

Morphological Comparisons of Host Races 1 and 2 of *Meloidogyne arenaria* from Florida¹

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Abstract: Morphometric comparisons of two populations each of Races 1 and 2 of *Meloidogyne arenaria* from tobacco, peanut, and soybean in different localities in Florida showed no significant differences in any characters measured by light microscopy. Thirteen morphometric characters of females, 22 of males, and 21 of infective second-stage juveniles were measured for each population. The stylet length in each population and in each life stage was the least variable character. Proposed character additions to supplement the description of *M. arenaria* and more precisely define the species include the following: female—metacarpus length and width, metacarpus valve length and width, vulva-anus distance; male—length of stylet shaft and knobs, stylet base to head end; infective juvenile—length of stylet shaft and knobs, head end to metacarpus valve, excretory pore to head end, metacarpus valve length and width, and d-ratio.

Key words: root-knot nematodes, morphometrics, population variation, light microscopy.

Meloidogyne arenaria (Neal, 1889) Chitwood, 1949 was described by Chitwood (1) from diseased peanut (*Arachis hypogaea* L.) in Georgia. He made reference to a similar nematode from ramie (*Boehmeria utilis* L.) that differed from *M. arenaria* in having a dorsal esophageal gland orifice that was only 3 μm behind the stylet base in both

males and females. This nematode did not reproduce on Spanish peanut and was subsequently diagnosed as a subspecies, *M. arenaria thamesi* (2).

In 1978, two host races of *M. arenaria* were proposed (8): Race 1, which infects and reproduces on peanut; and Race 2, which does not. Both races are widespread in north-central and western Florida where they cause serious losses to agronomic, vegetable, ornamental, and fruit crops (5). Race 1 is more common than Race 2 in Florida; however, most populations of *M. arenaria* worldwide are Race 2 (7).

No distinguishing morphological or cy-

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tological differences between the two host races have been reported (7). However, thorough, statistically based morphometric comparisons of the two races, using numerous specimens and many characters, have not been made.

The objectives of this study were to characterize morphometrically and by hosts two field populations each of the two host races of *M. arenaria*; to compare the morphometric data of their females, males, infective second-stage juveniles, and eggs; and to update the morphometric analysis of the species.

MATERIALS AND METHODS

Sources in Florida of four field populations of *M. arenaria* were Suwanee County for populations 183—'G-28' tobacco (*Nicotiana tabacum* L.); Jackson County for populations 186 and 201—'Florunner' peanut; and Holmes County for population 202—'Davis' soybean (*Glycine max* (L) Merr.).

Populations from eggs and juveniles obtained from the field were established and propagated on 'Rutgers' tomato (*Lycopersicon esculentum* Mill.) in a greenhouse at 22–35 C. All ecologic, morphologic, and morphometric observations were performed on nematodes from these cultures.

Host differential test: Certain host preferences were investigated using nematodes of each population (8). Corn (*Zea mays* L. cv. Minnesota A-401) and strawberry (*Fragaria ananassa* Duch. cv. Albritton) were also included as differential hosts.

Seedlings of tobacco, pepper, tomato, and strawberry were transplanted into 10-cm-d pots (one plant per pot), and nematodes were added immediately. Seeds of corn, peanut, watermelon, and cotton were planted with nematodes added after the first true leaves had formed. Egg masses (15–20) taken from ca. 60-day-old 'Rutgers' tomato plants were added to each pot as inoculum. The *M. arenaria* populations were evaluated twice on peanut, pepper, and corn. Sixty days after the nematodes were added, the plants were harvested and the roots rated for galling and egg masses (6).

Light microscope studies: All measurements of females, males, infective juveniles, and eggs were made using a camera lucida and were completed within 30 min-

utes of mounting the nematodes. To facilitate measuring, females were removed from roots and inserted in a depression made by a needle in a block of 1.7% agar, a drop of water was added, and a coverslip applied. After a female was measured, it was used to prepare a perineal pattern (9). Males from cultures less than 60 days old were dissected from galled tomato roots and mounted live in a drop of water on a sealed slide. Ten minutes after mounting, fully extended males were measured.

Infective juveniles were collected from egg masses selected at random from tomato roots and incubated in water in a shallow dish for 24 hours at 25 C. Freshly hatched juveniles were measured as described for males.

Egg masses were dispersed in 0.5% sodium hypochlorite (4); eggs were then rinsed thoroughly with tap water on a 20- μ m-pore sieve, mounted in 2% formalin, and examined.

RESULTS AND DISCUSSION

Morphometrics of females, males, infective juveniles, and eggs identified all four populations as *M. arenaria*. Our measurements (Tables 1–4) revealed that the means (with a few exceptions) of the reported characters for each population were within the expected ranges according to Chitwood (1), Whitehead (10), or Eisenback et al. (3).

The host differential test identified populations 186 and 201 as *M. arenaria* Race 1 (reproduced on peanut) and populations 183 and 202 as *M. arenaria* Race 2 (did not reproduce on peanut). There were no differences among the four populations on the remaining seven plant differentials.

Significant differences were found in the means of various characters of the four developmental stages among the four populations (Tables 1–4). A total of 80 characters were measured for females, males, and infective juveniles. Of these characters, the means differed significantly for 27, 29, 39, and 17 for populations 186, 201, 183, and 202, respectively. These differences appeared frequently between the populations of Races 1 and 2 as well as among populations within each race. Population 183 was the most distinctive population with the greatest number of dissimilar characters, whereas population 202 was

TABLE 1. Measurements (μm) of females of two populations each of Races 1 and 2 of *Meloidogyne arenaria* from tomato (range, mean, standard deviation, and percent coefficient of variability).

Characters	Race 1 (N33)		Race 2 (N35)	
	186	201	183	202
Body length	666–981 (828 a \pm 81.5) 9.8	568–1,156 (803 a \pm 152.3) 19.0	565–962 (739 b \pm 100.0) 13.5	593–1,215 (802 a \pm 117.9) 14.7
Body width	381–791 (545 a \pm 114.7) 21.1	319–650 (485 bc \pm 98.1) 20.2	378–736 (524 ab \pm 85.0) 16.1	300–631 (458 c \pm 76.8) 16.8
Vulva-slit length	20.9–32.8 (27.1 a \pm 2.8) 10.3	15.9–30.9 (24.9 b \pm 4.7) 18.8	18.1–31.3 (24.0 b \pm 2.5) 10.3	16.6–30.0 (23.5 b \pm 8.2) 13.5
Vulva–anus distance	15.0–25.9 (19.8 a \pm 2.5) 12.4	16.9–22.2 (19.4 a \pm 1.6) 8.4	15.6–25.3 (19.6 a \pm 2.3) 11.7	12.5–22.8 (18.9 a \pm 2.2) 11.7
Stylet length	13.8–17.2 (15.2 a \pm 0.9) 6.1	13.1–17.5 (15.0 a \pm 1.1) 7.5	13.4–17.2 (15.5 a \pm 1.0) 6.4	13.1–17.5 (15.4 a \pm 1.3) 8.3
Stylet knob height	1.9–3.8 (3.0 a \pm 0.4) 14.3	1.6–3.8 (2.8 a \pm 0.6) 21.7	2.2–3.4 (2.8 a \pm 0.3) 11.4	2.2–3.8 (2.8 a \pm 0.4) 15.8
Stylet knob width	3.4–5.3 (4.6 a \pm 0.5) 9.9	2.8–4.7 (3.9 c \pm 0.5) 12.3	3.1–5.0 (4.3 b \pm 0.5) 12.8	2.8–5.0 (4.1 bc \pm 0.5) 12.2
DGO	3.4–6.6 (4.8 a \pm 0.7) 15.6	3.8–7.8 (5.1 a \pm 0.8) 16.4	2.5–6.3 (4.1 b \pm 0.9) 20.9	3.1–6.9 (4.9 a \pm 1.0) 19.6
Excretory pore to head end	24.7–75.9 (47 b \pm 12.5) 26.4	35.0–89.7 (56.8 a \pm 15.9) 28.0	21.9–56.3 (33.5 c \pm 7.5) 22.3	28.1–60.9 (37.3 c \pm 7.0) 18.6
Metacarpus length	40.6–66.6 (49.3 a \pm 5.2) 10.5	38.4–55.0 (46.1 b \pm 4.3) 9.4	38.4–50.9 (44.1 c \pm 3.4) 7.7	37.2–56.6 (47.7 a \pm 4.7) 9.9
Metacarpus width	35.0–50.0 (43.2 a \pm 3.9) 9.0	23.8–50.9 (38.6 b \pm 5.8) 15.0	35.0–52.5 (42.5 a \pm 4.2) 9.8	34.4–51.6 (42.2 a \pm 4.3) 10.3
Metacarpus valve length	13.4–20.9 (17.4 a \pm 1.8) 10.3	10.0–18.4 (16.5 b \pm 1.8) 10.8	10.0–17.8 (14.4 c \pm 1.7) 11.7	11.9–18.4 (15.8 b \pm 1.5) 9.7
Metacarpus valve width	9.1–13.8 (11.5 a \pm 1.3) 10.9	8.1–13.4 (10.5 c \pm 1.3) 12.6	9.4–13.1 (11.1 ab \pm 1.0) 9.2	8.4–12.5 (10.8 bc \pm 1.1) 9.8
a-ratio	1.0–2.4 (1.6 b \pm 0.3) 19.0	1.2–2.2 (1.7 ab \pm 0.3) 16.8	1.1–2.1 (1.4 c \pm 0.2) 13.9	1.3–2.7 (1.8 a \pm 0.4) 19.6
Stylet knob width/height	1.2–2.3 (1.6 a \pm 0.2) 15.1	1.0–2.0 (1.5 a \pm 0.3) 19.5	1.1–2.0 (1.6 a \pm 0.2) 15.2	1.0–2.3 (1.5 a \pm 0.3) 19.3
Metacarpus length/width	0.9–1.4 (1.1 b \pm 0.1) 10.8	1.0–1.9 (1.2 a \pm 0.2) 14.9	0.9–1.2 (1.0 c \pm 0.1) 6.2	0.9–1.3 (1.1 b \pm 0.1) 8.0
Metacarpus valve length/width	1.2–1.9 (1.5 ab \pm 0.2) 10.3	1.2–1.9 (1.6 a \pm 0.2) 12.4	1.0–1.6 (1.3 c \pm 0.2) 13.4	1.1–1.9 (1.5 b \pm 0.2) 12.0
Excretory pore (%)	3.3–8.2 (5.7 b \pm 1.4) 24.7	4.0–8.9 (6.9 a \pm 1.3) 18.9	3.3–7.5 (4.6 c \pm 1.0) 20.9	3.5–7.5 (4.8 c \pm 1.0) 21.7

Means in rows with different letters are significantly different at the 5% level according to Duncan's new multiple-range test.

TABLE 2. Measurements (μm) of males of two populations each of Races 1 and 2 of *Meloidogyne arenaria* from tomato (range, mean, standard deviation, and percent coefficient of variability).

Characters	Race 1		Race 2	
	186 (N33)	201 (N38)	186 (N36)	202 (N33)
Body length	987-2,018 (1,544 c \pm 233) 15.1	821-1,525 (1,155 d \pm 180) 15.6	1,556-2,446 (1,996 a \pm 205) 10.3	1,387-2,240 (1,873 b \pm 205) 10.9
Greatest body width	25.6-36.3 (31.7 b \pm 2.8) 8.8	18.8-30.0 (25.3 c \pm 2.6) 10.2	30.9-45.0 (38.1 a \pm 2.8) 7.3	25.0-40.0 (32.1 b \pm 3.4) 10.5
Body width at stylet knobs	15.0-23.4 (19.5 b \pm 1.8) 9.0	14.7-20.9 (18.0 c \pm 1.8) 9.8	20.0-25.9 (22.4 a \pm 1.5) 6.7	16.6-24.4 (20.2 b \pm 1.6) 8.0
Body width at excretory pore	20.3-30.6 (26.9 b \pm 2.5) 9.2	20.0-26.6 (22.8 c \pm 1.7) 7.6	22.5-34.7 (29.7 a \pm 2.7) 9.0	21.3-33.1 (27.7 b \pm 2.8) 10.0
Head region height	4.1-7.5 (6.1 c \pm 0.6) 10.5	5.0-8.4 (6.2 bc \pm 0.6) 10.1	5.3-10.0 (7.3 a \pm 1.0) 13.3	4.7-9.4 (6.6 b \pm 1.0) 14.5
Head region width	10.0-13.1 (11.8 c \pm 0.8) 6.7	10.3-13.8 (12.0 c \pm 1.0) 8.1	11.9-15.6 (14.0 a \pm 0.8) 5.4	9.4-14.4 (12.9 b \pm 1.1) 8.5
Stylet length	17.5-25.9 (22.6 b \pm 1.8) 7.8	17.8-22.5 (20.1 c \pm 1.3) 6.6	20.0-26.9 (24.3 a \pm 1.7) 7.1	19.4-25.9 (22.8 b \pm 1.6) 7.1
Stylet base to head end	18.1-28.8 (24.5 b \pm 2.0) 8.1	18.4-26.4 (22.7 c \pm 1.7) 7.4	21.6-30.0 (26.4 a \pm 1.9) 7.0	22.2-28.8 (25.6 a \pm 1.5) 5.7
Stylet shaft and knobs	6.9-12.2 (10.6 b \pm 1.1) 10.2	8.1-12.2 (10.0 c \pm 0.9) 9.4	10.0-14.1 (11.9 a \pm 1.0) 8.2	9.4-14.1 (11.4 a \pm 1.0) 9.0
Stylet knob height	2.5-3.8 (3.3 b \pm 0.4) 12.9	1.9-4.4 (2.9c \pm 0.5) 17.6	2.8-4.7 (3.6 a \pm 0.5) 13.5	2.8-4.7 (3.6 a \pm 0.5) 13.0
Stylet knob width	3.4-5.9 (4.5 c \pm 0.5) 10.1	2.8-5.3 (4.0 d \pm 0.5) 11.5	4.4-6.3 (5.5 a \pm 0.4) 7.3	3.8-6.3 (5.0 b \pm 0.5) 10.3
DGO	4.7-7.2 (6.0 a \pm 0.7) 10.9	3.1-7.2 (4.8 c \pm 1.0) 21.1	2.5-6.3 (3.8 d \pm 0.8) 20.3	4.1-7.5 (5.6 b \pm 0.8) 14.5
Head end to metacarpus valve	64-116 (100 b \pm 12.7) 12.7	79-107 (92 c \pm 7.3) 8.0	65-119 (97 bc \pm 11.0) 11.4	80-130 (106 a \pm 12.7) 12.0
Metacarpus valve length	6.9-14.7 (8.9 a \pm 1.7) 18.8	5.9-10.9 (7.8 bc \pm 1.2) 15.0	5.9-10.0 (7.3 c \pm 1.0) 12.5	6.3-10.9 (8.1 b \pm 1.1) 13.2
Metacarpus valve width	4.1-8.4 (6.1 a \pm 1.1) 18.4	3.1-5.9 (5.0 c \pm 0.6) 12.4	4.7-6.6 (5.5 b \pm 0.5) 8.0	4.1-7.2 (5.6 b \pm 0.8) 13.7
Metacarpus width	9.4-18.8 (14.0 a \pm 2.2) 15.4	8.8-15.0 (11.3 b \pm 1.5) 13.3	10.0-17.2 (14.2 a \pm 1.6) 11.6	10.0-17.2 (13.9 a \pm 1.8) 12.7
Excretory pore to head end	118-213 (166 ab \pm 24.1) 14.5	133-182 (158 b \pm 13.0) 8.2	130-206 (174 a \pm 19.1) 11.0	132-215 (172 a \pm 19.8) 11.5
Tail length	9.7-19.4 (14.9 a \pm 2.3) 15.2	8.1-14.4 (11.2 c \pm 1.7) 15.7	10.3-15.6 (13.1 b \pm 1.5) 11.1	9.1-17.2 (13.9 b \pm 1.8) 12.8
Phasmid to tail end	13.1-21.6 (17.3 a \pm 2.6) 15.2	6.9-15.6 (11.1 c \pm 2.7) 25.0	12.2-20.6 (15.8 ab \pm 2.4) 15.3	11.6-18.4 (15.0 b \pm 2.4) 15.8
Spicule length	21.3-33.8 (26.8 b \pm 3.1) 11.7	16.9-29.1 (22.4 c \pm 3.4) 15.2	25.9-38.1 (31.1 a \pm 3.2) 10.3	21.3-36.9 (28.4 b \pm 3.9) 13.7
Gubernaculum length	7.2-8.8 (8.2 a \pm 0.4) 4.8	5.0-9.1 (8.1 a \pm 1.0) 12.7	6.6-13.1 (9.0 a \pm 2.0) 22.1	6.6-10.6 (8.4 a \pm 1.2) 14.1
Testis length	493-1,028 (755 b \pm 142) 18.8	372-925 (594 c \pm 109) 18.3	784-1,400 (1,090 a \pm 157) 14.4	512-1,168 (824 b \pm 183) 22.1
a-ratio	37.6-57.8 (48.6 c \pm 4.9) 10.1	33.5-57.5 (46.1 c \pm 4.5) 9.7	24.7-60.5 (51.5 b \pm 6.2) 12.0	47.7-68.7 (58.6 a \pm 5.2) 8.9
c-ratio	76-145 (104 a \pm 15.9) 15.2	78-149 (105 a \pm 16.9) 16.1	111-212 (155 c \pm 25.7) 16.6	107-178 (137 b \pm 17.4) 12.7
Body length/head end to metacarpus valve	12.7-19.7 (15.5 c \pm 1.7) 11.1	8.6-15.9 (12.5 d \pm 2.0) 15.9	15.9-26.0 (20.8 a \pm 3.1) 14.7	12.5-26.4 (17.8 b \pm 2.7) 15.0
Head region width/height	1.6-2.5 (2.0 a \pm 0.2) 10.3	1.6-2.5 (1.9 a \pm 0.2) 10.3	1.4-2.6 (1.9 a \pm 0.2) 12.5	1.5-2.8 (2.0 a \pm 0.3) 13.1
Stylet knob width/height	1.1-1.9 (1.4 b \pm 0.2) 12.2	0.9-1.8 (1.4 b \pm 0.2) 15.7	1.2-2.0 (1.6 a \pm 0.2) 12.7	1.0-1.7 (1.4 a \pm 0.2) 12.0
Metacarpus valve length/width	1.1-2.0 (1.5 a \pm 0.2) 14.4	1.2-3.1 (1.6 a \pm 0.4) 23.7	1.0-1.7 (1.3 b \pm 0.2) 12.9	1.2-1.9 (1.5 a \pm 0.2) 14.4
Excretory pore (%)	8.7-14.0 (11.0 b \pm 1.5) 13.9	11.2-18.3 (14.4 a \pm 1.9) 13.4	6.5-11.1 (8.8 c \pm 1.0) 11.8	7.7-12.7 (9.2 c \pm 1.1) 12.2
T (%)	38.2-56.1 (47.6 bc \pm 5.0) 10.4	41.0-64.2 (49.5 b \pm 5.6) 11.3	39.4-71.7 (54.5 a \pm 6.5) 12.0	25.2-60.5 (44.3 c \pm 9.0) 20.4

Means in rows with different letters are significantly different at the 5% level according to Duncan's new multiple-range test.

TABLE 3. Measurements (μm) of infective juveniles of two populations each of Races 1 and 2 of *Meloidogyne arenaria* from tomato (range, mean, standard deviation, and percent coefficient of variability).

Characters	Race 1		Race 2	
	186 (N56)	201 (N50)	183 (N53)	202 (N55)
Body length	413–556 (494 b \pm 3.4) 6.3	447–521 (486 b \pm 17.8) 3.6	400–484 (430 c \pm 18.1) 4.2	459–550 (507 a \pm 23.1) 4.6
Greatest body width	14.4–17.8 (15.8 a \pm 0.8) 4.9	14.1–18.8 (15.9 a \pm 0.9) 5.6	14.1–16.9 (15.2 b \pm 0.7) 4.6	14.7–17.8 (15.8 a \pm 0.7) 4.3
Body width at excretory pore	13.8–15.9 (14.8 a \pm 0.6) 3.9	13.4–17.8 (14.9 a \pm 0.8) 5.5	13.1–16.3 (14.4 b \pm 0.7) 5.1	13.4–19.7 (14.9 a \pm 1.0) 6.6
Body width at anus	10.0–13.1 (11.5 a \pm 0.7) 6.5	8.8–13.8 (11.1 b \pm 0.9) 7.9	9.4–13.4 (10.7 c \pm 0.8) 7.0	9.7–13.1 (11.0 bc \pm 0.8) 6.9
Head region height	1.9–3.1 (2.5 c \pm 0.3) 11.8	1.6–4.7 (2.4 c \pm 0.5) 22.1	2.2–3.8 (2.8 b \pm 0.4) 13.0	1.9–4.1 (2.9 a \pm 0.5) 16.6
Head region width	5.0–6.9 (5.9 a \pm 0.5) 7.9	4.4–6.9 (5.6 b \pm 0.5) 9.5	4.1–6.6 (5.6 b \pm 0.5) 9.0	3.4–6.9 (5.6 b \pm 0.6) 11.0
Stylet length	10.9–14.4 (12.8 b \pm 0.9) 7.0	10.6–14.7 (12.6 b \pm 1.0) 7.7	10.9–15.6 (13.5 a \pm 0.9) 6.8	10.6–15.6 (13.5 a \pm 1.1) 8.4
Stylet base to head end	13.4–16.6 (15.2 c \pm 0.6) 4.1	13.1–18.1 (15.7 b \pm 0.8) 4.9	14.4–16.9 (15.6 b \pm 0.5) 3.5	13.8–18.4 (16.2 a \pm 0.7) 4.6
Stylet shaft and knobs	4.7–6.3 (5.4 b \pm 0.4) 8.1	5.0–7.5 (6.0 a \pm 0.6) 9.9	4.1–6.6 (5.3 b \pm 0.5) 9.2	5.0–6.9 (6.0 a \pm 0.4) 7.3
Stylet knob height	0.9–2.5 (1.5 a \pm 0.3) 21.3	0.9–2.5 (1.5 a \pm 0.3) 22.7	0.9–1.9 (1.3 b \pm 0.2) 17.9	0.9–2.2 (1.5 a \pm 0.3) 19.9
Stylet knob width	1.3–2.5 (2.0 b \pm 0.3) 13.7	1.3–2.8 (2.0 b \pm 0.3) 17.1	1.3–2.8 (2.1 b \pm 0.3) 14.7	1.6–3.1 (2.3 a \pm 0.3) 14.3
DGO	2.5–5.0 (4.0 b \pm 0.7) 17.0	2.2–5.6 (4.3 a \pm 0.8) 18.4	2.2–4.1 (3.1 c \pm 0.4) 13.7	2.8–5.3 (4.1 ab \pm 0.6) 13.4
Head end to metacarpus valve	49.4–69.7 (61.6 b \pm 4.3) 7.0	56.6–69.3 (64.2 a \pm 3.1) 4.8	52.5–63.8 (58.0 c \pm 2.8) 4.9	54.7–69.3 (62.9 ab \pm 3.9) 6.2
Metacarpus valve length	4.1–6.0 (4.8 a \pm 0.4) 8.8	3.8–5.4 (4.6 b \pm 0.3) 7.4	3.8–5.3 (4.7 ab \pm 0.4) 7.5	4.1–5.6 (4.8 a \pm 0.3) 6.4
Metacarpus valve width	3.4–4.7 (4.0 a \pm 0.3) 8.1	3.1–4.7 (3.8 b \pm 0.4) 9.7	3.1–4.7 (4.0 ab \pm 0.3) 8.1	2.5–4.4 (3.9 b \pm 0.4) 11.2
Excretory pore to head end	71–102 (90 b \pm 6.7) 7.5	79–104 (94 a \pm 6.4) 6.8	72–96 (84 c \pm 4.4) 5.3	79–103 (93 a \pm 5.7) 6.1
Tail length	53.1–75.0 (66.1 a \pm 4.6) 6.9	54.1–69.7 (61.4 c \pm 3.3) 5.4	48.4–63.4 (55.0 d \pm 3.3) 6.0	55.0–72.5 (64.3 b \pm 4.3) 6.7
Tail terminus length	8.1–14.4 (10.8 c \pm 1.6) 14.5	8.1–15.9 (11.9 b \pm 2.1) 17.2	10.9–16.3 (13.4 a \pm 1.2) 9.3	10.0–17.5 (13.4 a \pm 1.7) 12.8
Tail terminus width at beginning	2.5–4.7 (3.5 b \pm 0.5) 12.9	2.5–4.7 (3.5 b \pm 0.5) 15.6	3.1–4.7 (3.9 a \pm 0.5) 12.2	2.5–4.1 (3.4 b \pm 0.4) 12.4
Phasmid to tail end	35.9–59.4 (46.4 a \pm 5.4) 11.6	40.6–51.6 (45.2 a \pm 3.3) 7.3	35.0–48.4 (41.5 b \pm 3.8) 9.1	40.0–55.6 (47.0 a \pm 4.8) 10.2
Genital primordium to tail end	164–230 (196 b \pm 17.3) 8.8	152–190 (173 c \pm 9.6) 5.6	145–185 (163 d \pm 9.0) 5.5	185–229 (205 a \pm 11.1) 5.4
a-ratio	24.9–36.7 (31.2 b \pm 2.2) 7.1	26.0–33.5 (30.5 b \pm 1.6) 5.2	25.5–31.8 (28.3 c \pm 1.2) 4.3	28.3–35.9 (32.2 a \pm 1.8) 5.5
c-ratio	6.9–8.4 (7.5 b \pm 0.3) 4.6	7.1–9.0 (7.9 a \pm 0.5) 5.8	7.3–8.5 (7.8 a \pm 0.3) 3.6	6.9–9.4 (7.9 a \pm 0.5) 6.8
d-ratio	4.9–6.9 (5.8 a \pm 0.4) 7.6	4.9–7.0 (5.6 b \pm 0.4) 8.1	4.4–5.9 (5.1 c \pm 0.3) 6.4	4.7–6.7 (5.9 a \pm 0.4) 7.4
Head region width/height	1.7–3.0 (2.4 a \pm 0.3) 11.6	1.4–3.2 (2.3 a \pm 0.4) 16.6	1.5–2.8 (2.0 b \pm 0.3) 13.9	1.0–2.7 (2.0 b \pm 0.4) 18.5
Stylet knob width/height	0.8–2.0 (1.4 b \pm 0.3) 21.5	0.7–2.3 (1.5 b \pm 0.4) 26.3	1.0–2.4 (1.6 a \pm 0.3) 20.9	1.0–2.7 (1.6 ab \pm 0.3) 21.8
Metacarpus valve length/width	1.0–1.5 (1.2 b \pm 0.1) 8.3	1.0–1.5 (1.2 ab \pm 0.1) 10.8	1.0–1.4 (1.2 b \pm 0.1) 9.2	1.0–2.1 (1.3 a \pm 0.2) 15.3
Tail length/tail terminus length	4.5–8.8 (6.2 a \pm 0.9) 15.0	3.7–6.9 (5.3 b \pm 0.9) 16.9	3.6–5.0 (4.1 d \pm 0.3) 6.7	3.9–6.7 (5.0 c \pm 0.6) 12.5
Tail terminus length/stylet length	0.6–1.2 (0.8 c \pm 0.1) 17.4	0.7–1.4 (0.9 b \pm 0.1) 18.8	0.8–1.2 (1.0 ab \pm 0.1) 11.2	0.8–1.5 (1.0 a \pm 0.2) 16.9
Excretory pore (%)	15.8–21.6 (18.2 b \pm 1.2) 6.6	17.1–22.0 (19.4 a \pm 1.1) 5.9	17.1–21.1 (19.5 a \pm 0.9) 4.6	16.3–20.6 (18.4 b \pm 1.2) 6.6
Genital primordium (%)	33.1–44.2 (39.2 b \pm 2.4) 6.0	32.2–38.4 (35.6 d \pm 1.7) 4.7	34.0–41.7 (38.0 c \pm 1.5) 4.0	37.9–45.9 (41.0 a \pm 2.2) 5.5
Phasmids (%)	7.4–11.4 (9.4 a \pm 1.0) 10.4	8.5–10.7 (9.3 a \pm 0.7) 7.2	8.6–10.8 (9.6 a \pm 0.7) 7.3	7.7–10.8 (9.3 a \pm 0.9) 9.6

Means in rows with different letters are significantly different at the 5% level according to Duncan's new multiple-range test.

TABLE 4. Measurements (μm) of 50 eggs of two populations each of Races 1 and 2 of *Meloidogyne arenaria* from tomato (range, standard deviation, and percent coefficient of variability).

Characters	Race 1		Race 2	
	186	201	183	202
Length	85-113 (97 c \pm 5.9) 6.0	94-109 (100 b \pm 5.7) 5.7	75-97 (85 d \pm 5.0) 5.9	87-125 (105 a \pm 7.5) 7.1
Width	41-53 (47 a \pm 3.4) 7.3	32-41 (40 d \pm 1.8) 4.6	38-47 (41 c \pm 2.6) 6.3	38-56 (44 b \pm 3.2) 7.2

Means in rows with different letters are significantly different at the 5% level according to Duncan's new multiple-range test.

TABLE 5. Amended and previous ranges for several important diagnostic characteristics of *Meloidogyne arenaria*.

Characters	Amended range (μm)	Previous range (μm)*
Female		
Stylet knob width	3.9-5.0	4.0-5.0
Stylet knob height	2.0-3.0	2.0
Male		
Body length	1,155-2,000	1,270-2,000
Stylet knob width	4.0-5.5	4.0-5.0
Stylet knob height	2.9-3.6	3.0
DGO	3.8-7.0	4.0-7.0
Spicule length	22.4-34.0	31.0-34.0
Infective juvenile		
Stylet length	10.0-13.5	10.0
Stylet base to head end	14.0-16.2	14.0-16.0
Stylet knob width	2.0-2.3	2.0
Stylet knob height	1.0-1.5	1.0
DGO	3.0-4.3	3.0
a-ratio	26.0-32.2	26.0-32.0
c-ratio	6.0-7.9	6.0-7.5
Egg		
Total width	32.0-47.0	32.0-44.0

* Composite of previously published measurements (1,3,10).

the least distinctive with the fewest number of dissimilar characters. Populations 186 and 201 lay in an intermediate position. However, the ranges for the characters overlapped, and most of the means fit within those described for *M. arenaria*.

Our analysis of the two host races of *M. arenaria* by light microscopy did not reveal any distinguishing morphometric characters. All four populations generally fit the original description, including perineal patterns as reported by Chitwood (1) and updated by Whitehead (10) and Eisenback et al. (3). However, differences in the ranges for a few characters were observed among our populations of *M. arenaria* and those reported by previous workers. We, therefore, amend the ranges for these characters to more precisely define the species (Table 5).

Furthermore, we suggest that the following characters, all of which can be measured easily with the light microscope, be added to the description of *M. arenaria*: female—metacarpus width 24-53 (41.6), metacarpus length 37-67 (46.7), metacarpus valve length 10-21 (16), metacarpus

valve width 8–14 (11), vulva–anus distance 13–26 (19); male—stylet base to head end 18–30 (24.8), stylet shaft and knobs 7–14 (10.9); infective juvenile—stylet shaft and knobs 4–8 (5.7), head end to metacarpus valve 49–70 (61.6), excretory pore to head end 71–104 (90.0), metacarpus valve length 4–6 (4.7), metacarpus valve width 3–5 (3.9), d-ratio 4–7 (5.6). Measurements are in μm .

LITERATURE CITED

1. Chitwood, B. G. 1949. Root-knot nematodes. I. A revision of the genus *Meloidogyne* Goeldi, 1887. Proceedings of the Helminthological Society of Washington 16:90–104.
2. Chitwood, B. G., A. W. Specht, and L. Havis. 1952. Root-knot nematodes. 3. Effects of *Meloidogyne incognita* and *M. javanica* on some peach rootstocks. Plant and Soil 4:77–95.
3. Eisenback, J. D., H. Hirschmann, J. N. Sasser, and A. C. Triantaphyllou. 1981. A guide to the four most common species of root-knot nematodes (*Meloidogyne* species), with a pictorial key. Raleigh: North Carolina State University Graphics.
4. Hussey, R. S., and K. R. Barker. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp. including a new technique. Plant Disease Reporter 57:1025–1028.
5. Kirby, M. F., D. W. Dickson, and G. C. Smart, Jr. 1975. Physiological variation within species of *Meloidogyne* occurring in Florida. Plant Disease Reporter 4:353–356.
6. Sasser, J. N. 1954. Identification and host parasite relationships of certain root-knot nematodes (*Meloidogyne* spp.). University of Maryland Agricultural Experiment Station Bulletin A77.
7. Sasser, J. N., and C. C. Carter. 1982. Root-knot nematodes (*Meloidogyne* spp.): Identification, morphological and physiological variation, host range, ecology, and control. Pp. 21–32 in R. D. Riggs, ed. Nematology in the southern region of the United States. Arkansas Agricultural Experiment Station, Southern Cooperative Series Bulletin 276.
8. Taylor, A. L., and J. N. Sasser. 1978. Biology, identification, and control of root-knot nematodes (*Meloidogyne* species). Raleigh: North Carolina State University Graphics.
9. Taylor, D. P., and C. Netscher. 1974. An improved technique for preparing perineal patterns of *Meloidogyne* spp. Nematologica 20:268–269.
10. Whitehead, A. G. 1968. Taxonomy of *Meloidogyne* (Nematodea: Heteroderidae) with descriptions of four new species. Transactions of the Zoological Society of London 31:263–401.