Yield of Peanut Genotypes Resistant to Root-Knot Nematodes[1]

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ABSTRACT

Yields of six runner-, two spanish-, and one virginia-type breeding lines of peanut with resistance to the root-knot nematode, *Meloidogyne arenaria,* were compared to yields of susceptible cultivars in nematode-infested and noninfested field plots in 1996. Pod yields of resistant runner-, virginia-, and one of the spanish-type breeding lines were 1.5 to 4 times greater ($P = 0.05$) than pod yields of the susceptible cultivars Florunner, NC-7, and Tamspan 90 in two nematode-infested fields. Final nematode population densities on most resistant breeding lines were lower ($P = 0.05$) than those on the susceptible cultivars. In the noninfested field, all but one runner- and the two spanish-type resistant breeding lines had pod yields that were not different from that of the susceptible cultivars. Yields of the resistant breeding lines ranged from 3890 to 5152 kg/ha in the noninfested field. In 1997, yields of three of the runner-type breeding lines were compared to the yields of Florunner and Tamrun 96 in three fields not infested with *M. arenaria*. In one field, no differences were observed in pod yield among the breeding lines and cultivars; in the second field the yield of two of the breeding lines were not different from the susceptible cultivars; and in the third field, only TP259-3-5 had pod yield equivalent to that of the susceptible cultivars. These data indicate that resistant runner-type genotypes with high yield potential have been developed, but additional breeding efforts are needed to develop nematode resistance in high yielding spanish- and virginia-type peanuts.

Key Words: *Arachis hypogaea*, host resistance, *Meloidogyne arenaria*.

The root-knot nematode, *Meloidogyne arenaria*, is widespread in the peanut production regions of the U.S. (7,9,13) and is responsible for substantial yield losses annually (6). Although no cultivar of peanut currently available is resistant to *M. arenaria*, genes for resistance to the nematode have been identified in several wild *Arachis* species (3, 8). Furthermore, these genes have been introgressed into genotypes cross-compatible with cultivated peanut (10, 11). We have used a backcross breeding program to incorporate genes for resistance to *M. arenaria* into runner-, spanish-, and virginia-type breeding lines of peanut. During this backcross program, selection of individuals for advancement has been based primarily on the level of nematode resistance, measured as nematode reproduction on individual plants in greenhouse tests (12). Secondary assessments have been based on subjective evaluations of plant and pod appearance. Herein we report on the yield potential and nematode resistance of selected lines from the fifth backcross generation.

Materials and Methods

Seed of F_3 individuals selected for resistance in the F_2 generation from the fifth backcross ($BC_5F_{2:3}$) of six runner-, two spanish-, and one virginia-type breeding lines, along with the cultivars Florunner, Tamspan 90, and NC 7 were planted in two row by 2.5 m long plots, with 0.91 m between rows, in a randomized complete block design at three locations in 1996. All plots were planted at a rate of 17 seeds per m of row. Two locations were commercial fields naturally infested with *M. arenaria* as determined by symptoms present on roots and pods of peanut crops grown in those fields in 1995. The third location was at the Texas A&M Univ. Agric. Res. and Ext. Center at Stephenville and was not infested with root-knot nematodes. The soils at each location were Windthorst fine sandy loams. There were three replications of each genotype at each of the nematode-infested fields and four replications at the noninfested site. Plots were maintained following standard cultural practices recommended for the region, except no soil applications of an insecticide or nematicide were made. All sites were irrigated to minimize the effects of

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drought stress.

Composite soil samples (15 to 20 cores, each 2.5-cm diam. and 25-cm deep) were collected from each plot immediately prior to harvest. Second-stage juveniles (J2) of *M. arenaria* were extracted from 500-cm^3 aliquots of each sample by elutriation (1) and centrifugation (5). Eggs were extracted from root fragments recovered during elutriation by treatment with 1.0% NaOCl (4). Nematode population densities were recorded as total eggs and J2 per 500 cm^3 soil.

All plots were harvested at 150 to 162 d after planting with an inverter-digger and left in the windrow to cure. Plot yields were dried, cleaned of soil and other debris, and weighed. At 7% moisture a 250-g sample was collected from the yield of each plot, and the standard USDA grade, without foreign material, was determined. The raw data were converted to percentages for statistical analyses.

To determine the amount of segregation for resistance in the nematode-resistant breeding lines, 50 seeds of each of four lines ($BC_5F_{2:4}$) that had the highest yields in 1996 were planted separately into 15-cm diam. pots filled with a washed sand-peat (6:1, v/v) potting mix. Ten additional pots were planted to the susceptible cultivar Florunner. Each pot was infested with 10,000 eggs of *M. arenaria* after expansion of the first true leaves. Nematode cultures were maintained on tomato, and inoculum was obtained by extraction of infected tomato roots with 0.5% NaOCl (4). At 8 wk after inoculation, the plants were harvested by washing soil from the roots with tap water, blotting the roots dry, and weighing. Nematode eggs were extracted from the roots with 1% NaOCl and counted. Plants that had fewer that 10% of the eggs per g roots than the mean number of eggs per g roots for Florunner were classified as resistant (12).

In 1997, three of the four nematode-resistant lines ($BC_5F_{2:4}$) with high yield and high levels of nematode resistance in the 1996 tests were planted in three nematode-free fields, along with the susceptible cultivars Florunner and Tamrun 96. The experimental design and plot size in 1997 were identical to tests in 1996, except with four replications of each genotype at each location. All three fields were irrigated to minimize the effects of drought stress. These tests were harvested at 148 to 156 d after planting. Yield and grade were determined as described for previously.

Data from field experiments were subjected to analysis of variance using the SAS (SAS Institute, Cary, NC) general linear model procedure. Treatment means were separated using least significant differences or Duncan's multiple range test. Nematode count data were log (X + 1) transformed prior to analysis with treatment means reported as actual counts.

Results

Nematode damage to the susceptible cultivars in the two nematode-infested fields in 1996 caused many plants of the susceptible cultivar to senscence prior to maturity, whereas the nematode-resistant lines maintained good vigor throughout the growing season (Fig. 1). No disease or pest problems, other than root-knot nematodes, were observed in either of the infested fields. Pod yield of the susceptible cultivars in the infested fields (Table 1) ranged from 17 to 49% of the yield in the noninfested field (Table 2). The runner-type breeding lines had yields that were 2.3 to 6.5 times greater ($P \leq 0.05$) than Florunner in nematode-infested field 1, and 3.2 to 4.0 times greater than Florunner ($P \leq 0.05$) in nematode-infested field 2 (Table 1). Similarly, yield of the virginia-type breeding line was 3.1 and 1.9 times greater ($P \leq 0.05$) than that of the susceptible cultivar NC 7 in infested fields 1 and 2, respectively. The spanish-type breeding lines had yields that were not different from Tamspan 90 in nematode-infested field 2 and only one line had a yield that was greater ($P \leq 0.05$) than Tamspan 90 in nematode-infested field 1 (Table 1). The SMK and 100 seed weights of the nematode-resistant breeding lines, except for one virginia market-type line, were equivalent to or greater than those of the susceptible cultivars in the nematode-infested fields (Table 1). The final nematode population density varied among peanut genotypes ($P \leq 0.05$), and the resistant lines generally had lower final population densities than the susceptible cultivars (Fig. 2). No other nematode species pathogenic to peanut was detected in test plots in fields 1 or 2.

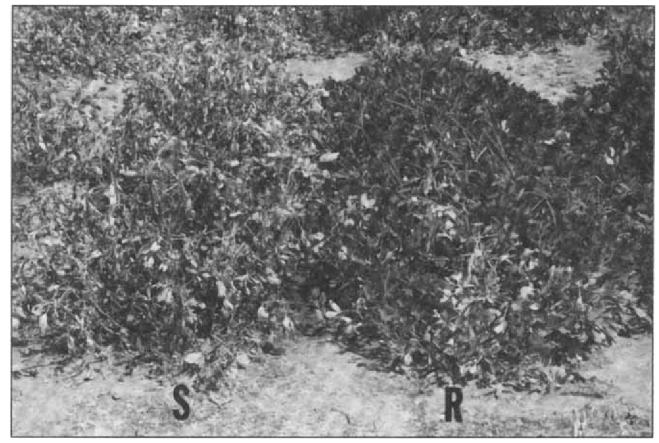

Fig. 1. Comparison of growth nematode-resistant breeding line TP262-3-5 (R) to that of the susceptible cultivar Florunner (S) at 120 d after planting in a field infested with *Meloidogyne arenaria* in 1996.

No pod or root gall symptoms were observed in the field not infested with *M. arenaria*. Yields of the runner- and virginia-type breeding lines in 1996 were not different ($P > 0.05$) from yields of the susceptible cultivars Florunner and NC 7 (Table 2) in this field. The SMK and 100 seed weight of the runner market types were not different from that of Florunner, whereas the SMK and 100 seed weight of the virginia market type line were 89.7 and 61.1%, respectively, of the values for NC 7. The pod yield of the two spanish market-type breeding lines was less than 70% of the yield of Tamspan 90 ($P \leq 0.05$), but the SMK and 100 seed weights were not different from those of Tamspan 90 ($P > 0.05$).

In greenhouse tests, resistance to *M. arenaria* was determined to be segregating in three of the breeding lines tested, since from 38 to 80% of the individuals supported nematode reproduction that was equal to or greater than 10% of the mean reproduction on Florunner (Fig. 3). The fourth line (TP262-3-5) had no individuals that were susceptible to *M. arenaria* based on numbers of eggs per g roots. In a second test of TP262-3-5, three of 50 individuals were susceptible and supported a level of nematode reproduction that was greater than 10% of the reproduction on Florunner (data not shown).

Table 1. Comparison of pod yield, sound mature kernals (SMK), and 100 seed weight of nine *Meloidogyne arenaria*-resistant peanut lines from the fifth backcross generation with that of three cultivars in two nematode-infested fields in 1996.[a]

Genotype	Market type	Pods		SMK		100 seed wt	
		Field 1	Field 2	Field 1	Field 2	Field 1	Field 2
		kg/ha		%		g	
TP262-3-5	Runner	3771 a	2976 a	68.3 a	67.7 abc	58 bc	57 ab
TP259-3-5	Runner	3196 ab	3114 a	68.0 a	67.0 ab	52 c	56 ab
TP273-3-1	Spanish	3057 ab	1090 cd	64.2 ab	54.4 d	45 d	46 cde
TP261-1-2	Runner	2705 ab	3204 a	65.8 ab	66.8 ab	52 c	49 bcd
TP271-2-5	Runner	2501 ab	2610 ab	68.6 a	59.5 bcd	58 b	54 b
TP260-1-9	Runner	2281 b	2295 abc	67.6 a	67.8 a	56 bc	52 bcd
TP269-1-10	Virginia	2688 ab	3101 a	56.6 cd	58.5 cd	58 b	63 a
TP273-3-2	Spanish	2119 bc	1625 bcd	67.7 a	66.1 abc	43 d	45 de
TP264-2-9	Runner	2143 bc	2526 ab	67.4 a	66.5 ab	56 bc	53 bc
Tamspan 90	Spanish	2027 bc	1467 bcd	59.5 bc	61.6 a-d	37 e	41 e
NC 7	Virginia	877 c	1643 bcd	51.6 d	64.4 ab	81 a	54 b
Florunner	Runner	914 c	794 d	51.5 d	61.1 a-d	46 d	50 bcd

[a]Values are means of three replications of plots having two 2.5-m long rows. Means within a column followed by the same letter(s) are not different at P = 0.05 based on Duncan's multiple range test.

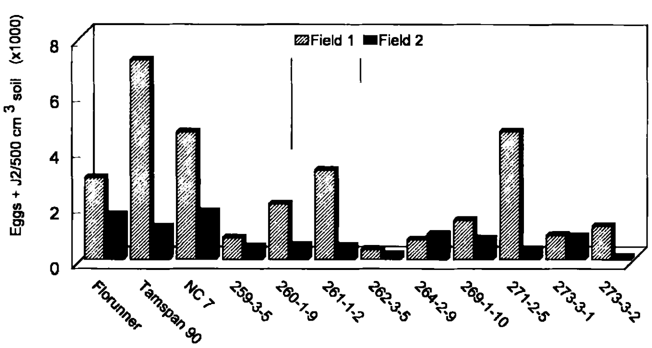

Fig. 2. Effects of peanut genotype on final population densities of *Meloidogyne arenaria* in field plots in 1996. Vertical lines under legend symbols represent $LSD_{0.05}$ values for each data set.

Based on yield in 1996 and the apparent level of resistance to nematode reproduction, three runner market-type breeding lines (TP259-3-5, TP261-1-2, and TP262-3-5) were tested for yield potential in 1997 in the absence of detectible levels of *M. arenaria*. In field 1, no difference in pod yield was observed between the resistant breeding lines and the susceptible cultivars ($P > 0.05$), whereas genotype did affect yield ($P \leq 0.05$) in the other two fields (Table 3). In field 2, TP262-35 had lower pod yield than did all other genotypes, and in field 3 both TP262-3-5 and TP261-1-2 had pod yields that were less than those of the susceptible cultivars.

In the absence of nematode parasitism, the nematode-resistant breeding lines were similar to the two susceptible cultivars with respect to SMK and 100 seed weight in 1997. Differences in SMK due to genotype ($P \leq 0.05$) were detected in only one of three fields, where Tamrun 96 and two breeding lines had SMK values lower than those for Florunner and the third breeding line (Table 3). Similarly, no consistent differences between the breeding lines and the susceptible cultivars were observed with respect to 100 seed weights. In field 1, genotype had no effect ($P > 0.05$) on 100 seed weight. One breeding line (TP259-3-5) had 100 seed weights that were lower ($P \leq 0.05$) than those of the susceptible cultivars in fields 2 and 3 (Table 3). Breeding lines TP261-1-2 and TP262-3-5 had 100 seed weights that were not different from that of Florunner in all three fields, and were different from Tamrun 96 only in field 2.

Table 2. Comparison of pod yield, sound mature kernals (SMK), and 100 seed weight of nine *Meloidogyne arenaria*-resistant peanut lines from the fifth backcross generation with that of three cultivars in a noninfested field in 1996.[a]

Genotype	Market type	Pod yield	SMK	100 seed wt
		kg/ha	%	g
TP259-3-5	Runner	5155 a	73.8 a	48 c
TP261-1-2	Runner	5011 ab	74.1 a	48 cd
TP260-1-9	Runner	4720 abc	73.5 a	51 bc
Florunner	Runner	4678 abc	73.6 a	51 bc
TP262-3-5	Runner	4484 abc	74.5 a	54 bc
TP264-2-9	Runner	4326 abc	71.9 a	49 c
TP269-1-10	Virginia	4571 abc	65.9 b	55 b
Tamspan 90	Spanish	4136 bc	73.0 a	37 e
NC 7	Virginia	3904 c	73.4 a	90 a
TP271-2-5	Runner	3890 c	71.4 a	51 bc
TP273-3-2	Spanish	2919 d	73.8 a	39 e
TP273-3-1	Spanish	2299 d	70.7 a	42 de

[a]Values are means of four replications of plots having two 2.5-m long rows. Means within a column followed by the same letter(s) are not different at P = 0.05 based on Duncan's multiple range test.

Discussion

Growing conditions for peanut were near ideal during 1996 and this was reflected in the relatively high yields of the susceptible cultivars and several nematode-

Table 3. Comparison of pod yield, sound mature kernals, (SMK), and 100 seed weight of three runner-type, *Meloidogyne arenaria*- resistant peanut lines from the fifth backcross generation with that of two cultivars in noninfested field plots in 1997.[a]

Genotype	Pod yield			SMK			100 seed wt		
	Field 1	Field 2	Field 3	Field 1	Field 2	Field 3	Field 1	Field 2	Field 3
	kg/ha			%			g		
TP259-3-5	2577 a	2870 a	2745 bc	67 b	70 a	70 a	50 a	53 b	49 b
TP261-1-2	2426 a	2910 a	2657 c	74 a	73 a	70 a	49 a	56 ab	54 a
TP262-3-5	1872 a	2198 b	2310 c	67 b	70 a	70 a	49 a	56 ab	57 a
Florunner	2520 a	3122 a	3248 b	71 a	70 a	73 a	48 a	55 ab	54 a
Tamrun 96	2078 a	3207 a	4064 a	68 b	70 a	73 a	50 a	60 a	56 a

[a]Values are means of four replications of plots having two 2.5-m rows. Means within a column followed by the same letter(s) are not different at P = 0.05 based on Duncan's multiple range test.

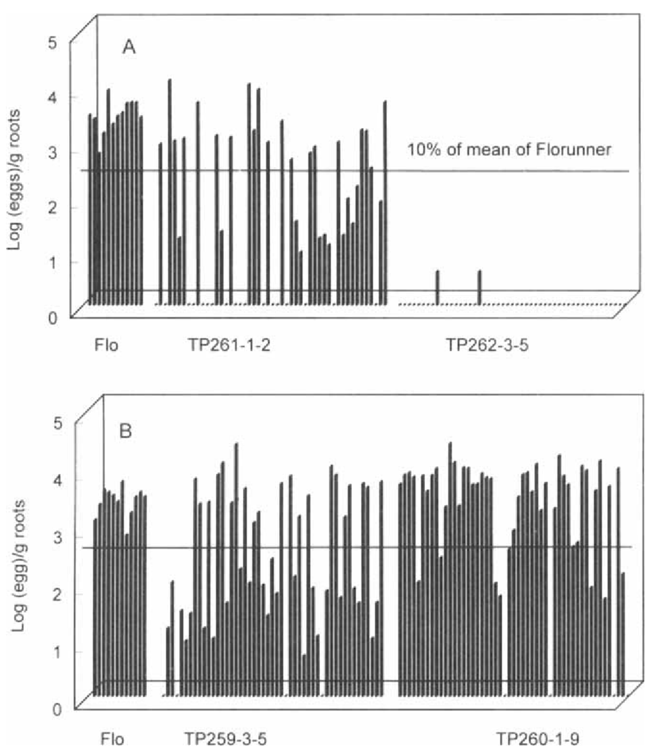

Fig. 3. Reproduction of *Meloidogyne arenaria* on individual plants of four $BC_5F_{2:4}$ breeding lines and the susceptible cultivar Florunner. Horizontal line represents 10% of mean reproduction on the susceptible recurrent parent Florunner. Individuals with less than 10% of the mean number of eggs per g roots on Florunner were classified resistant to reproduction of *M. arenaria*. A) Florunner versus TP261-1-2 and TP262-3-5. B) Florunner versus TP259-3-5 and TP260-1-9.

resistant breeding lines in the absence of nematode parasitism. The relatively low yields of the susceptible cultivars in 1997 were attributed to adverse growing conditions. The spring in 1997 was unusually cool and wet, followed by limited rainfall during June and July. The irrigation systems available were unable to completely compensate for drought conditions.

Data with respect to yield potential in nematode-infested fields and inhibition of nematode reproduction in greenhouse tests indicated that resistance to *M. arenaria* from wild *Arachis* species had been introgressed into advanced generation runner-type breeding lines. The yield potentials of these lines in the absence of nematode parasitism that were similar to that of the susceptible cultivars Florunner and Tamrun 96. In the nematode-infested fields, yield of these breeding lines was superior to that of the susceptible cultivars. Breeding lines with nematode resistance and yield potential equivalent to that of their recurrent parents were not identified among the spanish- or virginia-types from the BC_5 generation; however, additional breeding lines from the BC_6 and BC_7 generations have not been tested for yield potential. It is likely that spanish-, virginia-, and additional runner-type breeding lines with greater yield potentials will be identified from more advanced generation lines.

Two factors were thought to account for the lack of significant differences between final nematode population densities on some breeding lines and the susceptible cultivars in the 1996 tests. First, the greenhouse tests indicated that resistance was still a segregating trait in most of the nematode-resistant breeding lines; hence, final nematode population densities were means of both resistant and susceptible individuals. Second, the premature senescence of the susceptible cultivars due to severe damage from nematode parasitism limited nematode population development. The vigorous growth of the nematode-resistant breeding lines relative to that of the susceptible cultivars was evidence of the high level of resistance of these genotypes. Thus, the differences in final nematode population densities were not as great as would be expected if the susceptible cultivars had maintained the same vigorous growth until maturity as did the resistant breeding lines. TP262-3-5, for which resistance appears to be a fixed trait and which had the lowest final nematode population densities in the field tests, provides an example of the expected effect of resistance as a fixed trait on final nematode population densities.

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