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Variability among Populations of *Meloidogyne arenaria*[1]

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Abstract: Variability in reproduction and pathogenicity of 12 populations of *Meloidogyne arenaria* race 1 was evaluated on Florunner peanut, Centennial soybean, Rutgers tomato, G70, K326, and Mc944 tobacco, and Carolina Cayenne, Mississippi Nemaheart, and Santanka pepper. Differences among *M. arenaria* populations in rates of egg production 45 days after inoculation were observed for all cultivars except Santanka pepper. Differences among populations in dry top weights or fresh root weights were recorded on all cultivars. Numbers of nematode eggs produced on Florunner peanut varied from 3,419 to 11,593/g fresh root weight. On resistant tobacco cultivars (G70 and K326), one nematode population produced high numbers of eggs (12,042 and 6,499/g fresh root weight on G70 and K326, respectively), whereas the other populations produced low numbers of eggs (less than 500 eggs/g fresh root weight on both cultivars). Two variant *M. arenaria* race 1 populations were identified by factor analysis of reproductive rates on all nine cultivars. Differences in reproduction and pathogenicity observed among populations would affect the design of sustainable management systems for *M. arenaria.*

Key words: Arachis hypogaea, Capsicum frutescens, Glycine max, host suitability, *Lycopersicon esculentum, Meloidogyne arenaria,* nematode, *Nicotiana tabacum,* pathogenicity, peanut, pepper, reproduction, soybean, tomato, tobacco.

Meloidogyne arenaria (Neal) Chitood race 1 is pathogenic to peanut, *Arachis hypogaea* L. This nematode species is apomictic and reproduces exclusively by obligatory mitotic parthenogenesis (17). Under selection pressure, successful females may reproduce rapidly and establish an adapted population, so that phenotypic lineages may differ among locations and under different cropping systems (17).

High levels of variation within species typically occur in the genus *Meloidogyne.* This variability may be expressed in morphology, cytogenetics, physiology, and fecundity on selected host plants (10,12). Significant morphological and morphometric variation has been reported among populations of *M. arenaria,* but the degree of divergence was not considered sufficient for the designation of new species (3).

Two host races of *M. arenaria* have been defined according to pathogenicity on peanut; race 1, which reproduces on peanut, and race 2, which does not (14). Additionally, a naturally occurring population of *M. arenaria* from Senegal has been reported to reproduce on resistant tomato cultivars and was designated race B (11).

Diploid, hypotriploid, and triploid populations of *M. arenaria* have been identified (17) with chromosome numbers ranging from 2n = 30 to 2n = 56. Three common esterase isozyme phenotypes have also been reported for *M. arenaria* (4), but these physiological and cytogenetic types do not correspond with existing host races.

Due to geographic isolation and limited capability for movement, populations of *M. arenaria* race 1 in the southeastern United States may vary from field to field in reproduction on peanut and on crops commonly grown in rotation with peanut, such as soybean, *Glycine max* (L.) Merr. Variability among field populations of *M. arenaria* in population increases on the same host is a potential source of error in prescriptive management recommendations for nematode control. The degree of population variability and the extent to which that variability would alter the success of minimal-input management protocols needs to be determined, because nematode control recommendations have become less dependent on broad-spectrum fumigant nematicides. The purpose of this study was to assess the variability in reproduction and pathogenicity among populations of *M. arenaria* race 1 from the south-

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eastern United States on selected susceptible and resistant hosts.

Materials and Methods

Eleven populations of *M. arenaria* race 1 were collected from infected peanuts in Georgia (GA-1 to GA-9), Florida (FL-1), and Alabama (AL-1). Two North Carolina *M. arenaria* populations, race 1 (NC-1), and race 2 (NC-2), were obtained from greenhouse cultures maintained by K. R. Barker. Populations were characterized by examination of perineal patterns, a differential host-range test (14), and gel electrophoresis of esterase and malate dehydrogenase isozymes (4). The populations were maintained on Florunner peanut and transferred to Rutgers tomato, *Lycopersicon esculentum* Mill., 42 days before preparation of experimental inoculum.

Cultivars included in this study were Florunner peanut, Centennial soybean, Rutgers tomato, McNair Mc944, Northrup-King K326, and Speight G70 tobacco, *Nicotiana tabacum* L., and Carolina Cayenne, Mississippi Nemaheart, and Santanka pepper, *Capsicum frutescens* L. Centennial soybean (Maturity Group VI) is resistant to *M. incognita* (Kofoid & White) Chitwood, and susceptible to *M. arenaria* race 2 (9). K326 and G70 tobacco are resistant to *M. incognita* and moderately resistant to *M. arenaria* (1), and all three pepper cultivars are resistant to *M. incognita* (5–7). These cultivars were included to allow assessment of reproduction on suitable hosts, and under the selection pressure of resistance.

Three seeds of each cultivar were planted in 15-cm-d plastic pots filled with 1,500 cm^3 greenhouse soil mix. After emergence, seedlings were thinned to one per pot. Three-week-old transplants of tobacco cultivars were placed in the experimental pots at the same time the other cultivars were planted. For inoculum preparation, eggs of *M. arenaria* were collected from Rutgers tomato roots with 0.5% NaOCl (8); 10 days after planting, 20,000 eggs were suspended in 15 ml water and poured into three shallow depressions around the roots in each pot. Control plants received 15 ml water in the same manner. All plants were placed on greenhouse benches in a randomized complete block design with four replications, and the experiment was repeated. Temperatures in the greenhouse ranged from 20 to 33 C with a mean daily temperature of 27 C. Supplemental light with a photosynthetic photon flux density of 310 $\mu mol \cdot s^{-1} \cdot m^{-2}$ in the 400–700-nm waveband, 45 cm from the greenhouse bench, was supplied for 14 hours/day. Plants were fertilized with 0.5 g each N, P, and K weekly.

Nematode reproduction and the effect of *M. arenaria* on each cultivar was assessed 45 days after inoculation. Roots were washed free of soil, and fresh root weights and fresh and dry top weights (48 hours at 60 C) were recorded. Eggs of *M. arenaria* were collected from roots with 1.0% NaOCl (15) and counted with a stereomicroscope. Reproductive factors were calculated as the number of eggs collected divided by the initial inoculum level.

Results from the two experiments were combined for analysis. Significant differences in nematode reproduction and plant growth were determined using analysis of variance techniques followed by mean separation with Duncan's multiple-range test ($P = 0.05$) (13).

Factor analysis is a multivariate statistical method that formulates composite factors from a set of variables (13,16). The factors are formulated as linear combinations of the variables that account for the largest possible portion of variability in observed characteristics. Factors are usually interpreted according to the patterns of correlations for variables used to formulate the factor. Factors may be rotated by a number of methods to enhance the patterns. Rotations are usually done to aid in interpretation, since a rotated factor provides a more obvious pattern of correlations for individual variables. Factor analysis was used to analyze and interpret variation among the *M. arenaria* populations by utilizing repro-

duction data from all nine cultivars as variables. Data were standardized (mean = 0, standard deviation = 1), and three principal factors were adjusted with promax rotation to assist in interpretation.

Results

Population GA-8 produced more eggs on Florunner peanut than did the other *M. arenaria* race 1 populations (Table 1). The number of eggs produced by GA-8 was approximately three times the number produced by GA-6 or GA-9. Most of the egg production rates were between 3,000 and 6,000 eggs/g fresh root. A large gap in rates of eggs produced occurred between GA-8 and the other *M. arenaria* race 1 populations. Population GA-2 produced more eggs on Centennial soybean than eight of the other populations, and produced ca. three times more eggs than GA-5. Populations GA-7 and GA-8 produced more eggs than GA-3 and AL-1 on Rutgers tomato. A continuum of reproductive rates was observed on soybean (503–1,420 eggs/g root) and tomato (29,134–54,545 eggs/g root); however, population differences were least evident on tomato. Mean reproductive factors (Rf) were 6.5 times higher on peanut than on soybean and 7.2 times higher on tomato than on peanut.

Populations GA-4, GA-6, GA-9, and NC-1 suppressed dry top weights of peanut when compared to uninoculated control plants (Table 2). Changes in dry top weight compared to uninoculated plants ranged from a 29% decrease for GA-4 to a slight increase of 4% for AL-1. Fresh root weights did not differ from the control for any population, although there were differences among populations. There were no differences among dry top weights of soybean. All populations increased fresh root weights of soybean as compared to the control. Populations GA-1, GA-2, GA-8, and AL-1 reduced dry top weights of tomato when compared to the uninoculated control. The decrease in dry top weights of tomato ranged from 31% for GA-2 to 13% for GA-5. There were no differences among fresh root weights of tomato.

Population GA-7 produced more eggs on resistant tobacco cultivars (G70 and K326) than did any other population (Table 3). The Rfs for GA-7 were 48 on G70 and 29.6 on K326 tobacco, whereas all the other *M. arenaria* race 1 populations had Rfs of 3.0 or less on these cultivars. Populations GA-9, AL-1, and the race 2 population, NC-2, had Rfs greater than 1.0 on the resistant tobacco cultivars. The *M. arenaria* race 2 population did not produce more eggs on tobacco than the race 1 populations. The population rankings were similar between the two resistant tobacco cultivars but changed on the susceptible cultivar (Mc944), where Rfs were all above 20, and AL-1 produced the most eggs.

Populations FL-1, NC-1, GA-1, and GA-5 reduced dry top weights of G70 tobacco when compared to uninoculated controls (Table 4). Population FL-1 also reduced fresh root weight of G70 compared to the control. There were within-cultivar differences in fresh root weights of K326 and Mc944 tobacco, but dry top weights were not affected.

Carolina Cayenne, Mississippi Nemaheart, and Santanka pepper were resistant to *M. arenaria* races 1 and 2 (Table 5). Although egg production was very low for all populations on all three pepper cultivars, there were differences among populations in numbers of eggs produced. The race 2 population (NC-2) produced more eggs on Carolina Cayenne and Mississippi Nemaheart pepper than most of the race 1 populations.

There were few differences among dry top weights and fresh root weights of Carolina Cayenne and Santanka pepper inoculated with different *M. arenaria* populations (Table 6). Population GA-5 increased fresh root weight of Carolina Cayenne pepper when compared to uninoculated controls, but there were no other differences in dry top weights or fresh root weights compared to the control.

Populations GA-7 and GA-8 were separated from the other *M. arenaria* race 1 populations by principal factor analysis. Population GA-7 was separated from the

TABLE 1. Reproduction of 12 *Meloidogyne arenaria* race 1 populations on Florunner peanut, Centennial soybean, and Rutgers tomato 45 days after inoculation.

Population	Florunner peanut				Centennial soybean				Rutgers tomato			
	Number of eggs/g root	Rank†	Rf‡	Rank	Number of eggs/g root	Rank	Rf	Rank	Number of eggs/g root	Rank	Rf	Rank
GA-1	5,630 c	8	6.9 bcde	7	669 bc	9	1.1 c	9	39,427 ab	7	64.6 ab	6
GA-2	5,755 c	7	6.2 cde	8	1,420 a	1	2.9 a	1	33,884 b	10	50.5 ab	11
GA-3	5,448 c	9	5.3 e	11	1,163 ab	3	2.3 ab	3	31,319 b	11	55.1 ab	9
GA-4	8,804 bc	4	9.9 bc	3	673 bc	8	1.5 bc	6	42,083 ab	6	68.0 ab	5
GA-5	5,057 c	10	5.9 cde	9	503 c	12	1.0 c	12	42,837 ab	5	72.8 ab	2
GA-6	4,702 c	12	5.7 de	10	570 c	10	1.1 c	11	34,135 b	9	57.5 ab	8
GA-7	7,541 bc	5	8.2 bcde	6	842 bc	5	1.6 bc	5	54,545 a	1	79.9 a	1
GA-8	15,399 a	1	14.2 a	1	931 abc	4	1.7 bc	4	47,176 ab	2	69.1 ab	4
GA-9	4,810 c	11	4.7 e	12	529 c	11	1.1 c	10	43,435 b	4	61.8 ab	7
AL-1	7,370 bc	6	8.7 bcde	5	746 bc	6	1.3 bc	8	29,134 b	12	40.9 b	12
FL-1	9,242 bc	3	10.4 b	2	1,199 ab	2	2.4 ab	2	35,756 ab	8	53.9 ab	10
NC-1	10,595 b	2	9.4 bcd	4	675 bc	7	1.4 bc	7	45,495 ab	3	70.6 ab	3
Mean	7,447		7.9		820		1.6		39,941		62.0	
CV	55.7		44.7		55.9		60.0		40.5		44.3	

Mean of eight replications. Means within columns followed by the same letter are not different ($P = 0.05$).
† Rank of population within column to immediate left in descending order, from 1 = highest to 12 = lowest.
‡ Reproductive factor (Rf) defined as total number of eggs per plant divided by inoculum rate.

TABLE 2. Dry top and fresh root weights (grams) of Florunner peanut, Centennial soybean, and Rutgers tomato 45 days after inoculation with 12 *Meloidogyne arenaria* race 1 populations.

	Florunner peanut				Centennial soybean				Rutgers tomato			
Population	Top dry weight	Rank†	Fresh root weight	Rank	Top dry weight	Rank	Fresh root weight	Rank	Top dry weight	Rank	Fresh root weight	Rank
GA-1	6.5 abc	5	25.5 abc	11	8.6 a	3	35.6 b	2	6.6 b	4	32.6 a	10
GA-2	6.5 abc	6	24.0 abc	9	8.7 a	5	41.5 a	9	6.2 b	1	32.5 a	9
GA-3	6.9 abc	8	21.3 bc	3	9.1 a	7	40.1 ab	8	7.4 ab	10	34.1 a	13
GA-4	5.6 c	1	22.2 abc	5	8.3 a	1	42.2 a	11	7.6 ab	11	32.4 a	8
GA-5	7.1 abc	10	27.4 a	13	9.8 a	13	41.8 a	10	7.8 ab	12	33.2 a	11
GA-6	5.9 c	3	26.2 ab	12	9.5 a	10	39.9 ab	7	7.4 ab	9	33.9 a	12
GA-7	7.7 ab	11	22.7 abc	7	9.3 a	9	38.9 ab	5	7.3 ab	8	30.2 a	6
GA-8	6.7 abc	7	20.3 c	1	8.5 a	2	37.5 ab	4	6.3 b	2	29.4 a	4
GA-9	5.9 c	2	21.4 bc	4	9.3 a	8	42.4 a	12	6.9 ab	5	28.0 a	1
AL-1	8.2 a	13	24.8 abc	10	9.1 a	6	37.5 ab	3	6.6 b	3	29.5 a	5
FL-1	7.0 abc	9	22.8 abc	8	9.6 a	11	39.7 ab	6	7.3 ab	7	28.8 a	3
NC-1	6.2 bc	4	21.3 bc	2	9.8 a	12	42.9 a	13	7.0 ab	6	31.5 a	7
Control	7.9 a	12	22.5 abc	6	8.6 a	4	30.1 c	1	9.0 a	13	28.3 a	2
Mean	6.8		23.3		9.1		39.2		7.2		31.1	
CV	21.8		20.2		16.7		12.2		26.2		20.0	

Mean of eight replications. Means within columns followed by the same letter are not different ($P = 0.05$).
† Rank of population or uninoculated control within column to immediate left in ascending order, from 1 = lowest to 13 = highest.

TABLE 3. Reproduction of 12 *Meloidogyne arenaria* race 1 populations and one *M. arenaria* race 2 (NC-2) population on resistant (Speight G-70 and Northrup-King K-326) and susceptible (McNair 944) tobacco 45 days after inoculation.

	Speight G-70				Northrup-King K-326				McNair 944			
Population	Number of eggs/g root	Rank†	Rf‡	Rank	Number of eggs/g root	Rank	Rf	Rank	Number of eggs/g root	Rank	Rf	Rank
GA-1	124 b	8	0.4 b	9	216 b	5	1.0 b	5	8,970 ab	5	38.9 ab	6
GA-2	33 b	13	0.1 b	13	52 b	12	0.3 b	12	8,251 b	6	31.7 ab	7
GA-3	42 b	12	0.2 b	11	50 b	13	0.3 b	10	8,088 b	7	44.2 ab	3
GA-4	51 b	11	0.2 b	12	55 b	10	0.3 b	13	9,653 ab	3	43.6 ab	4
GA-5	84 b	10	0.4 b	10	52 b	11	0.3 b	11	7,443 b	8	26.9 b	12
GA-6	150 b	7	0.7 b	7	84 b	9	0.4 b	8	5,318 b	13	27.8 b	11
GA-7	12,042 a	1	48.0 a	1	6,449 a	1	29.6 a	1	9,358 ab	4	42.9 ab	5
GA-8	114 b	9	0.4 b	8	88 b	8	0.4 b	9	7,009 b	11	31.1 ab	9
GA-9	853 b	2	3.0 b	3	422 b	2	1.9 b	2	7,054 b	10	30.6 ab	10
AL-1	476 b	4	1.5 b	4	233 b	4	1.2 b	4	14,568 a	1	54.6 a	1
FL-1	262 b	5	0.8 b	5	141 b	7	0.7 b	7	5,532 b	12	23.7 b	13
NC-1	215 b	6	0.7 b	6	152 b	6	0.8 b	6	10,949 ab	2	47.9 ab	2
NC-2	751 b	3	3.0 b	2	326 b	3	1.7 b	3	7,157 b	9	31.3 ab	8
Mean	1,177		4.6		644		3.0		8,566		37.1	
CV	183.6		117.4		131.6		160.8		56.7		55.8	

Mean of eight replications. Means within columns followed by the same letter are not different ($P = 0.05$).
† Rank of population within column to immediate left in descending order, from 1 = highest to 12 = lowest.
‡ Reproductive factor (Rf) defined as total number of eggs per plant divided by inoculum rate.

TABLE 4. Dry top and fresh root weights (grams) of resistant (Speight G-70 and Northrup-King K-326) and susceptible (McNair 944) tobacco 45 days after inoculation with 12 *Meloidogyne arenaria* race 1 populations and one *M. arenaria* race 2 (NC-2) population.

	Speight G-70				Northrup-King K-326				McNair 944			
Population	Top dry weight	Rank†	Root fresh weight	Rank	Top dry weight	Rank	Root fresh weight	Rank	Top dry weight	Rank	Root fresh weight	Rank
GA-1	22.9 bc	4	78.5 ab	4	28.0 a	14	110.0 ab	6	19.4 a	3	81.1 ab	6
GA-2	28.9 ab	13	93.7 a	9	27.7 a	13	114.9 ab	11	16.2 a	1	73.6 b	1
GA-3	28.4 abc	11	94.0 a	10	26.8 a	12	132.9 a	14	25.5 a	10	112.2 a	14
GA-4	28.5 abc	12	95.4 a	13	24.4 a	8	122.0 ab	13	26.7 a	13	94.0 ab	12
GA-5	21.6 bc	3	83.1 ab	6	25.8 a	9	121.2 ab	12	19.0 a	2	80.0 ab	4
GA-6	26.2 abc	9	94.8 a	12	26.2 a	10	108.5 ab	5	24.8 a	8	104.8 ab	13
GA-7	24.2 abc	6	86.9 ab	8	20.8 a	1	98.9 b	1	21.7 a	5	83.9 ab	7
GA-8	24.2 abc	5	80.4 ab	5	22.3 a	4	112.6 ab	7	25.8 a	11	92.9 ab	11
GA-9	24.3 abc	7	74.5 ab	3	22.2 a	3	103.3 ab	3	25.0 a	9	80.3 ab	5
AL-1	25.2 abc	8	83.8 ab	7	22.3 a	5	100.9 b	2	22.9 a	7	80.0 ab	3
FL-1	20.3 c	1	65.1 b	1	22.8 a	6	113.8 ab	8	22.4 a	6	84.5 ab	8
NC-1	20.4 c	2	72.4 ab	2	22.1 a	2	105.3 ab	4	20.9 a	4	79.0 b	2
NC-2	27.4 abc	10	94.5 a	11	24.0 a	7	114.5 ab	9	26.5 a	12	86.1 ab	9
Control	32.2 a	14	96.8 a	14	26.7 a	11	114.9 ab	10	27.2 a	14	89.7 ab	10
Mean	25.4		85.5		24.5		112.5		23.1		86.8	
CV	27.2		23.7		29.1		22.3		40.0		30.3	

Mean of eight replications. Means within columns followed by the same letter are not different ($P = 0.05$).

† Rank of population or uninoculated control within column to immediate left in ascending order, from 1 = lowest to 13 = highest.

TABLE 5. Reproduction of 12 *Meloidogyne arenaria* race 1 populations and one *M. arenaria* race 2 (NC-2) population on pepper cultivars 45 days after inoculation.

Population	Carolina Cayenne				Mississippi Nemaheart				Santanka			
	Number of eggs/g root	Rank†	Rf‡	Rank	Number of eggs/g root	Rank	Rf	Rank	Number of eggs/g root	Rank	Rf	Rank
GA-1	8.0 ab	4	0.014 ab	9	5.3 bc	7	0.005 bc	7	2.2 a	12	0.005 a	10
GA-2	5.7 ab	7	0.014 ab	8	14.0 bc	3	0.014 bc	3	5.6 a	6	0.010 a	7
GA-3	5.2 ab	9	0.013 ab	11	2.7 c	9	0.002 c	9	2.9 a	11	0.005 a	11
GA-4	7.6 ab	5	0.016 ab	6	0.3 c	12	0.001 c	12	2.9 a	10	0.004 a	12
GA-5	4.9 ab	11	0.015 ab	7	7.8 bc	4	0.014 bc	4	1.4 a	13	0.003 a	13
GA-6	2.4 b	13	0.006 b	13	0.9 c	11	0.002 c	11	9.0 a	1	0.018 a	2
GA-7	5.1 ab	10	0.013 ab	10	4.5 bc	8	0.005 bc	8	8.4 a	2	0.020 a	1
GA-8	5.2 ab	8	0.018 ab	5	45.0 ab	2	0.042 ab	2	7.6 a	3	0.012 a	5
GA-9	3.8 b	12	0.009 ab	12	6.0 bc	6	0.010 bc	5	6.1 a	5	0.017 a	3
AL-1	10.0 ab	2	0.018 ab	4	0.0 c	13	0.000 c	13	5.4 a	7	0.010 a	6
FL-1	8.5 ab	3	0.021 ab	2	6.4 bc	5	0.008 bc	6	7.5 a	4	0.014 a	4
NC-1	7.3 ab	6	0.019 ab	3	1.7 c	10	0.002 c	10	4.2 a	9	0.007 a	9
NC-2	16.6 a	1	0.033 a	1	56.1 a	1	0.062 a	1	4.9 a	8	0.008 a	8
Mean	7.0		0.016		11.6		0.013		5.2		0.010	
CV	142.1		136.0		246.0		201.7		153.1		162.0	

Mean of eight replications. Means within columns followed by the same letter are not different ($P = 0.05$).
† Rank of population within column to immediate left in descending order, from 1 = highest to 12 = lowest.
‡ Reproductive factor (Rf) defined as total number of eggs per plant divided by inoculum rate.

TABLE 6. Dry top and fresh root weights (grams) of pepper cultivars 45 days after inoculation with 12 *Meloidogyne arenaria* race 1 populations and one *M. arenaria* race 2 (NC-2) population.

	Carolina Cayenne				Mississippi Nemaheart				Santanka			
Population	Top dry weight	Rank†	Fresh root weight	Rank	Top dry weight	Rank	Fresh root weight	Rank	Top dry weight	Rank	Fresh root weight	Rank
GA-1	10.1 ab	6	36.4 de	3	7.3 a	12	29.1 a	13	9.7 a	14	34.5 ab	13
GA-2	13.7 a	14	52.5 ab	13	6.3 a	6	21.1 a	1	7.1 ab	5	30.6 abc	6
GA-3	12.6 a	12	49.1 abcd	11	8.7 a	14	22.4 a	2	8.1 ab	9	30.5 abc	4
GA-4	10.3 ab	7	40.1 abcde	7	6.0 a	4	28.7 a	12	5.9 b	1	26.1 bc	2
GA-5	13.5 a	13	53.2 a	14	7.9 a	13	27.3 a	11	6.1 b	2	25.3 c	1
GA-6	6.1 b	1	31.3 e	1	7.1 a	11	22.9 a	3	9.5 a	13	32.9 abc	11
GA-7	10.6 ab	10	38.4 cde	4	6.6 a	7	25.1 a	7	8.2 ab	11	33.7 abc	12
GA-8	11.8 a	11	51.3 abc	12	6.8 a	9	25.0 a	6	8.0 ab	8	32.4 abc	10
GA-9	9.8 ab	4	42.9 abcde	10	7.0 a	10	29.2 a	14	9.4 a	12	38.7 a	14
AL-1	9.2 ab	3	35.1 e	2	5.4 a	2	25.1 a	8	6.9 ab	4	31.4 abc	8
FL-1	9.9 ab	5	42.5 abcde	9	6.0 a	5	25.4 a	9	8.1 ab	10	31.6 abc	9
NC-1	10.5 ab	9	42.0 abcde	8	6.7 a	8	24.1 a	5	6.2 b	3	30.5 abc	5
NC-2	9.1 ab	2	39.1 cde	5	5.7 a	3	26.2 a	10	7.3 ab	7	28.3 bc	3
Control	10.3 ab	8	39.3 bcde	6	4.4 a	1	23.0 a	4	7.2 ab	6	31.1 abc	7
Mean	10.5		42.4		6.6		25.3		7.7		31.3	
CV	37.9		26.9		44.9		31.3		33.8		23.8	

Mean of eight replications. Means within columns followed by the same letter are not different ($P = 0.05$).

† Rank of population or uninoculated control within column to immediate left in ascending order, from 1 = lowest to 13 = highest.

other populations along axis 1, which was determined primarily by levels of egg production on resistant tobacco cultivars, G70 and K326 (Fig. 1). Population GA-8 was separated along axis 2, which was determined by levels of egg production on Florunner peanut and Mississippi Nemaheart pepper. The other *M. arenaria* race 1 populations were closely clustered along the principal factor axes. The three populations from outside Georgia were within the range of variability of the Georgia populations. The first three principal factors (Table 7) accounted for 94% of the variance in the data structure.

Discussion

The differences detected in fecundity and pathogenicity among *M. arenaria* race 1 populations would be sufficient to require changing recommended management protocols. The 3-to-1 ratio in egg production between the highest (GA-8) and lowest (GA-6) producing populations

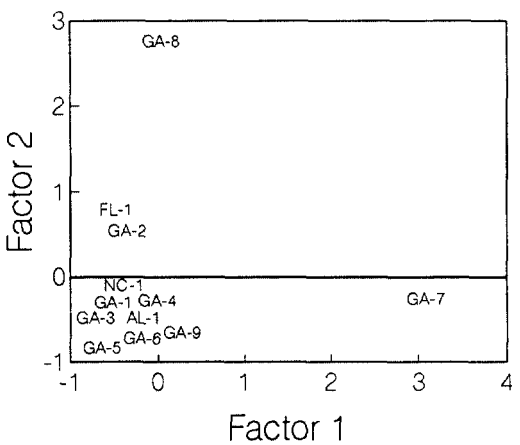

Fig. 1. Plot of scores on first two factors axes for 12 *Meloidogyne arenaria* race 1 populations. Nine of the populations (GA-1 to GA-9) are from Georgia, and one each are from Alabama (AL-1), Florida (FL-1), and North Carolina (NC-1). Factors are based on numbers of nematode eggs produced on Florunner peanut, Centennial soybean, Rutgers tomato, Speight G70, Northrup-King K326, and McNair Mc944 tobacco, and Carolina Cayenne, Mississippi Nemaheart, and Santanka pepper. Factor structures appear in Table 7. Note that populations GA-7 and GA-8 are separated from the other populations along factor axes 1 and 2, respectively.

on peanut would affect recommended crop rotation sequences, as well as the necessity to treat with a nematicide during the next growing season. Differences in pathogenicity among populations were also critical, because some populations decreased peanut growth up to 29%, whereas others had no observed effect on plant growth.

Likewise, one population (GA-7) produced more than 40 times as many eggs on resistant tobacco as other *M. arenaria* race 1 populations. This difference could have considerable impact on crop management recommendations. A few populations (GA-1, GA-5, FL-1, and NC-1) also reduced G70 tobacco growth but had no effect on K326 or Mc944, as compared to uninoculated controls. The variant population that produced more eggs on resistant tobacco (GA-7) apparently was not more pathogenic on tobacco.

Even on the highly resistant pepper cultivars, a few females were able to mature and reproduce. Resulting egg counts were very low, but differences were observed among the populations. There was no indication of a new race of *M. arenaria* under the extreme selection pressure of these resistant pepper cultivars.

These results confirm previously reported high levels of variability within the genus *Meloidogyne*. Similar variability in reproduction on tomato cultivars has been reported among field populations of *M. incognita* in California (12). Previously reported Rfs on Centennial soybean ranged from 0.4 to 3.3 for populations of *M. incognita* race 1, and from 1.4 to 18.8 for *M. incognita* race 3 (13). Differences have been reported in reproduction among three field populations of *M. arenaria* race 2 on soybean cultivars (2), although the degree of differences was not as great as reported here for *M. arenaria* race 1.

Variation in reproduction and pathogenicity among field populations must be considered as a source of error in making management recommendations. It is not likely that growers could obtain adequate information on field-specific *Meloidogyne*

TABLE 7. Factor structure (correlations) for analysis of variability in reproduction by 12 populations of *Meloidogyne arenaria* race 1 on nine cultivars.

Crop	Cultivar	Factor 1	Factor 2	Factor 3
Peanut	Florunner	7	88*	19
Soybean	Centennial	−4	52*	−4
Tomato	Rutgers	54*	30	−20
Tobacco	Speight G-70	98*	−9	0
Tobacco	Northrup-King K-326	98*	−9	1
Tobacco	McNair 944	8	−19	90*
Pepper	Carolina Cayenne	−21	10	90*
Pepper	Mississippi Nemaheart	2	91*	−33
Pepper	Santanka	47	34	−43

* Symbol indicates significant correlation coefficient (×100) ($P = 0.05$).

species characteristics, but the quantitative assessment of variance presented in this study would provide working safety margins for management specialists. Also, these results may explain unexpected failures of recommended protocols. Of particular concern for growers with peanut–tobacco rotations would be the possibility of encountering a population similar to GA-7.

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