PEANUT

Peanut Response to Inoculation and Nitrogen Fertilizer

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ABSTRACT

Experiments were conducted from 2000 through 2003 in North Carolina to compare peanut (*Arachis hypogaea* L.) response to inoculation with *Bradyrhizobium*. In one study that included 20 experiments, peanut pod yield was compared following no inoculation or inoculation with commercial granular or liquid in-furrow products. In six of these experiments, inoculant was also applied to the seed before planting. In six other experiments within this study, pod yield of inoculated and noninoculated peanut was determined following surface applications of N approximately 40 d after planting. 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. In a third study, interactions of in-furrow inoculation and fumigation with metam sodium were compared. Peanut pod yield was higher following inoculation in 7 of 20 experiments. In six of the seven experiments where a yield response to inoculation was observed, peanut had not been planted previously in these fields. In experiments where peanut responded positively to inoculant, pod yield was higher when inoculant was applied in the seed furrow rather than to seed before planting. Nitrogen increased pod yield linearly in three of six experiments ($p \leq 0.05$). Inoculating both rows of peanut seeded in twin row patterns yielded higher in two of four 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.

Nitrogen is an 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 *Rhizobium*, almost eliminating the need for N fertilizer. Although yield increases following inoculation were 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 rotated regularly with peanut (Reid and Cox, 1973; Walker et al., 1976).

Legume response to N fertilization has been inconsistent (Huber, 1956; Walker and Ethredge, 1974; Trostle and Long, 2003, 2004). The most consistent responses to N 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 root hair infection and nodule initiation, development, and function (Gibson, 1977). Lack of a yield response in soybean to N fertilization occurred because soil N replaced SNF (Allos and Bartholomew, 1955; Weber, 1966). Variable response of peanut to N fertilizer has been attributed to differences in edaphic and environmental conditions, as well as managerial decisions (Reddy et al., 1981). Although little or no response by peanut to N fertilization has been reported (Collins and Morris, 1942), Gore (1956) reported a pod yield increase of 450 kg ha^{-1} with N fertilization compared with nontreated peanut. Growers may need to apply N fertilizers because inoculants do not perform under environmental and edaphic conditions that minimize survival of bacteria in the field or because bacteria are improperly handled or stored before planting peanut. Additionally, peanut is grown on soils that are sandy and contain low levels of residual N and limited early season growth. A positive response in vegetative growth early in the season following N application may benefit peanut before establishment of the SNF process.

Cylindrocladium black rot (CBR) (caused by the *Cylindrocladium parasiticum*) 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 *Bradyrizobium* in the soil resulting in poor nodulation. This issue has not been resolved in the literature.

Although the majority of peanut in the USA is seeded in single rows spaced 91 to 100 cm apart, research indicates 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 of peanut (Jordan et al., 2001; Hurt et al., 2003). However, twice as much insecticide is needed to adequately control insects and promote peanut growth in twin row planting patterns compared with peanut plant in single rows. It is suspected that applying inoculant in just one of the two seed rows could result in poor nodulation in twin row planting patterns. However, growers attempting to reduce production costs question whether or not both of the twin rows require inoculation.

Recent changes in federal farm legislation have resulted in movement of peanut production to other regions where peanut has never been grown (Brown, 2004). Determining interactions of inoculation with fumigants and peanut response to application of N will assist growers and their advisors develop efficient production practices for peanut. Also, determining if yield advantages occur when applying in-furrow inoculant to fields that

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Abbreviations: SNF, symbiotic nitrogen fixation.

have had peanut previously could help reduce production cost by defining which fields need inoculation. Therefore, research was conducted to compare pod yield when peanut was planted using combinations of inoculants and fumigants, inoculants and N, and interactions of inoculants and planting patterns.

MATERIALS AND METHODS

Comparison of Inoculated and Noninoculated Peanut

Experiments were conducted in North Carolina in grower fields located near Bladenboro (2001), Burgaw (2003), Sunbury (2000–2002), Tarboro (2001), and Williamston (2001). The experiment was also conducted in North Carolina at the Peanut Belt Research Station located near Lewiston-Woodville (2000–2003), 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, Burgaw, Lewiston-Woodville, Tarboro, and Williamston was a Norfolk sandy loam (fine-loamy, siliceous, thermic Aquic Paleudalts). Soil at Rocky Mount and Tarboro was a Goldsboro sandy loam (fine-loamy, mixed, thermic Aquic Paleudalts). Soil 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) was present at Goldsboro. With the exception of Lewiston-Woodville from 2000 through 2002, where the cultivar VA 98R was present, the cultivar NC-V 11 was planted. 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 with no border rows between experimental units. Three other crops—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. Only two non-peanut crops were planted between peanut crops at Lewiston-Woodville. Producers at Burgaw, Goldsboro, and Sunbury indicated that peanut had not been planted in these fields in recent memory.

Treatments in all experiments consisted of no in-furrow inoculant or the in-furrow inoculant Rhizo-Flo (Urbana Laboratories, 310 South Third Street, St. Joseph, MO 64502) at 7.8 kg ha^{-1} or Lift (Nitragin Corp., 13100 West Lisbon Rd, Suite 600, Brookfield, WI 53005) 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 7.8×10^{11} viable cells of bacteria (*Bradyrhizobium* sp.) ha^{-1} and 2.2×10^{12} viable cells of bacteria ha^{-1}, respectively. Additional treatments at Burgaw, Lewiston-Woodville in 2000 and 2003, Rocky Mount in 2001, and Sunbury in 2000 and 2002 included application of humus-based inoculant (Peanut-Stick, Becker Underwood, 801 Dayton Ave., Ames, IA 50010) directly to seed before planting at 10 g kg^{-1} seed. This rate of inoculant delivers approximately 2.7×10^{11} viable cells of bacteria ha^{-1} when applied with seed at the seeding rate and row spacing used in these experiments. Rates for the three inoculant formulations are consistent with those recommended by manufacturers. Aldicarb (*O*, *S*-dimethylacetylphosphoramidothioate) was applied in the seed furrow 7.8 kg a.i. ha^{-1} at all locations. A split applicator box mounted behind the hopper box containing seed was used to apply the granular insecticide aldicarb and the in-furrow inoculant Rhizo-Flo. The aldicarb and inoculant were partitioned in the applicator box but were delivered in the same tube extending to the seed furrow. Aldicarb was applied in the same manner when the in-furrow inoculant Lift was sprayed in the seed furrow. Aldicarb and inoculant were applied following seed drop but before closure of the seed furrow with a press wheel. Lift was applied in water at 19 L ha^{-1} using a regular flat fan spray nozzle. 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 late September or early October. No attempt was made to determine pod maturity among treatments based on pod mesocarp color (Williams and Drexler, 1981). Pods were harvested 4 to 7 d after digging and vine inversion. Data for pod yield were subjected to analysis of variance appropriate for the 2 (inoculation) $\times$ 14 (experiment) factorial treatment arrangement. An additional analysis of variance was performed for the experiments that included application of inoculant directly to seed before planning appropriate for a 3 (inoculant treatment) $\times$ six (experiment) 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 effects (McIntosh, 1982).

Peanut Response to Inoculation and Nitrogen

Experiments were conducted in North Carolina at the Peanut Belt Research Station located near Lewistion-Woodville (2002), the Upper Coastal Plain Research Station located near Rocky Mount (2002), 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. 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}. Peanut had not been planted in previous years at Goldsboro, Sunbury, and Whiteville. Two crops other than peanut separated peanut crops at Lewiston-Woodville, and five non-peanut crops separating planted before peanut at Rocky Mount.

Treatments consisted of two levels of inoculation (no inoculation or in-furrow inoculation) and six levels of N as ammonium sulfate (21% N, 0% P_2O_5, 0% K_2O, 23% S) rate applied to the soil surface approximately 40 d after planting (0, 23, 70, 115, 160, and 210 kg ha^{-1}). Peanut leaves at some of the locations were beginning to show signs of N deficiency 40 d after planting. 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. 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 6 (experiment) $\times$ 2 (inoculation treatment) $\times$ 6 (N rates) factorial arrangement of treatments. 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

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

Inoculant	Bladenboro	Goldsboro	Lewiston-Woodville 2001	Lewiston-Woodville 2002	Rocky Mount, 2002	Sunbury, 2001	Tarboro	Williamston
	kg ha^{-1}							
No	3080	3880	3790	2860	4020	2160	5390	5560
Yes	3600	4220	3570	3140	4510	4900	5290	5660
Years between peanut crops	3	NP†	2	2	4	NP	3	3
LSD(0.05)	NS	NS	NS	NS	*	*	NS	NS

* Indicates significance at $p \leq 0.05$.
† NP = no historical evidence of peanut planted in previous years.

yield vs. N rate ($p \leq 0.05$) based on results of the factorial analysis.

Peanut Response to Inoculation in Twin Row Planting Patterns

The experiment was conducted during 2000 and 2001 in North Carolina on a private farm located near Sunbury and at the Peanut Belt Research Station located near Lewiston-Woodsville. Soil at Sunbury 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 (twin rows spaced 18 cm apart on 91-cm centers) with in-row plant population of 15 seed m^{-1} at both locations. Plot size was 2 rows (91-cm spacing) 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 3 yr earlier at Lewiston-Woodville.

Treatments consisted of 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. 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 4 (experiment) × 4 (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. 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 harvested as described previously. Data for pod yield were subjected to analysis of variance appropriate for a 2 (year) × 2 (fumigation treatment) × 2 (inoculant treatment) factorial treatment arrangement. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Comparison of Inoculated and Noninoculated Peanut

The interaction of experiment × inoculant treatment (no inoculation vs. in-furrow inoculation) was significant ($p = 0.0001$) for peanut pod yield when all 14 experiments were included. Additionally, the interaction of experiment by inoculation treatment was also significant ($p = 0.0001$) in the analysis where all three inoculation treatments were included (six experiments). When comparing individual experiments, differences were noted between noninoculated and in-row inoculated peanut at Rocky Mount in 2002 and Sunbury in 2001 (Table 1) and at Burgaw in 2003 and Sunbury in 2000 (Table 2). The increase in pod yield following inoculation ranged from 490 to 3760 kg ha^{-1} in these experiments. Pod yield was 520 kg ha^{-1} higher ($p = 0.0697$) at Badenboro when peanut was inoculated compared with noninoculated peanut. Numerical differences (statistically nonsig-

Table 2. Peanut pod yield as influenced by in-furrow inoculation.*

Inoculant	Burgaw	Lewiston-Woodville 2000	Lewiston-Woodville 2003	Rocky Mount, 2001	Sunbury 2000	Sunbury 2002
	kg ha^{-1}					
None	3090 c	4850 a	5800 a	4860 a	1540 c	3360 a
Seed furrow	6850 a	4610 a	5670 a	4790 a	4580 a	3370 a
Directly to seed	5610 b	4820 a	5750 a	4910 a	3670 b	3250 a
Years between peanut crops	NP†	2	2	4	NP	NP

* Means within a year and location followed by the same letter are not significantly different according to Fisher's Protected LSD test ($p \leq 0.05$).
† NP = no historical evidence of peanut planted in previous years.

nificant) in yield comparing inoculated and noninoculated peanut ranged from 100 to 440 kg ha^{-1} at Sunbury and Lewiston-Woodville in 2002 and at Williamston and Goldsboro. A numerical (statistically nonsignificant) decrease in pod yield of 100 to 240 kg ha^{-1} was noted at Lewiston-Woodville in 2000 and 2001 and at Tarboro. A positive response to inoculation was expected at Burgaw in 2003 and at Sunbury in 2000 and 2001 because peanut had never been grown in these fields before these experiments. However, lack of response in 2002 at Sunbury and at Goldsboro was not expected because peanut had never been grown in these fields. Additionally, a positive response to inoculation was noted at Rocky Mount in 2002, a field that had peanut present 5 yr 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.

At Burgaw and at Sunbury in 2000, pod yield was 910 and 1240 kg ha^{-1} higher when inoculant was applied in the seed furrow rather than to the seed before planting (Table 2). At Lewiston-Woodville in 2000 and 2003 and at Rocky Mount in 2001 pod yield was similar for these two treatments; however, peanut did not respond to either inoculation treatment in these experiments. Higher yields following inoculation in the seed furrow compared with seed treatment may have resulted from greater uniformity of application for in-furrow application compared with application to seed. Peanut plants were uniformly green when inoculant was applied in the seed furrow. In contrast, although many of the peanut plants were green in plots where inoculant was applied to seed, some plants expressed a N deficiency. It is suspected that application to seed does not uniformly distribute inoculant as well as in-furrow application of inoculant. In addition to possible differences in uniformity among methods of application, a higher rate of viable cells of bacteria were delivered in the in-furrow granular and in-furrow spray treatments (2.2×10^{12} or 7.8×10^{11}) compared with the seed treatment (2.7×10^{11}). Fewer viable cells of bacteria delivered in the seed treatment may have contributed to lower pod yields with the seed treatment compared with in-furrow treatments. Trostle and Long (2004) reported that peanut yield with in-furrow application of granular or liquid inoculant exceeded that of peanut yield when inoculant was applied with to seed in the hopper box before planting.

Peanut Response to Inoculation and Nitrogen Fertilization

The interaction of experiment × inoculation × N rate was not significant for peanut pod yield ($p = 0.8204$). Additionally, the interaction of inoculation × N rate was not significant ($p = 0.7194$). However, main effects of experiment ($p = 0.0001$), inoculation ($p = 0.0001$), and N rate (0.0014) were significant for pod yield. The interaction of experiment by N rate was also significant ($p = 0.0109$).

When pooled over N rates, pod yield increased in three of six experiments following in-furrow inoculation (Table 3). At Goldsboro, Lewiston-Woodville, and Sunbury in 2002, pod yield was not affected by inoculation. In contrast, when pooled over N rates, pod yield was 250, 630, and 410 kg ha^{-1} higher when peanut was inoculated at Rocky Mount, Sunbury in 2001, and Whiteville, respectively. Positive response to inoculation was expected at Goldsboro, Sunbury during both years, and Whiteville where peanut had not been planted in previous years. However, response to inoculant expected at Goldsboro and Sunbury in 2002 but did not occur. Lack of response could not be explained. Residual N applied to previous crops may have remained in the soil and subsequently affected peanut response to inoculation.

The linear function of pod yield (kg ha^{-1}) vs. N rate was significant at Goldsboro ($p = 0.0001$; $r^2 = 0.30$), Sunbury in 2001 ($p = 0.0001$; $r^2 = 0.29$), Sunbury in 2002 ($p = 0.0514$; $r^2 = 0.08$), and Whiteville ($p = 0.0658$, $r^2 = 0.07$) when data were pooled over inoculated and noninoculated treatments (Table 4). Pod yield increased linearly as N rate increased in these experiments. Lack of significant quadratic and cubic functions suggest that higher rates of N than those applied in these experiments may have increased yield above the maximums observed. In a separate regression analysis using only noninoculated peanut when N was applied, significant linear functions were noted at Goldsboro ($p = 0.0539$, $r^2 = 0.16$), Rocky Mount ($p = 0.0500$, $r^2 = 0.05$), and Sunbury in 2001 ($p = 0.0001$, $r^2 = 0.61$) (Table 4). Pod yield of inoculated peanut without supplemental N exceeded that of predicted values for N rates of 210 and 160 kg ha^{-1} at Rocky Mount and Sunbury in 2001, respectively (Table 4). In contrast, pod yield was lower when peanut was inoculated and N was not applied at Goldsboro. Additional research is needed to more accurately define yield response to supplemental N and to determine the source of variation in response to both applied N and inoculation.

Table 3. Pod yield as influenced by in-furrow inoculation.

Inoculation	Goldsboro	Lewiston-Woodville	Rocky Mount 2001	Sunbury 2001	Sunbury 2002	Whiteville
	kg ha^{-1}					
No	4210	4900	3300	4830	3500	5560
Yes	4240	4940	3550	5460	3490	5970
LSD(0.05)	NS	NS	*	*	NS	*
Years between peanut crops	NP†	2	5	NP	NP	NP

* Indicates significance at $p \leq 0.05$. Data are pooled over N rates.
† NP = no historical evidence of peanut planted in previous years.

Table 4. Regression analyses (p values) for pod yield vs. N rate.

Location	Year	Linear	Regression equation	Yield estimates for corresponding N rates, kg ha^{-1} 0	23	70	115	160	210	Inoculated only
		p value		kg ha^{-1}						
Goldsboro	2001	0.0001	$y = 4.64x + 4410, r^2 = 0.30$	4410	4520	4730	4940	5150	5680	–
Lewiston-Woodville	2001	0.6483	$y = -0.368x + 4957, r^2 = -0.01$	4960	4950	4930	4920	4900	4880	–
Rocky Mount	2001	0.1072	$y = 1.708x + 3327, r^2 = 0.06$	3340	3370	3450	3520	3600	3690	–
Sunbury	2001	0.0001	$y = 1.366x + 4143, r^2 = 0.30$	4140	4280	4570	4840	5110	5410	–
Sunbury	2002	0.0514	$y = 1.010x + 3235, r^2 = 0.08$	3240	3280	3380	3470	3570	3660	–
Whiteville	2002	0.0658	$y = 1.817x + 5592, r^2 = 0.07$	5590	5630	5720	5800	5880	5970	–
Goldsboro	2001	0.0539	$y = 3.541x + 4492, r^2 = 0.16$	4500	4580	4740	4900	5060	5230	4390
Lewiston-Woodville	2001	0.4993	$y = -0.796x + 4979, r^2 = -0.02$	4980	4960	4920	4890	4850	4810	4990
Rocky Mount	2001	0.0500	$y = 1.581x + 3346, r^2 = 0.05$	3350	3380	3460	3530	3600	3670	3740
Sunbury	2001	0.0001	$y = 7.693x + 3464, r^2 = 0.61$	3460	3640	4000	4350	4710	5070	4930
Sunbury	2002	0.1818	$y = 2.101x + 3106, r^2 = 0.08$	3110	3160	3250	3350	3450	3540	3540
Whiteville	2002	0.1026	$y = 2.215x + 5349, r^2 = 0.12$	5350	5400	5500	5610	5710	5810	5600

Peanut Response to Inoculation in Twin Rows

The interaction of experiment × 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 2000 and 2001 ($p = 0.2080$ and 0.0672, respectively).

Pod yield ranged from 4540 to 4940 kg ha^{-1} in 2000 and 3100 to 3700 kg ha^{-1} in 2001 at Lewiston-Woodville (Table 5). In contrast, pod yield 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 noninoculated 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 L ha^{-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. Additionally, 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 also 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.

Table 5. Pod yield as influenced by inoculant rate and placement in twin rows.

Lift rate	Placement in twin rows	Lewiston-Woodville 2000	2001	Sunbury 2000	2001
L ha^{-1}		kg ha^{-1}			
0	Both twins	4940 a	3100 a	3500 c	2340 d
1.1	Both twins	4540 a	3420 a	4530 a	5290 b
0.67	Both twins	4890 a	3700 a	4160 b	5800 a
1.1	One twin	4940 a	3450 a	4100 b	4490 c
Years between peanut crops	–	3	3	NP†	NP

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

† NP = no historical evidence of peanut planted at that location in prior years.

Peanut Response to Inoculation and Fumigation

The interaction of year × inoculation treatment × fumigation treatment was not significant for peanut pod yield ($p = 0.7010$). Additionally, main effects of inoculation ($p = 0.5635$) and fumigation ($p = 0.2815$) were not significant. Pod yield in 2001 and 2002 averaged 5060 and 4360 kg ha^{-1}, respectively, when pooled over inoculant and fumigation treatments (data not presented). Although the number of nodules and health of nodules were not compared in these experiments, these data indicate that fumigation most likely will not affect *Bradyrhizobium* inoculant enough to cause a pod yield reduction in absence of commercial inoculation. This experiment was conducted in a peanut field with a history of peanut production. Additional research is needed to determine if a similar response would occur in fields without a history of peanut production.

SUMMARY

Collectively, these data reinforce that peanut will not always respond to inoculation of *Bradyrhizobium*. These data also indicate that peanut response to inoculation and AMS applied after planting can affect peanut independently. Peanut pod yield appeared to increase with increasing rates of N fertilizer even though peanut was inoculated. This demonstrates that peanut have a high N demand to produce high yields, and may not be able to fix enough N through SNF. Fumigation did not affect inoculation sufficiently to reduce pod yield. Inoculating both rows in twin row planting patterns was needed when peanut is seeded in fields where native inoculum is not present. Applying inoculant in the seed furrow is a more effective method than application to the seed when peanut is planted in fields where a commercial inoculant is needed.

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REFERENCES

Allos, H.F., and W.V. Bartholomew. 1955. Effect of available nitrogen on symbiotic fixation. Soil Sci. Soc. Am. Proc. 19:182–184.

Brown, A.B. 2004. 2004 outlook and situation. p. 1–13 *In* 2004 Peanut Information. North Carolina Coop. Ext. Service Publ. AG-331. North Carolina State Univ., Raleigh, NC.

Collins, E.R., and H.D. Morris. 1942. Soil fertility studies with peanuts. North Carolina Agric. Exp. Stn. Bull. 330:1–23.

Gibson, A.H. 1977. Influence of environment and managerial practices on the legume–*Rhizobium* symbiosis. *In* A treatise on nitrogen fixation: IV. Agronomy and ecology. p. 420–450. *In* A.H. Gibson (ed.) Wiley-Interscience Publ., New York.

Gore, W.R. 1956. Cultural and fertilization studies with peanuts. Georgia Exp. Stn. Bull. 209:1–19.

Huber, A. 1956. Some observation on the correlated influence of fertilizer on peanut yield and vegetative development of the plant. Plant Soil 8:126–131.

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

Jordan, D.L., J.B. Beam, P.D. Johnson, and J.F. Spears. 2001. Peanut response to prohexadione calcium in three seeding rate-row pattern planting systems. Agron. J. 93:232–236.

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

Reddy, V.M., J.W. Tanner, R.C. Roy, and J.M. Elliot. 1981. The effect of irrigation, inoculants and fertilizer nitrogen on peanut (*Arachis hypogaea* L.). II. Yield. Peanut Sci. 8:125–128.

Reid, P.H., and F.R. Cox. 1973. Soil properties, mineral nutrition and fertilizer practices. *In* C.T. Wilson (ed.) Peanuts: Culture and uses. A symposium. Am. Peanut Res. and Educ. Assoc., Stillwater, OK.

Schiffman, J., and Y. Alper. 1968. Effects of *Rhizobium*–inoculum placement on peanut inoculation. Exp. Agric. 4:203–208.

Shimshi, D., J. Schiffman, Y. Kost, H. Bielorai, and Y. Alper. 1967. Effects of soil moisture regime on nodulation of inoculated peanuts. Agron. J. 59:397–400.

Trostle, C.L., and S.K. Long. 2003. Is nitrogen fertilization of west Texas peanut justified? Proc. Am. Peanut Res. Educ. Soc. 35:74.

Trostle, C.L., and S.K. Long. 2004. Is double rate *Bradyrhizobium* inoculation in west Texas peanut justified? Proc. Am. Peanut Res. Educ. Soc. 36:(in press).

Walker, M.E., and J. Ethredge. 1974. Effects of N rate and application on Spanish peanut (*Arachis hypogaea* L.) yield and seed grade, N and oil. Peanut Sci. 1:45–47.

Walker, M.E., N.A. Minton, and C.C. Dowler. 1976. Effects of herbicides, a nematicide and *Rhizobium* inoculant on yield, chemical composition and nodulation of Starr peanuts (*Arachis hypogaea* L.). Peanut Sci. 3:49–51.

Weber, C.R. 1966. Nodulating and non-nodulating soybean isolines: II. Response to applied nitrogen and modified soil conditions. Agron. J. 58:46–49.

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