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Field Evaluation of Susceptibility to *Meloidogyne arenaria* in *Arachis hypogaea* Plant Introductions[1]

J. P. Noe,[2] C. C. Holbrook,[3] and N. A. Minton[4]

Abstract: Resistance to *Meloidogyne arenaria* race 1 is not currently available in commercial peanut cultivars. Moderate levels of resistance have been identified in *Arachis hypogaea* plant introductions (PI) in previous greenhouse studies. The purpose of this work was to evaluate the effects of resistance in peanut PI on populations dynamics of *M. arenaria* in field plots. The PI designated as resistant in greenhouse studies had fewer *M. arenaria* in roots than the most susceptible PI. At midseason and at the end of the season, resistant PI had fewer *M. arenaria* in rhizosphere soil than the most susceptible PI. Seven resistant PI had lower numbers of *M. arenaria* than 'Florunner' at the end of the growing season. Gall index, egg mass index, number of eggs/plant, and number of eggs/g root from greenhouse screening were highly correlated with population levels of *M. arenaria* in the field, especially at midseason. These greenhouse indices should provide reliable estimates of host suitability in future studies.

Key words: Arachis hypogaea, Meloidogyne arenaria, nematode, peanut, resistance, root-knot nematode.

Plant resistance is a preferred method of control of damage caused by plant-parasitic nematodes. Resistance is becoming increasingly important in nematode management as chemical nematicides become less available due to environmental and human health concerns. At this time, commercially available cultivars of peanut, *Arachis hypogaea* L., are all susceptible to the peanut root-knot nematode, *Meloidogyne arenaria* (Neal) Chitwood race 1. High levels of resistance to *M. arenaria* have been identified in wild *Arachis* species (4,8, 9), but similar levels of resistance have not been found in *A. hypogaea* germplasm.

Earlier efforts to identify resistance to *M. arenaria* in peanut plant introductions (PI) were unsuccessful (6,7). Holbrook et al. (3) evaluated 260 PI in greenhouse and field screenings and reported that there were no high levels of resistance, based on root galling and egg mass indices.

Resistance to plant-parasitic nematodes has been defined as limiting nematode reproduction (12). Recently, moderate levels of resistance to *M. arenaria* were identified in *A. hypogaea* by analysis of nematode egg numbers produced on roots of 1,321 peanut PI (5). Egg production of *M. arenaria* on the most resistant PI was only 30% of that on 'Florunner' peanut. Reduced levels of egg production indicate that resistance is available, but the practical significance of these levels has not been determined.

Although high levels of resistance to *M. arenaria* may not be available within PI collections, existing resistance could provide economically acceptable levels of control when used as part of an intensive, sustainable management protocol. An essential component of sustainability in a cropping system designed to limit losses due to nematodes is the rate of population increase, or decline, under various host plants (10). The purpose of this study was to evaluate the impact of resistance in peanut PI on population dynamics of *M. arenaria.*

Materials and Methods

Twelve peanut PI were selected as resistant (25–50% of the eggs produced on Florunner), and six were selected as susceptible (100–160% of the eggs produced on Florunner), based on the results of a previous greenhouse evaluation (5). Seed for the PI were obtained from the USDA

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[2] Assistant Professor, Department of Plant Pathology, University of Georgia, Athens, GA 30602.
[3] Research Geneticist and [4]Research Nematologist, USDA, ARS, Coastal Plain Experiment Station, Tifton, GA 31793.
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Southern Regional Plant Introduction Station, Experiment, Georgia. All 18 entries and Florunner were planted on 23 May 1990 in a randomized complete block design with nine replications. The experimental site was a Tifton sandy loam field near Tifton, Georgia, with an overall mean population density of 381 *M. arenaria* second-stage juveniles (J2)/100 cm^3 soil at planting. Plots consisted of one bed, two rows wide by 1.5 m long, with 80 cm between rows on the bed and 1 m between beds (adjacent plots). Entries were planted at a rate of seven seeds/m. Plots were managed throughout the growing season by standard grower practices and were irrigated as needed.

Soil population levels of plant-parasitic nematodes were assayed in all plots at planting. Plants in three replications were dug at midseason (19 July 1990) for determination of the number and growth stages of *M. arenaria* within the roots. Three plants were dug from each plot, and the roots were washed free of soil. Roots were cut into 2-cm pieces, and 1-g samples were removed from the roots of each plant. *Meloidogyne arenaria* within the root samples were stained with acid fuchsin (2) and counted. Each nematode was classified as vermiform = J2 showing no signs of development; swollen = some degree of swelling indicating that development to the adult stage had been initiated; and globose = spherical shape, adult or preadult form. The three replications from which roots were dug were not used for soil nematode population assays.

At midseason (19 July 1990) and at the end of the growing season (10 September 1990), soil population levels of plant-parasitic nematodes were determined in six replications. Nematode population levels were determined by collecting 10 2.5-cm-d by 20-dm-deep soil cores in a systematic pattern from the rhizospheres of each plot. Cores were bulked within plots, and plant-parasitic nematodes were extracted from 500 cm^3 soil by elutriation and sucrose centrifugation (1). At midseason and at the end of the season, *M. arenaria* J2 also were collected from roots eluted from the soil sample. Roots were placed in an intermittent-mist chamber, and nematodes were collected after 48 hours (1). Numbers reported for *M. arenaria* represent the sum of J2 collected from soil and root fractions. Host efficiencies were calculated as total numbers of nematodes at midseason or harvest divided by numbers of nematodes counted at planting.

Analysis of variance followed by separation of means by Duncan's multiple-range test ($P = 0.05$) was used to detect differences among entries (11). Contrasts were calculated for comparisons of resistant and susceptible PI (11). Correlation analysis was used to determine the relationship of gall index, egg mass index, number of eggs/plant, and number of eggs/g root determined from screening peanut PI in the greenhouse, with *M. arenaria* population densities at midseason and harvest.

Results

Numbers of *M. arenaria* per gram of root differed among PI for all nematode growth stages (Table 1). There were fewer vermiform *M. arenaria* in roots of PI 247378, 259639, and 270786 than in roots of susceptible PI 153331, 210833, 269106, and 270870. Similar differences were observed for the numbers of swollen and globose *M. arenaria,* although the individual PI with highest and lowest numbers were different among nematode growth stages. Contrast analysis showed that resistant PI had fewer *M. arenaria* in roots than were in the roots of susceptible PI for all nematode growth stages. None of the resistant PI had significantly fewer *M. arenaria* in roots than Florunner. The resistant PI 210833, 259639, 259777, 270786, and 270792 had more globose, adult form *M. arenaria* in roots than were in roots of Florunner. The susceptible PI 270870 had more *M. arenaria* in roots than Florunner for all nematode growth stages.

Differences were observed among PI in numbers of *M. arenaria* J2 recovered from

TABLE 1. Numbers of *Meloidogyne arenaria* in roots of *Arachis hypogaea* plant introductions and 'Florunner' peanut at midseason.

Plant introduction number	Resistant (R) or susceptible (S)†	Country of origin	Number of *M. arenaria* per gram of root‡			
			Vermiform	Swollen	Globose	Total
145681	S	Egypt	20.0 bcde	46.9 bcdef	112.4 bc	179.3 bcd
153331	S	S. Africa	33.6 b	50.2 bcde	137.1 b	220.9 b
196736	R	Nigeria	10.6 bcde	45.7 bcdef	77.9 cd	134.1 bcd
210833	R	Argentina	28.2 bc	44.9 bcdef	136.7 b	209.8 b
230193	R	Philippines	6.2 cde	13.4 f	82.9 bcd	102.9 d
242100	R	Rep. of China	9.4 cde	34.9 bcdef	96.4 bcd	140.8 bcd
247378	R	Ivory Coast	1.3 e	19.3 def	87.3 bcd	108.0 d
259572	R	Uruguay	5.6 cde	22.2 def	75.6 cd	103.3 d
259639	R	Cuba	1.8 e	16.0 def	123.6 bc	141.3 bcd
259777	R	Malawi	15.1 bcde	32.9 bcdef	118.2 bc	166.2 bcd
268885	S	Zimbabwe	15.8 bcde	60.7 bc	100.2 bcd	176.7 bcd
269106	S	Zimbabwe	27.0 bcd	51.4 bcd	126.3 bc	204.8 bc
270786	R	Zimbabwe	2.4 e	15.4 ef	126.7 bc	144.6 bcd
270792	R	Zimbabwe	8.9 cde	35.1 bcdef	107.6 bc	151.6 bcd
270807	S	Zimbabwe	20.2 bcde	64.0 b	93.1 bcd	177.3 bcd
270849	R	Zimbabwe	9.8 cde	24.8 def	82.9 bcd	117.4 cd
270870	S	Zimbabwe	84.7 a	190.2 a	189.7 a	464.6 a
270974	R	Zimbabwe	3.8 de	26.2 cdef	104.7 bcd	134.7 bcd
Florunner		USA	20.7 bcde	45.3 bcdef	52.9 d	118.9 cd

Means within columns followed by the same letter are not different ($P = 0.05$) by Duncan's multiple-range test, n = nine observations per mean. The contrast between resistant (R) and susceptible (S) plant introductions was significant ($P \leq 0.01$) for each developmental category and for total *M. arenaria*/g root.

† Plant introduction determined to be resistant (R) or susceptible (S) in a previous greenhouse evaluation (5).

‡ Nematode development category: vermiform = no development; swollen = development initiated; globose = fully swollen spherical adult form.

the rhizosphere soil at midseason (Table 2). The resistant PI with the fewest number of J2, PI 196736, supported only 27% as many *M. arenaria* as the most susceptible genotype, PI 145681, and 55% of the number of J2 recovered from Florunner. Host efficiencies at midseason ranged from 0.8 (poor host) for PI 230193 to 3.5 (good host) for PI 145681.

Seven of the resistant PI had fewer numbers of *M. arenaria* J2 in rhizosphere soil than were recovered from Florunner plots at the end of the growing season (Table 2). The most resistant genotype, PI 270849, had 36% as many *M. arenaria* J2 at the end of the season as were recovered from Florunner. Final *M. arenaria* counts and host efficiencies were low for most of the PI, including those that were classified as susceptible. Contrast analysis showed that numbers of *M. arenaria* J2 were lower ($P \leq 0.01$) in plots with resistant PI than in plots with susceptible PI on both sampling dates.

Correlation coefficients indicated that results from greenhouse screening of peanut PI for resistance to *M. arenaria* were good indicators of nematode population levels in the field plots (Table 3). Correlations of gall index, egg mass index, number of eggs/plant, and number of eggs/g root with the midseason rhizosphere nematode counts, and with midseason host efficiencies, were quite high ($r \geq 0.65$, $P \leq 0.01$). Correlations of greenhouse indices with the number of nematodes in roots, and with final rhizosphere nematode counts, were not as high as with the midseason data.

DISCUSSION

Low to moderate levels of resistance to *M. arenaria* race 1 are present within the existing collection of *A. hypogaea* plant introductions. A cultivar that restricts population increases of *M. arenaria* compared to Florunner could be useful in a sustainable production system in conjunction with

TABLE 2. Numbers of *Meloidogyne arenaria* and host efficiencies at midseason and end of season on *Arachis hypogaea* plant introductions and 'Florunner' peanut.

Plant introduction number	Resistant (R) or susceptible (S)†	Midseason		End of Season	
		Number of *M. arenaria*/ 100 cm^3 soil	Host efficiency‡	Number of *M. arenaria*/ 100 cm^3 soil	Host efficiency‡
145681	S	1,308 a	3.5 a	833 a	2.9 a
153331	S	621 bc	1.8 bcde	365 cd	1.2 c
196736	R	356 c	1.3 de	319 d	1.1 c
210833	R	698 bc	1.8 bcde	452 bcd	1.0 c
230193	R	469 bc	0.8 e	456 bcd	1.0 c
242100	R	584 bc	1.8 bcde	266 d	0.8 c
247378	R	614 bc	2.0 abcde	419 bcd	1.1 c
259572	R	484 bc	1.1 de	340 cd	0.8 c
259639	R	387 bc	1.3 cde	342 cd	1.1 c
259777	R	597 bc	1.4 cde	291 d	1.0 c
268885	S	827 abc	2.9 abc	494 bcd	1.7 bc
269106	S	1,011 ab	3.2 ab	641 abc	2.1 ab
270786	R	573 bc	2.0 abcde	409 bcd	1.2 c
270792	R	410 bc	0.9 e	408 bcd	0.8 c
270807	S	796 abc	2.5 abcd	345 cd	1.1 c
270849	R	526 bc	1.9 bcde	256 d	0.9 c
270870	S	836 abc	2.6 abcd	303 d	0.9 c
270974	R	407 bc	1.2 de	278 d	0.9 c
Florunner		651 bc	2.0 abcde	717 ab	2.2 ab

Means within columns followed by the same letter are not different ($P = 0.05$) by Duncan's multiple-range test, n = six observations per mean. The contrast between resistant (R) and susceptible (S) plant introductions was significant ($P \leq 0.01$) for numbers of *M. arenaria* and host efficiencies at both midseason and end of season.

† Plant introductions determined to be resistant (R) or susceptible (S) in previous greenhouse evaluation (5).

‡ Host efficiency = number of nematodes in soil at midseason or end of season divided by number of nematodes in soil at planting.

other practices, such as crop rotation, biological control, and less frequent or lower application rates of chemical pesticides. The high phenotypic variability in the collection, which also includes PI more susceptible than Florunner, could be exploited to create progeny that segregate more clearly for resistance to *M. arenaria*, possibly enhancing existing resistance levels.

The high degree of correlation between greenhouse and field evaluations of peanut PI indicates that more rapid and efficient greenhouse screening protocols for *M. arenaria* resistance in peanut could be developed without losing predictive value

TABLE 3. Correlation coefficients (r) of data from field trials with gall index, egg mass index, number of eggs/plant, and number of eggs/g root from previous greenhouse screening (5) for levels of resistance to *Meloidogyne arenaria* race 1 among *Arachis hypogaea* entries.

Greenhouse screen	Field data correlated				
	Midseason			Harvest	
	Number of nematodes in roots	Number of nematodes in soil	Host efficiency†	Number of nematodes in soil	Host efficiency†
Gall index	0.56*	0.68**	0.82***	0.28	0.45
Egg mass index	0.57**	0.77***	0.81***	0.51*	0.64**
Eggs/plant	0.52*	0.84***	0.84***	0.51*	0.66**
Eggs/g root	0.49*	0.65**	0.70***	0.46*	0.57**

† Host efficiency = number of nematodes in soil at midseason or harvest divided by number of nematodes in soil at planting.

*, **, *** indicate $P \leq 0.05$, 0.01, and 0.001, respectively, with P = probability of $>|r|$, for $n = 19$ observations.

for performance under field conditions. Similarly high correlations between greenhouse and field results were reported in an evaluation of wild *Arachis* species (8). More efficient screening protocols will be required to evaluate the large numbers of progeny likely to result from crosses within the PI collection and with commercially available cultivars.

Examination of *M. arenaria* within roots indicated that slightly less penetration and postinfectional development may be part of the mechanism of resistance in peanut PI. Nelson et al. (9) reported two different mechanisms of resistance to *M. arenaria* in wild *Arachis* species. *Arachis cardenasii* Krap & Greg exhibited hypersensitivity to the nematodes, with penetration but no postinfectional development to the adult stage. However, *M. arenaria* penetrated and developed to adults on *A. batizocoi* Krap & Greg, although nematode development was slower as compared with 'Tamnut 74' peanut, and no eggs were produced 30 days after inoculation. The type of resistance in the PI evaluated in this study appeared to more closely resemble that found in *A. batizocoi,* because *M. arenaria* developed to adults and produced eggs.

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