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Damage Functions for Three *Meloidogyne* Species on *Arachis hypogaea* in Texas

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Abstract: The yield response of Florunner peanut to different initial population (Pi) densities of *Meloidogyne arenaria, M. javanica,* and an undescribed *Meloidogyne* species (isolate 93-13a) was determined in microplots in 1995 and 1996. Seven Pi's (0, 0.5, 1, 5, 10, 50, and 100 eggs and J2/500 cm^3 soil) were used for each *Meloidogyne* species in both years. The three species reproduced abundantly on Florunner in both years. In 1995, mean reproduction differed among the three species; mean Rf values were 10,253 for isolate 93-13, 4,256 for *M. arenaria,* and 513 for *M. javanica.* In 1996, the reproduction of *M. arenaria* (mean Rf = 7,820) and isolate 93-13a (mean Rf = 7,506) were similar, and both had greater reproduction on peanut than did *M. javanica* (mean Rf = 2,325). All three nematode species caused root and pod galling, and a positive relationship was observed between Pi and the percentage of pods galled. *Meloidogyne arenaria* caused a higher percentage of pod galling than did *M. javanica* or isolate 93-13a. A negative linear relationship between $\log_{10}$ (Pi + 1) and pod yield was observed for all three nematode species each year. The yield response slopes were similar except for that of *M. javanica,* which was less negative than that of isolate 93-13a in 1995, and less negative than that of *M. arenaria* and isolate 93-13a in 1996.

Key words: Arachis hypogaea, damage function, *Meloidogyne arenaria, Meloidogyne javanica, Meloidogyne* spp., nematode, peanut, root-knot nematode.

Peanut is an important crop in the southern United States including Texas, which ranks second among peanut-producing states. The occurrence of *Meloidogyne* species on peanut is worldwide. *Meloidogyne arenaria* (Neal) Chitwood is the most common species on peanut in Alabama, Georgia, and Texas (Ingram and Rodríguez-Kábana, 1980; Motsinger et al., 1976; Wheeler and Starr, 1987), and *M. hapla* Chitwood is the dominant species in Virginia, North Carolina, and Oklahoma (Minton and Baujard, 1990). *Meloidogyne javanica* is common in Egypt (Tomaszewski et al., 1994), where it was the only species parasitizing peanut in 13 fields sampled from three governorates, and in India (Sharma et al., 1995). *Meloidogyne javanica* has been reported twice on peanut in the United States—once from Georgia (Minton et al., 1969) and once from Texas (Tomaszewski et al., 1994). Additionally, an undescribed *Meloidogyne* species has been found parasitizing peanut in two fields in Texas (unpubl.). This species was associated with stunted chlorotic plants that exhibited extensive root galling.

The damage threshold for a nematode species is defined as that population density at which a detectable yield loss occurs, whereas the economic threshold is the population density at which the cost of the yield loss equals the cost of control (Chiang, 1979). The importance of damage threshold determination is its role in the decision-making process and in development of management strategies. Damage thresholds may differ for the same nematode species from one environment to another, among nematode species, among populations of a species, and among host cultivars (McSorley and Phillips, 1993). The damage threshold for *M. arenaria* on peanut was estimated to be 48–120 eggs and second-stage juveniles (J2)/500 cm^3 soil in Texas (Wheeler and Starr, 1987) and 0–1 egg/100 cm^3 soil in Florida (McSorley et al., 1992). In North Carolina, the damage threshold for *M. arenaria* on peanut was estimated to be 4 eggs/500 cm^3, whereas for *M. hapla* it was estimated at 16 eggs/500 cm^3 soil (Koenning and Barker, 1992). Damage thresholds for *M. javanica* and the undescribed *Meloidogyne* sp. from Texas have not been examined. The objective of this study was to compare the damage functions of *M. javanica* and the undescribed species to that of *M. arenaria* on a common peanut cultivar.

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Materials and Methods

Meloidogyne arenaria (isolate no. 82-4) and *M. javanica* (isolate no. 93-9) were isolated from peanut and potato plants, respectively. An undescribed *Meloidogyne* species (isolate 93-13a) was isolated from peanut grown in Collingsworth County in north Texas. Identification of these nematode populations was based on the characteristics of perineal patterns and isozyme phenotypes (Esbenshade and Triantaphyllou, 1990). Analysis of morphological traits (J. D. Eisenback, pers. comm.) and esterase and malate dehydrogenase (MDH) phenotypes of isolate 93-13a (unpubl.) confirmed that it differed from previously described *Meloidogyne* species. All nematode isolates were reared on tomato (*Lycopersicon esculentum* Mill. 'Rutgers') in the greenhouse.

Seven initial population densities (0, 5, 10, 50, 100, 500, and 1,000 eggs/pot) of each population were inoculated onto individual peanut plants (*Arachis hypogaea* 'Florunner') in a single greenhouse test. One germinated seed was planted in each of five 30-cm-diameter pots filled with loamy sand soil. Nematode reproduction was measured as the nematode reproductive factor (Rf = Pf/Pi) 8 weeks after inoculation. Final nematode population densities were estimated by extracting nematode eggs from infected peanut roots with an NaOCl method (Hussey and Barker, 1973). Data were subjected to analysis of variance using the SAS (SAS Institute, Cary, NC 27511) general linear model procedure.

Effect of initial population densities of isolate 93-13a, *M. arenaria,* and *M. javanica* on peanut yield and nematode reproduction was determined in field microplots. Microplots were plastic cylinders (55-cm diam. × 45 cm deep) filled with and buried in loamy sand soil (85% sand, 7% silt, 8% clay; pH 7.5). Microplots were fumigated with metham sodium (380 liters/ha) to eliminate existing pathogen populations. Nematode inocula were prepared by chopping infected tomato roots 8–10 weeks after infestation into small fragments and mixing them with the infested soil from which the roots were obtained. The mixture of infested soil and infected root fragments then was mixed with pasteurized sand (1:2 by vol.). The number of J2 and eggs per 500 cm^3 of this inoculum mix was estimated for each of the three nematode species. Second-stage juveniles were extracted from soil samples by elutriation (Byrd et al., 1976) and centrifugation (Jenkins, 1964). Eggs were extracted by the NaOCl method (Hussey and Barker, 1973) from root fragments collected during elutriation. This heavily infested soil was then mixed into the upper 25 cm of microplot soil to achieve the desired nematode population density in each microplot.

The experimental design was a 3 × 7 factorial with three nematode species and seven Pi levels for each species. The Pi levels were 0, 0.5, 1, 5, 10, 50, and 100 eggs and J2/500 cm^3 soil with six replications for each treatment. Eight Florunner peanut seeds were planted in each microplot and thinned to four plants per microplot immediately after emergence. Planting dates were 16 May 1995 and 17 April 1996.

Nematode population densities were determined 8 weeks after planting and just before harvest. Composite soil samples (eight cores, each 2.5-cm diam. × 25 cm deep) were collected from each plot. Second-stage juveniles were extracted from soil by elutriation (Byrd et al., 1976) and centrifugation (Jenkins, 1964). Eggs were extracted from collected root fragments by the NaOCl method (Hussey and Barker, 1973).

Peanuts were dug 140 days after planting, and pods were removed from the vines by hand, air-dried, and weighed. One hundred pods were then selected arbitrarily from the yield of each microplot, and the percentage of pods galled from each microplot was determined.

Data were subjected to analysis of variance and regression analysis using the SAS general linear models procedure to determine treatment effects and relationships between Pi and relative yield for each nematode species, and to compare the slopes among regression models (Ott, 1988).

Results

In the greenhouse test, *M. arenaria, M. javanica,* and isolate 93-13a reproduced abundantly on Florunner with Rf values as high as 2,846, 1,530, and 1,130, respectively. The mean of Rf for *M. arenaria* was greater ($P \leq 0.01$) than that of *M. javanica* or isolate 93-13a, which had similar Rf values. A negative relationship was found between the Pi levels and Rf of the three species ($r^2 = 0.78$, $P \leq 0.05$).

In microplot experiments, midseason Rf values in 1995 were greater than those obtained from the same treatments in 1996. No differences were found among nematode species or Pi levels in 1995; however, in 1996, mean Rf for *M. javanica* was lower ($P \leq 0.05$) than that for *M. arenaria* or isolate 93-13a. At the end of season, the Rf values were negatively related to the Pi for the three nematode species in both 1995 and 1996 ($r^2 = 0.45$ and 0.47, respectively; $P \leq 0.05$) (Fig. 1). The mean Rf for 93-13a was 10,254 and was higher ($P \leq 0.01$) than that of *M. arenaria* (mean Rf = 4,275) or *M. javanica* (mean Rf = 513). In 1996, the mean Rf for *M. javanica* was 2,352 and was lower ($P \leq 0.05$) than that of *M. arenaria* (Mean Rf = 7,820) or isolate 93-13a (mean Rf = 7,506).

All three nematode species caused root and pod galling. A positive relationship between Pi and percentage of pods galled was found in 1995 and 1996 ($r^2 = 0.75$ and 0.88, respectively; $P \leq 0.01$) (Fig. 2). The percentage of pods galled by *M. arenaria* was higher ($P \leq 0.01$) across all Pi levels than that caused by *M. javanica* or isolate 93-13a in 1995 and 1996. No difference was found in the percentage of pods galled by *M. javanica* and that galled by isolate 93-13a in either year (Fig. 2).

The three nematode species suppressed pod yield, and pod yield was negatively related to Pi levels. The relationship between Pi and yield was described by linear models in both years. The relative yield suppression by all species was greater in 1995 than in 1996. *Meloidogyne javanica* had the least effect on yield, with suppression of relative

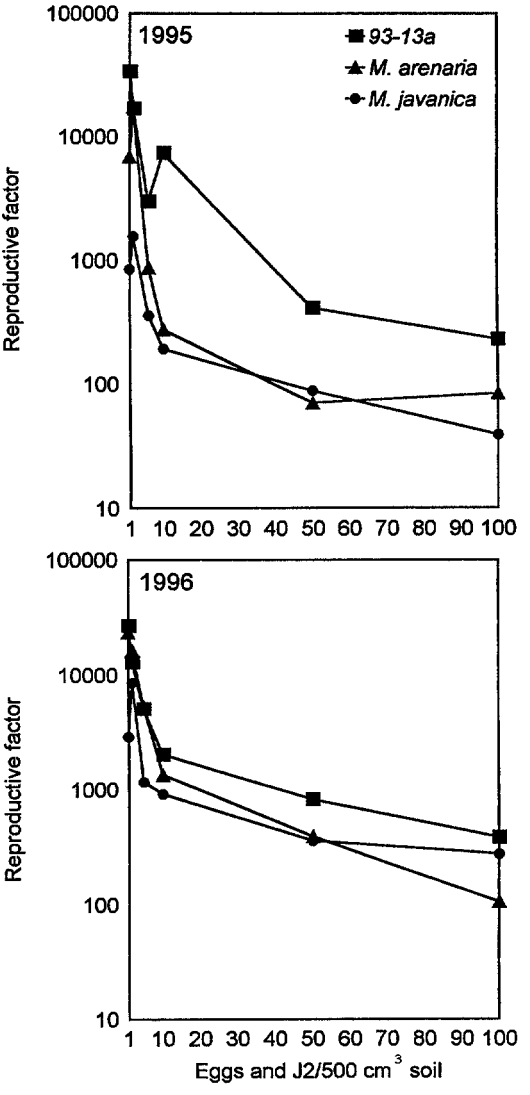

FIG. 1. Effects of initial population (Pi) densities of an undescribed *Meloidogyne* sp. (isolate 93-13a), *Meloidogyne arenaria,* and *M. javanica* on reproductive factors (Rf = Pf/Pi) on Florunner peanut in field microplots in 1995 and 1996.

yield from 16% to 74% in 1995 and from 8.5% to 72% in 1996. The suppression of relative yield caused by isolate 93-13a ranged from 54% to 80% in 1995 and from 22% to 84% in 1996 (Fig. 3). *Meloidogyne arenaria* suppressed relative yields ranging from 36% to 77% in 1995 and from 39% to 81% in 1996. The yield response curves for *M. arenaria* and 93-13a were similar in both years. The yield response curve for *M. javanica* was

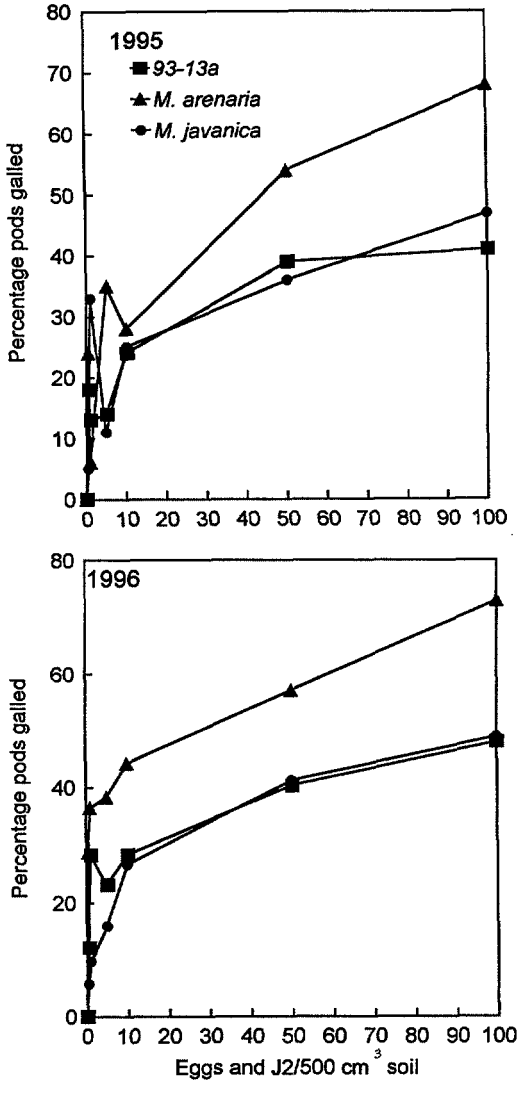

FIG. 2. Effects of initial population (Pi) densities of an undescribed *Meloidogyne* sp. (isolate 93-13a), *Meloidogyne arenaria*, and *M. javanica* on percentage of peanut pods galled in field microplots in 1995 and 1996.

less ($P \leq 0.01$) negative than that of 93-13a in 1995 ($P \leq 0.01$) and less negative than those of *M. arenaria* and 93-13a in 1996.

DISCUSSION

Parasitism of peanut by an undescribed *Meloidogyne* sp. (isolate 93-13a) recently discovered in Texas and a Texas isolate of *M. javanica* was confirmed in greenhouse tests and in field microplots. Even though reproduction by *M. javanica* on peanut was consistently less than those of *M. arenaria* and isolate 93-13a, peanut was a good host for all three species, with Rf values well above 1.0. The inverse relationship between Pi levels and reproductive factors for all species in greenhouse and field experiments was con-

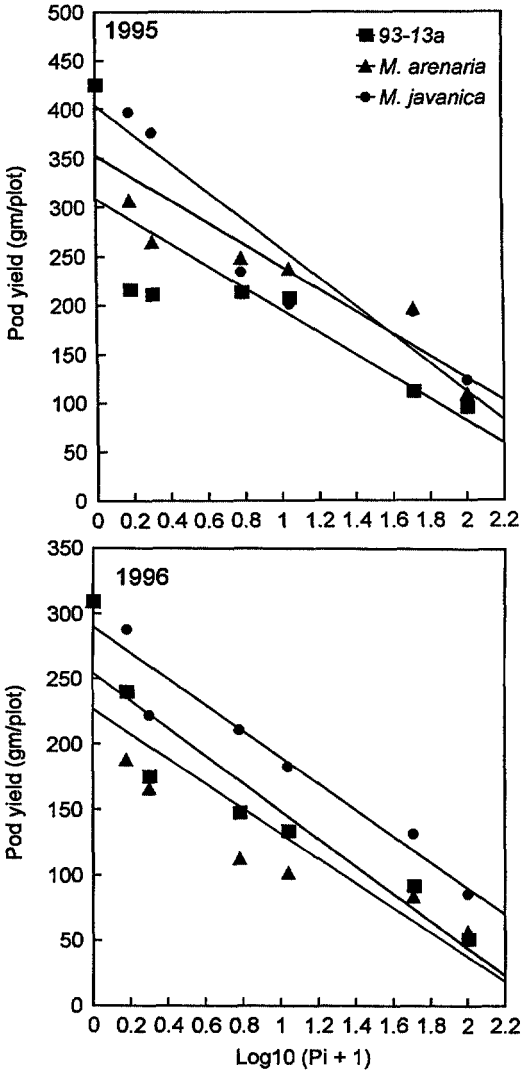

FIG. 3. Relationships between Pi of three *Meloidogyne* species and pod yield of the Florunner peanut in field microplots. Regression models for each species in 1995 were: $Y = 308.5 - 113.4$ log (Pi + 1) for isolate 93-13a ($r^2 = 0.66$, $P = 0.05$); $Y = 352.9 - 113.6$ log (Pi + 1) for *M. arenaria* ($r^2 = 0.81$, $P = 0.05$); and $Y = 403 - 145.8$ log (Pi + 1) for *M. javanica* ($r^2 = 0.90$, $P = 0.01$). In 1996, regression models were: $Y = 254.6 - 105.3$ log (Pi + 1) for isolate 93-13a ($r^2 = 0.86$, $P = 0.05$); $Y = 227 - 94.9$ log (Pi + 1) for *M. arenaria* ($r^2 = 0.74$, $P = 0.05$); and $Y = 290 - 100$ log (Pi + 1) for *M. javanica* ($r^2 = 0.94$, $P = 0.01$).

sistent with previous reports for *M. arenaria* and *M. hapla* on peanut (Koenning and Barker, 1992; McSorley et al., 1992).

In addition to root galling, each of the three nematode species attacked the peanut pods and caused symptomatic pod galling. This is the first report of *M. javanica* and the undescribed *Meloidogyne* sp. attacking peanut pods. Pod infection affects the quality and marketability of peanut, and may contribute to increased pod damage by soilborne fungal pathogens.

A negative, linear relationship was found between Pi and pod yield for the three nematode species. The damage functions of the undescribed species and *M. javanica* are described here for the first time. Differences in the relationship between years for each species were minor and probably reflect environmental influences. Detectable yield reductions were caused by Pi levels as low as 0.5 egg and J2/500 cm soil for the three root-knot species. The damage threshold for *M. arenaria* in this study was similar to that reported from Florida (McSorley et al., 1992) but lower than those reported from North Carolina (Koenning and Barker, 1992) and previously from Texas (Wheeler and Starr, 1987).

The similarity in damage functions of the three species indicates that the undescribed *Meloidogyne* sp. and *M. javanica* are a threat to the peanut industry in Texas, and possibly throughout the southern United States. If host resistance to *M. arenaria,* which is currently being developed (Starr et al., 1995), becomes widely used by peanut producers, it is likely that populations of *M. javanica* parasitic on peanut and the undescribed species will have a competitive advantage over populations of *M. arenaria* race 1 that are currently widespread in peanut production areas of Texas and the southern United States. Additional research is needed to further characterize the biology and host range of the undescribed *Meloidogyne* species. Crop rotation systems for management of *M. arenaria* on peanut may not be equally effective for management of *M. javanica* or the undescribed species. Work in progress suggests that whereas early generation breeding lines developed for resistance to *M. arenaria* also may be resistant to *M. javanica* (Abdel-Momen, 1997; Choi et al., 1996; Tomaszewski et al., 1994) and the undescribed species (Abdel-Momen, 1997), resistance to each nematode species may be conditioned by different genes (Choi et al., 1996; unpubl.). Thus, cultivars being developed with resistance to *M. arenaria* are unlikely to be resistant to *M. javanica* or the undescribed *Meloidogyne* sp.

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