Journal of Nematology 30(3):341–346. 1998.

Resistance of Interspecific *Arachis* Breeding Lines to *Meloidogyne javanica* and an Undescribed *Meloidogyne* Species

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Abstract: Resistance to a peanut-parasitic population of *Meloidogyne javanica* and an undescribed *Meloidogyne* sp. in peanut breeding lines selected for resistance to *M. arenaria* was examined in greenhouse tests. The interspecific hybrid TxAG-7 was resistant to reproduction of *M. arenaria, M. javanica,* and *Meloidogyne* sp. An *M. arenaria*-resistant selection from the second backcross (BC) of TxAG-7 to the susceptible cultivar Florunner also was resistant to *M. javanica* but appeared to be segregating for resistance to the *Meloidogyne* sp. When reproduction of *M. javanica* and *M. arenaria* were compared on five BC4F3 peanut breeding lines, each derived from *M. arenaria*-susceptible BC4F2 individuals, all five lines segregated for resistance to *M. javanica,* whereas four of the lines appeared to be susceptible to *M. arenaria.* These data indicate that several peanut lines selected for resistance to *M. arenaria* also contain genes for resistance to populations of *M. javanica* and the undescribed *Meloidogyne* sp. that are parasitic on peanut. Further, differences in segregation patterns suggest that resistance to each *Meloidogyne* sp. is conditioned by different genes.

Key words: *Arachis hypogaea,* genetics, *Meloidogyne arenaria, Meloidogyne javanica, Meloidogyne* sp., nematode, peanut, resistance, root-knot nematode.

Peanut (*Arachis hypogaea*) is a host for four species of root-knot nematode (*Meloidogyne* spp.). *Meloidogyne arenaria* is the dominant species on peanut in Alabama, Georgia, and Texas (Ingram and Rodríguez-Kábana, 1980; Motsinger et al., 1976; Wheeler and Starr, 1987). *Meloidogyne hapla* is the common species on peanut in Virginia, North Carolina, and Oklahoma (Schmitt and Barker, 1988). Populations of *M. javanica* parasitic on peanut are rare in the United States, having been identified only once each from Georgia (Minton et al., 1969) and Texas (Tomaszewski et al., 1994), but are common in Egypt (Tomaszewski et al., 1994) and India (Sharma et al., 1995). An additional *Meloidogyne* sp. parasitic on peanut has been found in Texas (Abdel-Momen and Starr, 1997); this population appears to be a new species based on esterase and malate dehydrogenase phenotypes (J. L. Starr, unpubl.) and morphological characteristics (J. D. Eisenback, pers. comm.). *Meloidogyne hapla* generally is considered to be a less aggressive pathogen of peanut than *M. arenaria* (Koenning and Barker, 1992). *Meloidogyne javanica* and the undescribed species appear to be similar to *M. arenaria* in terms of their relationships between initial nematode population densities (Pi) and peanut yields (Abdel-Momen and Starr, 1997).

Control of nematodes on peanut is achieved primarily by use of nematicides and crop rotations. Host resistance to nematodes, which can be defined as the suppression of nematode reproduction by the resistant plant relative to reproduction on a susceptible genotype (Cook and Evans, 1987), provides an excellent method of control when resistance is available. Peanut cultivars with resistance to *M. arenaria* are unavailable, but resistance to *M. arenaria* has been found in several wild *Arachis* spp. germplasm lines (Holbrook and Noe, 1990; Nelson et al., 1989) and introgressed from these species into peanut genotypes that are cross-compatible with *A. hypogaea* (Nelson et al., 1989; Simpson, 1991; Stalker et al., 1995). TxAG-6 is an interspecific hybrid derived from *A. batizocoi, A. digoi,* and *A. cardenasii.* TxAG-7 is derived from a cross of Florunner × TxAG-6 that was backcrossed once to Florunner (Simpson et al., 1993). TP-223 is an *M. arenaria*-resistant selection from the second backcross of TxAG-7 to Florunner (BC2F4). Although TxAG-7 and TP-223 were selected for resistance to *M. arenaria,*

Received for publication 4 August 1997.
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TxAG-7 was found also to be resistant to isolates of *M. javanica* from Egypt (Tomaszewski et al., 1994). The objective of this study was to compare the responses of the *M. arenaria*-resistant TxAG-7 and TP-223 to Texas isolates of *M. javanica* and the undescribed *Meloidogyne* sp.

Materials and Methods

Resistance of TxAG-7 and TP-223 to *M. arenaria* (isolate no. 82-4), *M. javanica* (isolate no. 93-9), and an isolate (93-13a) of the undescribed *Meloidogyne* sp. from peanut in Collingsworth County, Texas, was tested in greenhouse experiments. Identification of each isolate was confirmed by analysis of esterase phenotype (Esbenshade and Triantaphyllou, 1990). All isolates were maintained on tomato (*Lycopersicon esculentum* Mill. 'Rutgers') in the greenhouse. Eggs for inoculum were extracted from infected tomato roots with 1.0% NaOCl (Hussey and Barker, 1973).

Reproduction of the three *Meloidogyne* spp. on Florunner and TxAG-7 was examined in one test, and reproduction of the three species on Florunner and TP-223 was compared in a second test. For each test, peanut seeds were germinated on rolled, moist paper towels at 25 °C for 7 days. One germinated seed of each line was planted separately into 15-cm-diam. pots filled with a loamy sand soil (85% sand, 8% clay, 7% silt; pH 7.5). The pots were infested separately with *M. arenaria, M. javanica,* or isolate 93-13a at planting with 1,000 or 10,000 eggs/pot. There were six single-plant replications of each inoculum level. Eight weeks after infestation, roots from each pot were collected and weighed. Eggs were extracted from the roots with 1.0% NaOCl and counted with the aid of a stereomicroscope. The effects of peanut genotype on numbers of eggs per gram of roots was analyzed with the SAS general linear model procedure (SAS Institute, Cary, NC).

The variation in reproduction of isolate 93-13a on TP-223 was examined in a greenhouse test. Forty pots containing TP-223 and eight pots containing Florunner each were infested with 10,000 eggs/pot of isolate 93-13a. Eight weeks after infestation, roots from each plant were collected, weighed, and the eggs extracted with NaOCl. TP-223 individuals with 10% or less of the mean number of eggs per gram of roots produced on Florunner were classified as resistant.

To determine if resistance to *M. javanica* co-segregated with resistance to *M. arenaria,* seed of each of five F3 breeding lines from the fourth backcross of resistant progeny from the cross of TxAG-7 × Florunner, with Florunner as the recurrent parent, were each inoculated separately with 10,000 eggs of *M. arenaria* or *M. javanica.* These breeding lines were progeny of individual *M. arenaria*-susceptible F2 plants of the fourth backcross. Florunner was included in this test as a susceptible control. Eight weeks after infestation, roots from each plant were collected and weighed, and the eggs were extracted with 1.0% NaOCl. Individuals with 10% or less of the number of eggs per gram of root produced on Florunner were classified as resistant.

Results

The effect of inoculum concentration was not significant ($P \geq 0.05$) in five of the six nematode species by peanut genotype combinations in the two experiments; therefore, data from different inoculum concentrations were combined for further analysis. No difference ($P \geq 0.05$) in reproduction on Florunner was observed among the three *Meloidogyne* spp. tested. Mean reproduction of *M. arenaria, M. javanica,* and isolate 93-13a was lower ($P \leq 0.05$) on TxAG-7 than on Florunner (Table 1). For each *Meloidogyne* spp., mean reproduction on TxAG-7 was less than 10% of the mean reproduction on Florunner.

On TP-223, mean reproduction of *M. arenaria* and *M. javanica* was lower ($P \leq 0.01$) than that on Florunner (Table 1). Even though reproduction of isolate 93-13a on TP-223 was only 3% of the mean reproduction on Florunner, this difference in reproduction on the two peanut genotypes was not significant ($P \geq 0.10$) due to high varia-

TABLE 1. Reproduction (eggs per g root) at 8 weeks after inoculation of three *Meloidogyne* spp. on the susceptible peanut Florunner and two breeding lines resistant to *M. arenaria* in greenhouse tests.

Meloidogyne species	Peanut genotype			
	Florunner	TxAG-7	TP-223	*P*
		Test 1		
Meloidogyne sp.	27,501	107	—	0.046
M. javanica	6,386	539	—	0.032
M. arenaria	14,347	378	—	0.020
		Test 2		
Meloidogyne sp.	10,070	—	314	0.131
M. javanica	1,754	—	243	0.002
M. arenaria	6,339	—	25	0.001

tion. When a larger number of TP-223 individuals were tested, mean reproduction of isolate 93-13a on TP-223 was less than mean reproduction on Florunner ($P \leq 0.5$) and ranged from 0 to 6,151 eggs/g roots on 39 surviving plants compared to a range of 554 to 7,188 eggs/g roots on seven surviving Florunner plants (Fig. 1). Twenty-one of the TP-223 individuals supported reproduction of isolate 93-13a that was less than 10% of its mean reproduction on Florunner.

In the final test, mean reproduction of *M. arenaria* and *M. javanica* on five F3 *M. arenaria*-susceptible breeding lines was not different from mean reproduction of each species on Florunner ($P \geq 0.10$). Reproduction of *M. javanica,* however, was more variable on these breeding lines than was reproduction on *M. arenaria.* Thirty to 70% of the individuals of each breeding line were classified as resistant to *M. javanica,* with several individuals having no detectible reproduction (Fig. 2A). In contrast, all individuals from four of five of these breeding lines were classified as susceptible to *M. arenaria.* In the fifth breeding line (250-2A), 4 of 10 individuals were classified as resistant (Fig. 2B).

DISCUSSION

The resistance of peanut breeding lines TxAG-7 (Nelson et al., 1989; Simpson et al., 1993) and TP-223 to *M. arenaria,* based on inhibition of nematode reproduction, was confirmed in greenhouse tests. The resistance of TxAG-7 to the peanut-parasitic isolate of *M. javanica* from Texas confirms the previous report that this breeding line was resistant to isolates of *M. javanica* from Egypt (Tomaszewski et al., 1994).

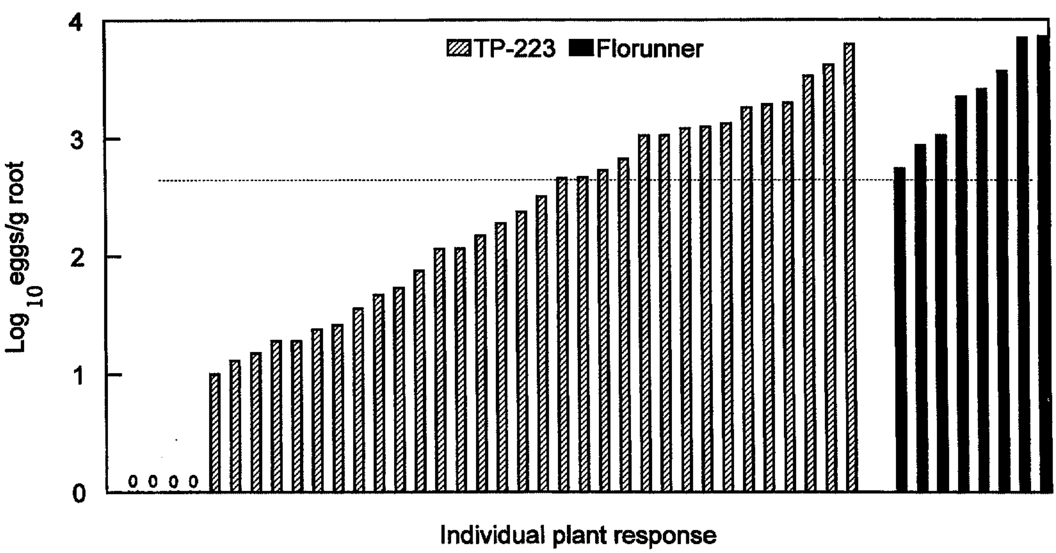

FIG. 1. Reproduction of an undescribed *Meloidogyne* sp. (isolate 93-13a) on TP-223 (n = 39) and Florunner (n = 7) in greenhouse tests. Each bar represents reproduction on an individual plant. Zeroes indicate plants supporting no reproduction. The dotted horizontal line represents 10% of the mean number of eggs per gram of roots produced on Florunner.

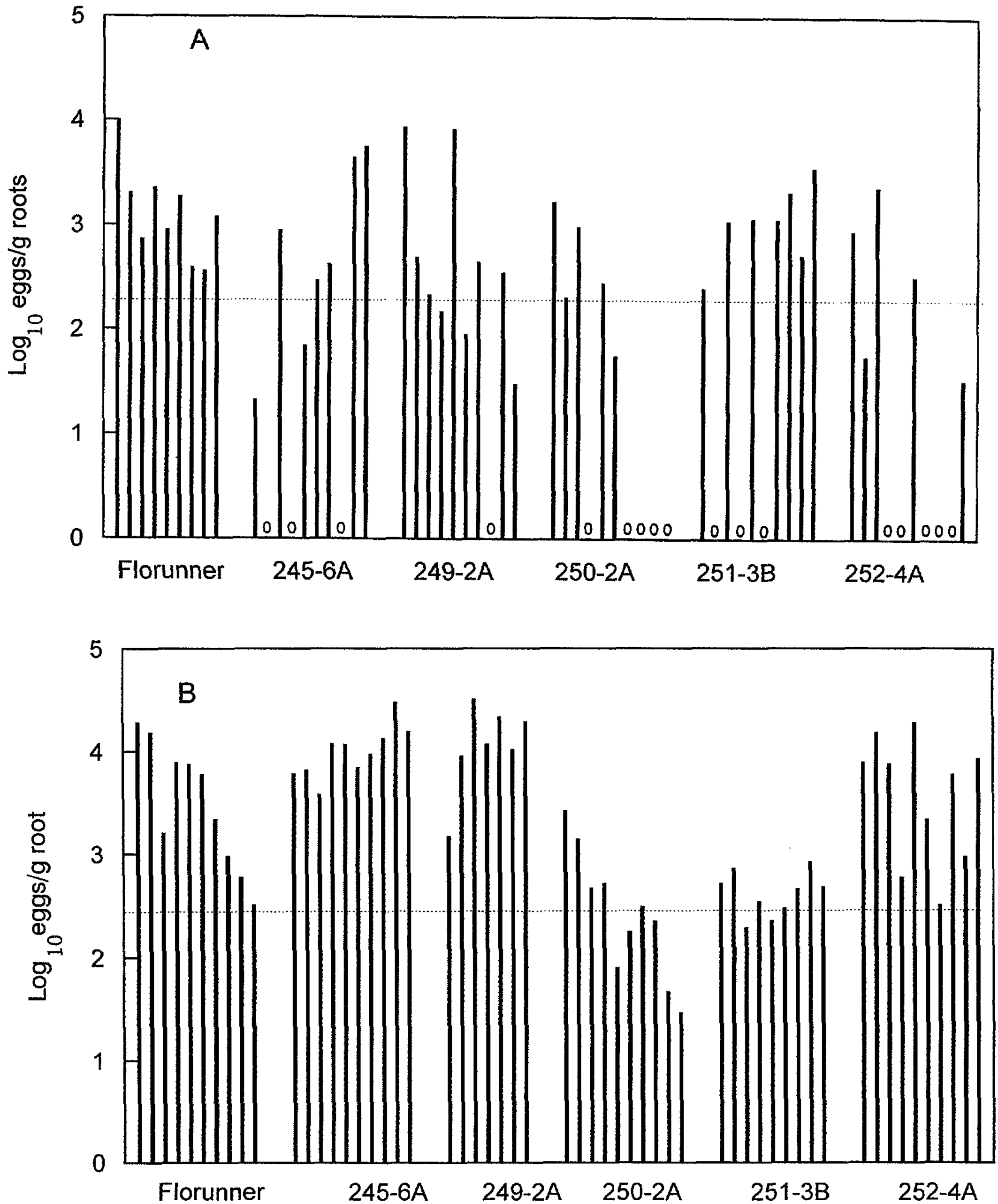

FIG. 2. Reproduction of A) *Meloidogyne javanica* and B) *M. arenaria* on Florunner peanut and on five BC4F3 peanut breeding lines. Each bar represents reproduction on an individual plant. Zeroes indicate plants supporting no reproduction. The dotted horizontal line represents 10% of the numbers of eggs per gram of roots produced on Florunner.

Few data are available on the genetic basis for resistance to *M. arenaria* in these peanut genotypes. TxAG-7 potentially has genes for resistance from three wild *Arachis* spp. (*A. batizocoi, A. cardenasii,* and *A. diogoi* [*A. chacoensis*]), each of which is resistant to *M. arenaria* (Holbrook and Noe, 1990; Nelson et al., 1989). *Arachis cardenasii* appears to have at least two dominant genes for resistance (Starr and Simpson, 1991), and the mechanism(s) of resistance in *A. cardenasii* is different from that of *A. batizocoi* (Nelson et al., 1990). Resistance to *M. arenaria* in some BC5 generation breeding lines appears to be conditioned by a single dominant gene, and RAPD markers linked to this gene have been identified (Burow et al., 1996). In other BC5 breeding lines, a second gene for resistance to *M. arenaria* may be present (Choi, 1997). In peanut breeding lines for which resistance was derived solely from *A. cardenasii,* resistance was conditioned by two genes (Garcia et al., 1996), one gene affecting nematode reproduction and one gene affecting root galling. DNA sequences linked to these resistance genes have been identified (Garcia et al., 1996).

That numerous F3 individuals in four BC4 breeding lines susceptible to *M. arenaria* are resistant to *M. javanica* suggests that the resistance to each of these species is conditioned by different genes. Given that all TP-223 individuals tested were resistant to *M. arenaria* and *M. javanica* but appeared to be segregating for resistance to the undescribed species, it is possible that resistance to the undescribed *Meloidogyne* sp. is conditioned by yet other genes. The broad range of levels of reproduction of isolate 93-13a on individual TP-223 plants suggests that resistance to the undescribed *Meloidogyne* sp. is conditioned by a system that is genetically more complex than a single dominant gene.

Meloidogyne arenaria is the principal root-knot nematode attacking peanut in the United States, and substantial progress is being made in efforts to develop peanut cultivars with high levels of resistance (Starr et al., 1995). The wild *Arachis* spp. that have been the sources of resistance to *M. arenaria* apparently also contain genes for resistance to other *Meloidogyne* spp. Resistance to *M. javanica* is likely to be useful in Egypt and India where this species is an important pathogen of peanut (Sharma et al., 1995; Tomaszewski et al., 1994). Even though populations of *M. javanica* parasitic on peanut and of the undescribed species are not currently widespread in the United States, genes for resistance to these populations already present in breeding lines derived from interspecific crosses are valuable genetic resources. It is likely that, as production of peanut cultivars with resistance to *M. arenaria* becomes common in the United States, the other *Meloidogyne* spp. parasitic on peanut will become more prevalent. This will be similar to the situation with tobacco in the southeastern United States, where the incidence of *M. arenaria* on tobacco increased after the introduction and widespread production of tobacco cultivars with resistance to *M. incognita* (Fortnum et al., 1984). The availability of resistance to several *Meloidogyne* spp. in breeding lines derived from interspecific crosses will enable peanut breeding programs to develop cultivars with resistance to all of these species.

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