. Additional research is needed to determine the effect of herbicide selection on TSWV severity in Virginia market type peanut.

SUMMARY

Collectively, these data suggest 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 suggest 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 standard single or twin row planting patterns were conducted under weed-free conditions. Quicker canopy closure in narrow twin rows planting patterns may improve weed control. Severity of TSWV differed among planting patterns, with less incidence observed in standard or narrow twin row planting patterns compared with single row planting patterns. Planting peanut in standard twin row planting patterns improved sicklepod control over single row patterns when sicklepod populations were high. Additional research is needed to determine if response would be similar with other weed species and when peanut are seeded in narrow twin 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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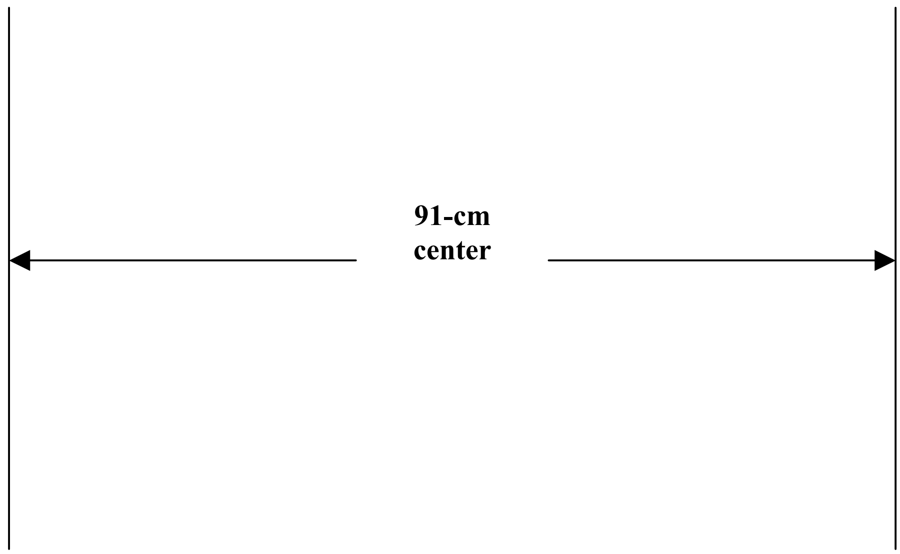
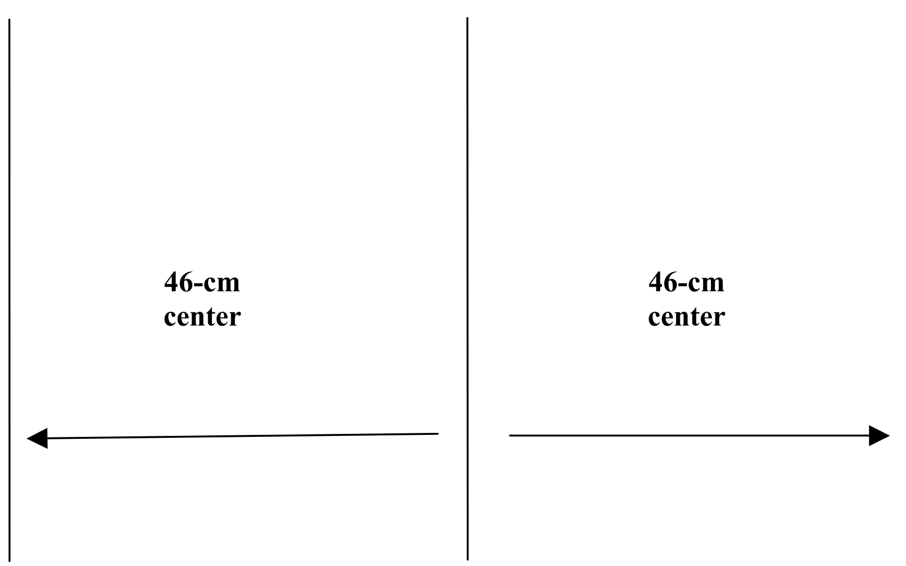
Figure 1. Diagram of row patterns consisting of: single row planting pattern with rows spaced 91 cm apart (A), narrow row single row planting pattern with rows spaced 46 cm apart (B), standard twin row planting pattern with rows spaced 18 cm apart on 91-cm centers (C), and narrow twin row planting pattern with rows spaced 18 cm apart on 46-cm centers (D). Solid lines indicate a row of peanuts.

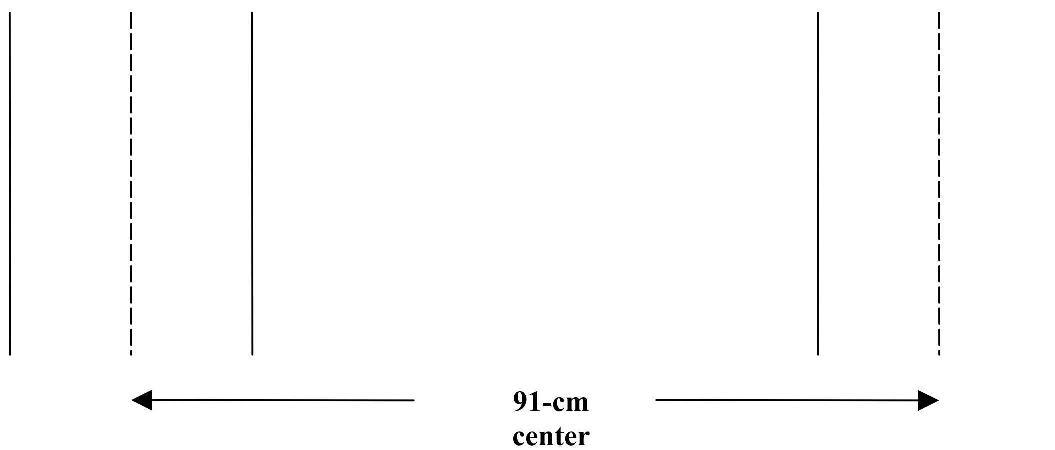
A. Standard single row pattern



B. Narrow single row pattern



C. Standard twin row pattern



D. Narrow twin row pattern

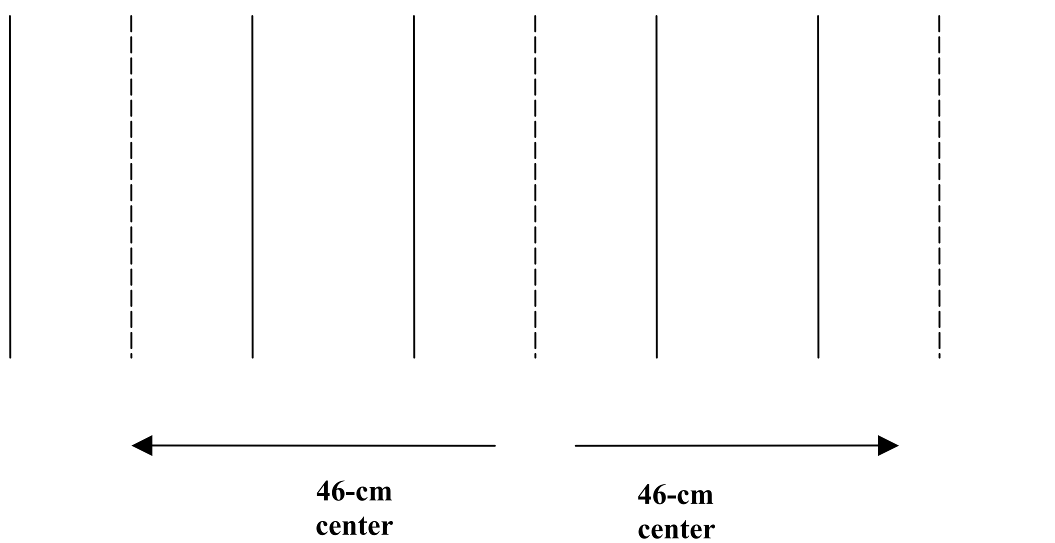


Table 1. Analysis of variance (p-values) for pod yield and percentages of extra large kernels (%ELK), fancy pods (%FP), and total sound mature kernels (% TSMK) as influenced by year, irrigation, and planting pattern.

Source	Pod Yield	%ELK	%FP	%TSMK
	p-value			
Year	0.0003	0.0001	0.9948	0.0036
Year * Irrigation	0.5957	0.0873	0.4592	0.6966
Irrigation	0.0057	0.9356	0.1461	0.0734
Planting pattern	0.0001	0.8124	0.5238	0.2893
Year * Planting pattern	0.0184	0.3446	0.8771	0.6291
Irrigation * Planting pattern	0.0039	0.2767	0.7469	0.3689
Year * Irrigation * Planting pattern	0.8105	0.4721	0.9721	0.1617
Coefficient of Variation	6.8	20.3	11.5	5.7

Table 2. Pod yield as influenced by year, planting pattern, population, and irrigation system.

Planting pattern	Row spacing centers	In-row population	Year*		Irrigation†	
			1999	2000	None	Yes
	cm	plants m^{-1}	kg ha^{-1}			
Single	96	12	4030b	4460e	4280c	4200cde
Standard	96	15	4350a	4980ab	4450abc	4880a
Twin‡						
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.

Table 3. Analysis of variance (p-values) for pod yield as influenced by experiment, cultivar, planting pattern, and digging date.

Source	Pod yield
	p-value
Experiment	0.0001
Digging Date	0.9390
Planting pattern	0.0029
Digging Date X Planting pattern	0.4538
Cultivar	0.0609
Digging Date X Cultivar	0.0030
Planting pattern X Cultivar	0.3437
Digging Date X Planting pattern X Cultivar	0.2199
Experiment X Digging Date	0.0001
Experiment X Planting pattern	0.1249
Experiment X Digging Date X Planting pattern	0.1112
Experiment X Cultivar	0.0001
Experiment X Digging Date X Cultivar	0.0252
Experiment X Planting pattern X Cultivar	0.5679
Experiment X Digging Date X Planting pattern X Cultivar	0.1121
Coefficient of Variation	11.4

Table 4. Pod yield as influenced by location, cultivar, and digging date at Gatesville and Williamston during 2000.

	Pod yield*			
	Gatesville		Williamston	
Cultivar	**Early Dig**	**Late Dig**	**Early Dig**	**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.

Table 5. 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.

Table 6. 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.

Table 7. Analysis of variance (p-values) for tomato spotted wilt severity and pod yield as influenced by experiment, planting pattern, and cultivar.

Source	Tomato spotted wilt virus	Pod yield
	p-value	
Experiment	0.0090	0.0001
Planting pattern	0.0001	0.0007
Cultivar	0.0465	0.2056
Planting pattern X Cultivar	0.6718	0.2369
Experiment X Planting pattern	0.6618	0.7348
Experiment X Cultivar	0.0064	0.0971
Experiment X Planting pattern X Cultivar	0.7149	0.2512
Coefficient of Variation	82.4	13.4

Table 8. Percentage of tomato spotted wilt virus as influenced by cultivar and year[*].

Cultivar	Lewiston-Woodville 2001	Lewiston-Woodville 2002	Rocky Mount 2001	Rocky Mount 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.

Table 9. Analysis of variance (p-values) for tomato spotted wilt severity (TSWV), pod yield, and percentages of extra large kernels (%ELK), fancy pods (%FP), total sound mature kernels (%TSMK) as influenced by year, planting pattern, and cultivar.

Source	TSWV	Pod yield	%FP	%ELK	%TSMK
	p-value				
Year	0.0673	0.1027	0.3015	0.0045	0.7097
Cultivar	0.0001	0.1995	0.1394	0.5935	0.6674
Planting pattern	0.0001	0.0004	0.2174	0.1040	0.0213
Year X Cultivar	0.0575	0.5676	0.3266	0.2896	0.1729
Year X Planting pattern	0.1037	0.3652	0.2705	0.9565	0.6683
Cultivar X Planting pattern	0.0101	0.3309	0.1783	0.1996	0.8780
Year X Cultivar X Planting pattern	0.2915	0.7359	0.0238	0.1967	0.7425
Coefficient of Variation	65.0	10.4	8.2	14.3	3.1

Table 10. 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*		Pod yield†	%TSMK†
		NC V-11	Perry		
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 significant according to Fisher's Protected LSD test at
$p \leq 0.05$. Data are pooled over years.
†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.
‡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 11. Percentage of fancy pods influenced by year, planting pattern, and cultivar.

		Fancy pods*			
		2001		2002	
Row spacing centers	**Planting pattern**	**NC V-11**	**Perry**	**NC V-11**	**Perry**
cm			**%**		
91	**Single Rows**	**68a**	**63b**	**71a**	**63c**
91	**Twin Rows†**	**68a**	**74a**	**72a**	**62c**
46	**Twin Rows‡**	**69a**	**68a**	**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 20 cm apart on 91-cm centers.
‡Narrow twin row pattern consisted of two rows spaced 20 cm apart on 46-cm centers.

Table 12. Analysis of variance (p-values) for canopy closure as influenced by year, cultivar, planting pattern, and days after planting.

Source	Canopy closure
	p-value
Year	0.0001
Cultivar	0.1255
Year X Cultivar	0.2197
Planting pattern	0.3243
Year X Planting pattern	0.3548
Cultivar X Planting pattern	0.6346
Year X Cultivar X Planting pattern	0.1654
Days after planting (DAP)	0.0001
Year X DAP	0.0001
Cultivar X DAP	0.0235
Year X Cultivar X DAP	0.8073
Planting pattern X DAP	0.8999
Year X Planting pattern X DAP	09506
Cultivar X Planting pattern X DAP	0.0545
Year X Cultivar X Planting pattern X DAP	0.9675
Coefficient of Variation	14.8

Table 13. Parameter estimates for peanut canopy closure using digital imaging as influenced by year and cultivar.

	Parameter estimates for peanut canopy closure*			
	Year		Cultivar	
Days after planting	2001	2002	NC-V 11	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.

Table 14. Analysis of variance (p-values) for sicklepod control in early August and early September and pod yield as influenced by year, planting pattern, and herbicide program.

Source	Sicklepod control		
	Early August	Early September	Pod yield
	p-value		
Year	0.0150	0.0053	0.0001
Planting pattern	0.0210	0.0851	0.0004
Herbicide program	0.0001	0.0001	0.0001
Year by Planting pattern	0.6389	0.0177	0.0092
Year by Herbicide program	0.0239	0.0244	0.0001
Planting pattern by Herbicide program	0.7788	0.4480	0.0635
Year by Planting pattern by Herbicide program	0.6392	0.1329	0.7198
Coefficient of Variation	28.5	34.1	19.4

Table 15. Sicklepod control and pod yield influenced by row pattern and year.

Planting Pattern	Sicklepod control			Pod yield[‡]	
		Early Sep.[‡]		2001	2002
	Early Aug.[*]	2001	2002		
	%			kg ha^{-1}	
Single Rows	**46b**	**54a**	**32b**	**3780a**	**1500b**
Twin Rows	**55a**	**51a**	**49a**	**3940a**	**2430a**

***Data are pooled over years and herbicide programs. Means followed by the same letter are not significantly different according to Fisher's Protected LSD test $p \leq 0.05$.**
[†]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 herbicide programs.
[‡]Means within a year followed by the same letter are not significantly different at $p \leq 0.05$. Data are pooled over herbicide programs.

Table 16. Influence of herbicide program on percent sicklepod control and yield*.

Herbicide Program†	Application method	Sicklepod Control‡				Pod yield§	
		Early August		Early September			
		2001	2002	2001	2002	2001	2002
		%				$kg\ ha^{-1}$	
Dimethenamid	PRE	5c	12b	0c	7b	210b	900c
Dimethenamid followed by Imazapic (HADSS)	PRE followed by POST	91a	77a	90a	62a	5100a	2480b
Dimethenamid plus Diclosulam	PRE plus PRE	35b	10b	29b	11b	4750a	1120c
Dimethenamid plus diclosulam followed by Imazapic (HADSS)	PRE followed by POST	91a	87a	92a	84a	5390a	3370a

*Abbreviations: HADSS, Herbicide Application Decision Support System; PRE, preemergence; POST, postemergence.
†Dimethenamid, imazapic, and diclosulam applied at 1.1, 0.07, and 0.027 kg ha^{-1}, respectively. Acifluorfen (0.28 kg ha^{-1}) plus bentazon (0.56 kg ha^{-1}) plus paraquat (0.14 kg ha^{-1}) applied over the entire test area at the cracking stage of peanut.
‡Means within a rating period and 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 planting patterns.
§Means within a year followed by the same letter are not significantly different according to Fisher's protected LSD at $p \leq 0.05$. Data are pooled over planting patterns.

Peanut Response to Inoculation and Nitrogen Fertilizer

ABSTRACT

Experiments were conducted from 2000 through 2002 in North Carolina to compare peanut response to inoculation with Bradyrhizobium and application of ammonium sulfate. In one study that included 17 trials, peanut pod yield was compared following no inoculation or with commercial granular or liquid in-furrow inoculants. In six of these experiments, pod yield of inoculated and non-inoculated peanut was determined following surface applications of ammonium sulfate 40 d after planting at rates of 0, 110, 340, 560, 780, and 1010 kg ha^{-1}. In a second study, peanut pod yield was compared in twin row planting patterns (two rows spaced 18 cm apart on 91-cm centers) when inoculant was applied in-furrow to one of the twin rows or to both of the twin rows. A no-inoculant control was included. In a third set of experiments, interactions of in-furrow inoculation and fumigation with metam sodium were compared. Peanut pod yield was higher following inoculation in 7 of 17 experiments. In 6 of the 7 experiments a positive response to inoculation was observed, peanut had not been previously grown in those fields Ammonium sulfate increased pod yield in 3 of 6 experiments, although the rate of ammonium sulfate needed to optimize yield varied by experiment. Inoculating both rows of peanut seeded in twin row patterns yielded higher in 2 of 4 experiments than when one of the twin rows was inoculated or when inoculant was not included. In the other two experiments peanut did not respond to inoculation. Fumigation with metam sodium did not affect pod yield, regardless of inoculation treatment.

Abbreviations: AMS (ammonium sulfate).

INTRODUCTION

Nitrogen is important element for all crops. Legume crops such as soybean [*Glycine max* (L.) Merr.] and peanut (*Arachis hypogaea* L.) are capable of symbiotic nitrogen fixation (SNF) with bacterial strains of *Rhizobium*, almost eliminating the need for nitrogen fertilizer. Although positive response to *Rhizobium* inoculant was observed for peanut (Schiffman and Alper, 1968; Shimshi et al., 1967), yield response is typically not observed when peanut is planted in fields that have been in a regular peanut rotation (Reid and Cox, 1973; Walker et al., 1976).

Legume response to nitrogen fertilization has been inconsistent (Huber, 1956; Walker and Ethredge 1974). The most consistent responses to nitrogen fertilization have been obtained in studies where the soil conditions were not suitable for nodulation of peanut (Reid and Cox, 1973). Nitrogen fertilization has been shown to inhibit *Rhizobium* root hair infection and with nodule initiation, development, and function (Gibson, 1977). The lack of a yield response in soybean to nitrogen fertilization occurred because soil nitrogen replaced SNF (Allos and Bartholomew, 1955; Weber, 1966).

Variable response of peanut to nitrogen fertilizer has been attributed to differences in edaphic and environmental conditions, as well as managerial decisions (Reedy et al., 1981). Although little or no response by peanut to nitrogen fertilization has been reported (Collins, 1942), Gore (1956) reported a pod yield increase of 450 kg ha^{-1} with nitrogen fertilization compared to non-treated peanut.

Cylindrocladium black rot (CBR) (caused by the *Cylindrocladium parasiticum*) is a soil borne disease which is found in most peanut production counties in North Carolina. Soil fumigation with metam sodium is used to control CBR, however, it is suspected by producers that metam sodium may reduce the amount of viable *Rhizobium* in the soil resulting in poor nodulation.

Although the majority of peanut in the United States is seeded in single rows spaced 91 to 100 cm apart, research suggests that seeding peanut in standard twin row planting patterns (rows spaced approximately 18 cm apart with centers of these rows spaced 91 to 100 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, twice as much insecticide and inoculant are need to adequately control insects and promote peanut growth. It is suspected that applying inoculant in just one of the two seed rows could result in poor nodulation in twin row planting pattern. However, growers attempting to reduce production costs question whether or not both of the twin rows require inoculation.

Determining interactions of inoculation with fumigants and peanut response to application of ammonium sulfate will assist growers and their advisors enhance or improve efficient production practices for peanut. Also, determining yield advantages occur of applying in-furrow inoculant to fields that have had peanuts previously could help reduce production cost by defining which fields need inoculation. Therefore, research was conducted to compare peanut pod yield when peanut was planted using combinations of inoculants and fumigants, inoculants and ammonium sulfate, and interactions of inoculants and planting patterns.

MATERIALS AND METHODS

Comparison of Inoculated and Non-inoculated Peanut

Experiments were conducted in North Carolina in grower fields located near Bladenboro (2001), Tarboro (2001), Williamston (2001), and Sunbury (2000 through 2002). Experiment were also conducted in North Carolina at the Peanut Belt Research Station located near Lewiston-Woodville (2000 through 2002), at the Upper Coast Plain Research Station located near Rocky Mount (2001 and 2002), and at the Cherry Research Unit located near Goldsboro (2002). Soil at Bladenboro was a Norfolk sandy loam (fine-loamy, siliceous, thermic Aquic Paleudalts), at Rocky Mount and Tarboro was a Goldsboro sandy loam (fine-loamy, mixed, thermic Aquic Paleudalts), at Lewiston-Woodville and Tarboro was a Norfolk sandy loam and at Sunbury was a Pantego fine sandy loam (fine-loamy, siliceous, thermic Umbric Paleaquults). A Wickham sandy loam (fine-loamy, mixed, semiactive, thermic Typic Hapludults) with 1.8 % organic matter and pH 6.2 was present at Goldsboro. With the exception of Lewiston-Woodville, where the cultivar VA 98R was used, all experiments were planted with NC-V 11. Peanut was seeded to achieve a final in-row plant population of 13 plants m^{-1}. Plot size was 2 rows (91-cm spacing) by 9 m. Three other crops, either cotton (*Gossypium hirsutum* L), corn (*Zea mays* L.), or tobacco (*Nicocianna tobaccum* L.), were planted between the current and previous peanut crops at Bladenboro, Tarboro, and Williamston. Four crops separated peanut crops at Rocky Mount, however only two non-peanut crops were planted between peanut crops at Lewiston-Woodville. Peanut had never been planted in fields at Sunbury or Goldsboro.

Treatments consisted of no in-furrow inoculant or the in-furrow inoculant Rhizo-Flo®

(Uarbna Laboratories, PO Box 1393, 310 South Third Street, St. Joseph, Missouri 64502) at 7.8 kg ha^{-1} or Lift®, (Nitragin Corp) at 1.1 L ha^{-1}. Rhizo-Flo® was applied at Williamston, Tarboro, Lewiston-Woodville, and Rocky Mount. Lift® was applied at the other locations. These rates of Rhizo-Flo® and Lift® deliver 60.5×10^{11} viable cells of bacteria ha^{-1} and 2.2×10^{11} viable cells of bacteria ha^{-1}, respectively. Aldicarb (*O*,*S*-dimethylacetylphosphoramidothioate) was applied in the seed furrow 7.8 kg ai ha^{-1} at all locations for early season pest. All other production and pest management practices were held constant over the entire test area and were based on North Carolina Cooperative Extension Service recommendations.

The experimental design was a randomized complete block with treatments replicated four times. Peanut was dug and vines inverted in early October of both years and pods were harvested 4 to 7 days after digging. No attempt was made to determine maturity based on pod mesocarp color determination (Williams and Drexler, 1981). Data for pod yield were subjected to analysis of variance appropriate for the two (inoculation) by ten (experiment) factorial treatment 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 effects (McIntosh, 1982).

Peanut Response to Inoculation in Twin Row Planting Patterns

The experiment was conducted during 2000 and 2001 at a private farm located near Sunbury and at the Peanut Belt Research Station located near Lewiston-Woodsville, NC. Soil at Gatesville and Lewiston-Woodville was a Pantego fine sandy loam and Norfolk sandy loam, respectively. The peanut cultivar NC-V 11 was seeded in conventionally prepared seedbeds in a standard twin row planting patterns with in-row plant population of 15 seed m^{-1}-row at both locations. Plot size was 2 rows by 9 m long. The previous crop at Sunbury was cotton, and peanut had never been planted in these fields. At Lewiston-Woodville, the previous crop was corn in 2000 and cotton in 2001. Peanut was planted in the field three years earlier at Lewiston-Woodville.

Treatments consisted no inoculant in either seed row of the twin row planting pattern, Lift® at 0.67 and 1.1 L ha^{-1} in both rows of the twin row planting pattern, and Lift® at 1.1 L ha^{-1} in one row of the twin row planting pattern. Aldicarb was applied in the seed furrow at 7.8 kg ha^{-1} in each of the twin rows for early season pest control. All other production and pest management inputs were common across the entire test area and were based on North Carolina Cooperative Extension Service recommendations.

The experimental design was a randomized complete block with treatments replicated four times. Peanut was dug and pods harvested as described previously. Data for pod yield were subjected to analysis of variance appropriate for a four (experiment) by four (inoculant treatment) factorial arrangement of treatments. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$.

Peanut Response to Inoculation and Fumigation

Experiments were conducted during 2001 and 2002 at the Peanut Belt Research Station located near Lewiston-Woodville, NC on the Norfolk sandy loam soil described previously. The peanut cultivar Gregory was planted in conventionally prepared seedbeds in plots with 4 rows (91-cm spacing) by 9 m long. The final in-row plant population was 10 plants m^{-1}. Two crops of corn separated peanut crops during both years.

Treatments consisted of two levels of fumigation (no fumigation or 93 L ha^{-1} metam sodium) and two levels of inoculant (no inoculant or Rhizo-Flo® at 7.8 kg ha^{-1} applied in the seed furrow). Fumigation was applied during the bedding process approximately 2 wk before planting. Fumigant was injected 20 to 25 cm below seed placement. Aldicarb was applied in the seed furrow as described previously for early season pest control. All other production and pest management inputs were common across the entire test area and were based on North Carolina Cooperative Extension Service recommendations.

The experimental design was a randomized complete block with treatments replicated 4 times. Peanut pods were harvested as described previously. Data for pod yield were subjected to analysis of variance appropriate for a two (year) by two (fumigation treatment) by two (inoculant treatment) factorial treatment arrangement. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$.

Peanut Response to Inoculation and Ammonium Sulfate

Experiments were conducted in North Carolina at the Peanut Belt Research Station located near Lewistion-Woodville (2001), the Upper Coastal Plain Research Station located near Rocky Mount (2001), the Cherry Research Unit located near Goldsboro (2001), the Tobacco Border Belt Research Station located near Whiteville (2002), and on a private farm located near Sunbury (2001 and 2002). Soils at Goldsboro, Lewiston-Woodville, Rocky Mount, and Sunbury were similar to those described previously. Soil at Whiteville was a Norfolk fine sandy loam (fine loamy, siliceous, thermic Typic

Paleudults). Plot size was 2 rows (91-cm spacing) by 9 m. The cultivar NC-V 11 was seeded at all locations except Lewiston-Woodville (cultivar VA 98R) at a rate designed to achieve a final in-row plant population of 12 plants m^{-1}.

Treatments consisted of two levels of inoculation (no inoculation or in-furrow inoculation) and six levels of ammonium sulfate (AMS) applied to the soil surface approximately 40 days after planting (0, 110, 340, 560, 780, and 1010 kg ha^{-1}). The in-furrow inoculant Lift® at 1.1 L ha^{-1} was applied in-furrow at Sunbury. The in-furrow inoculant Rhizo-Flo® at 7.8 kg ha^{-1} was applied in the seed furrow at the other locations. Aldicarb was applied in the seed furrow as described previously for early season pest control. All other production and pest management inputs were common across the entire test area and were based on North Carolina Cooperative Extension Service recommendations.

The experimental design was a randomized complete block with treatments replicated four times. Peanut pods were dug and harvested as described previously. Data for peanut pod yield were subjected to analysis of variance appropriate for a six (experiments) by two (inoculation treatment) by six (AMS rates) 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, quadratic, and cubic functions for peanut pod yield versus rate of AMS rate ($p \leq 0.05$) based on results from the factorial analysis.

RESULTS AND DISCUSSION

Comparison of Inoculated and Non-inoculated Peanut

The interactions of experiment by inoculant treatment was significant ($p = 0.0001$) for peanut pod yield. When comparing individual experiments, differences were noted between non-inoculated and inoculated peanut at Sunbury in 2000 and 2001 and at Rocky Mount (Table 1). Inoculation increased pod yield by 3040, 2770 and 490 kg ha^{-1} at these respective locations. Pod yield was 520 kg ha^{-1} higher ($p = 0.0697$) at Badenboro when peanut was inoculated compared with non-inoculated peanut. Numerical differences in yield comparing inoculated and non-inoculated peanut ranged from 100 to 440 kg ha^{-1} at Sunbury and Lewiston-Woodville in 2002 and at Williamston and Goldsboro. A numerical decrease in pod yield of 100 to 240 kg ha^{-1} were noted at Lewiston-Woodville in 2000 and 2001 and at Tarboro. The positive response to inoculation was expected at Sunbury in 2000 and 2001 because peanut had never been grown in these fields prior to these experiments. However, lack of response in 2002 at this location and at Goldsboro was not expected because peanut had not previously been grown in either these fields. Additionally, a positive response to inoculation was noted at Rocky Mount in 2002, a field that had peanut present five years earlier. Lack of response at Lewiston-Woodville, Tarboro, and Williamston was expected because of the relatively short rotation between peanut crops in those fields. Previous research (Reid and Cox, 1973; Walker et al., 1976) reported inconsistent response of peanut to inoculation, which our data confirms.

Peanut Response to Inoculation in Twin Rows

The interaction of experiment by inoculation treatment was significant for pod yield ($p = 0.0001$). When analyzed by experiment, the main effect of inoculation treatment affected pod yield at Sunbury in 2000 and 2001 ($p = 0.0049$ and 0.0001, respectively). At Lewiston-Woodville, pod yield was not affected during either year.

Pod yield ranged from 4540 to 4940 kg ha^{-1} in 2000 and 3100 to 3700 kg ha^{-1} in 2001 at Lewiston-Woodville, though these differences were not significant (Table 2). In contrast, pod yield significantly increased when peanut was inoculated at Sunbury during both years. In 2000, pod yield was higher when Lift® was applied at 1.1 L ha^{-1} under each of the twin rows compared with application of Lift® at 0.67 L ha^{-1} under one or both of the twin rows. In 2001, inoculation under both of the twin rows increased yield over non-inoculated peanut or when only one of the twin rows was inoculated. In contrast to results in 2000, pod yield following inoculation of Lift® at the lower rate, 0.67 Lha^{-1}, exceeded that of peanut inoculated at the higher rate of 1.1 kg ha^{-1}. The reason for this difference among rates could not be explained. A positive yield response to inoculation was expected at Sunbury because peanut had never been grown in these fields. Also as expected, peanut had been planted in fields at Lewiston-Woodville in previous years, and this most likely established sufficient inoculum to limit response to in-furrow inoculation. These data suggest that in fields where peanut have not been planted in previous years, inoculation under each of the twin rows is necessary to optimize pod yield.

Peanut Response to Inoculation and Fumigation

The interaction of year by inoculation treatment by fumigation treatment was not significant for peanut pod yield ($p = 0.7010$) (Table 3). Additionally, main effects of inoculation and fumigation were not significant (Table 3). Pod yield in 2001 and 2002 averaged 5060 and 4360 kg ha^{-1}, respectively, when pooled over inoculant and fumigation treatments (data not presented). These data suggest that fumigation does not affect *Rhizobium* inoculant and will not cause a pod yield reduction due to poor inoculation.

Peanut Response to Inoculation and Nitrogen Fertilization

The interaction of experiment by inoculation by AMS rate was not significant for peanut pod yield ($p = 0.8204$) nor was the interaction of inoculation by AMS rate was not significant ($p = 0.7194$) (Table 4). However, main effects of experiment ($p = 0.0001$), inoculation ($p = 0.0001$), and AMS rate (0.0014) were significant for pod yield as was the interaction of experiment by AMS rate was also significant ($p = 0.0109$).

When pooled over AMS rates, pod yield increased in 4 of 6 experiments (Table 5). At Sunbury in 2001 and Lewiston-Woodville, pod yield was not affected by inoculation. In contrast, pod yield was 1370, 1020, 250, and 410 kg ha^{-1} higher when peanut was inoculated at Sunbury in 2001, Goldsboro, Rocky Mount, and Whiteville, respectively. These data suggest that applying nitrogen does not adversely affect peanut response to inoculation.

The linear function of pod yield (kg ha^{-1}) versus AMS rate was significant at Sunbury in 2001 ($p = 0.0001$; $r^2 = 0.29$) and 2002 ($p = 0.0514$, $r^2 = 0.06$) and at Goldsboro ($p = 0.0001$; $r^2 = 0.30$) (Table 6). Pod yield increased linearly as AMS rate increased in these experiments (Table 6). Lack of significant quadratic and cubic functions suggest that higher rates of AMS than those applied in these experiments may have increased yield above the maximums observed. Additional research is needed to determine if yield increases continue above the rates applied in these experiments. Yield responses at Sunbury during both years and at Goldsboro were expected because these fields did not have peanut planted in them during previous years.

SUMMARY

Collectively, these data suggest that peanut will not always respond to inoculation of *Rhizobium*. These data also suggest peanut response to inoculation at planting and AMS applied after planting affect peanut independently. Peanut pod yield appeared to increase with increasing rates of nitrogen fertilizer even though peanut was inoculated. This demonstrates that peanut have a high nitrogen demand to produce high yields, and may not be able to fix enough nitrogen through SNF. Fumigation did not affect inoculation sufficiently to reduce pod yield. Inoculating both rows in twin row planting patterns was needed when peanut are seeded in fields where inoculum is not present.

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Table 1. Peanut pod yield as influenced by in-furrow inoculation.

Inoculant	Sunbury			Lewiston-Woodville			Rocky Mount	Bladen-boro	Golds-boro	Tar-boro	William-ston
	2000	2001	2002	2000	2001	2002					
	kg ha^{-1}										
No	1540	2160	2950	4850	3790	2860	4020	3080	3880	5390	5560
Yes	4580	4900	3390	4610	3570	3140	4510	3600	4220	5290	5660
LSD (0.05)	*	*	NS	NS	NS	NS	*	NS	NS	NS	NS

[*]Indicates significance at $p \leq 0.05$.

Table 2. Pod yield as influenced by inoculant rate and placement in twin rows.

Lift® rate	Placement in twin rows	Lewiston-Woodville 2000	Lewiston-Woodville 2001	Sunbury 2000	Sunbury 2001
L ha^{-1}		kg ha^{-1}			
0	Both twins	4940a	3100a	3500c	2340d
0.67	Both twins	4890a	3700a	4160b	5800a
1.1	Both twins	4540a	3420a	4530a	5290b
1.1	One twin	4940a	3450a	4100b	4490c

*Means within a year and location followed by the same letter are not significantly different according to Fisher's Protected LSD test ($p \leq 0.05$).

Table 3. Analyses of variance (p-values) for pod yield as influenced year, fumigation, and in-furrow inoculation.

Source	Yield
	p-value
Year	0.0350
Inoculation	0.5635
Year by Inoculation	0.9717
Fumigation	0.2815
Year by Fumigation	0.2478
Inoculation by Fumigation	0.1647
Year by Inoculation by Fumigation	0.7010
Coefficient of Variation	13.6

Table 4. Analyses of variance (p-values) for pod yield as influenced by inoculant and AMS rate.

Source	Pod yield
	p-value
Experiment	0.0001
Inoculant	0.0001
Experiment by Inoculant	0.0001
AMS rate	0.0014
Experiment by AMS rate	0.0109
Inoculant by AMS rate	0.7194
Experiment by Inoculant by AMS rate	0.8204
Coefficient of Variation	10.5

Table 5. Pod yield as influenced by in-furrow inoculation.

Inoculation	Sunbury 2001	Sunbury 2002	Goldsboro	Lewiston-Woodville	Rocky Mount	Whiteville
			kg ha^{-1}			
No	4830	3500	4210	4900	3300	5560
Yes	5460	3490	5240	4940	3550	5970
LSD (0.05)	*	NS	*	NS	*	*

*Indicates significance at $p \leq 0.05$. Data are pooled over AMS rates.

Table 6. Regression analyses (p-values) for pod yield versus AMS rates.

Location	Year	Linear p-value	Regression equation	AMS Rate Estimates (kg ha^{-1}) 0	110	340	560	780	1010
Goldsboro	2001	0.0001	$Y = 1.248X + 4141, r^2 = 0.30$	4140	4280	4560	4840	5120	5400
Lewiston-Woodville	2001	0.6536	$Y = -0.075X + 4956, r^2 = 0.01$	4960	4950	4930	4920	4900	4880
Rocky Mount	2001	0.1086	$Y = 0.314X + 3328, r^2 = 0.06$	3330	3370	3450	3530	3600	3680
Sunbury	2001	0.0001	$Y = 0.955X + 4409, r^2 = 0.29$	4410	4520	4730	4950	5160	5370
Sunbury	2002	0.0514	$Y = 0.419X + 3237, r^2 = 0.08$	3240	3280	3380	3470	3570	3660
Whiteville	2002	0.0655	$Y = 0.376X +5592, r^2 = 0.07$	5590	5630	5720	5800	5890	5970