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Relationship Between Morphology and Parasitism in Two Populations of *Meloidogyne incognita*[1]

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Abstract: The reliability of morphological characters and host differential plants for distinguishing between two populations of *Meloidogyne incognita* was studied. Population A (originally from North Carolina) had incognita-type perineal patterns. A single egg mass subpopulation of population A had a mixture of incognita and acrita perineal patterns with 33% of the patterns atypical for either species. Population B (from Georgia) had predominantly acrita-type patterns with only about 5% atypical patterns. The head shapes of males from both populations were mainly *M. incognita.* On the basis of stylet length, both populations conformed to *M. incognita acrita.* Both populations were identified as *M. incognita* race 1 by reaction on the North Carolina differential hosts. Reactions on azalea and pepper gave no clear identification of the populations. We concluded that there is no relation between perineal pattern, male head shape, and parasitism of host differentials with the two populations studied.

Key words: Meloidogyne incognita, races, morphology, taxonomy, parasitism.

Confusion of the taxonomy of root-knot nematodes has persisted since the first description of a root-galling nematode. Although variation in perineal patterns have been noted among individuals of a species, patterns typical of that species are more common than variants (2,14). Thus, perineal patterns are very useful for identifying species of *Meloidogyne* Goeldi, particularly the more common species. Recent scanning electron microscope and light microscope studies revealed that male head and female stylet shapes are also reliable characters for identifying the more common *Meloidogyne* spp. (4).

Differential hosts were first used in 1944 to distinguish species and intraspecific forms of root-knot nematodes (3). At present, a host test is recommended to distinguish the four more common *Meloidogyne* spp., four races of *M. incognita,* and two races of *M. arenaria* (16). It is recognized, however, that because of species mixtures or incomplete host data for a given species, identification of *Meloidogyne* spp. cannot be made solely with host differentials (4).

The existence of intraspecific forms of *M. incognita* is controversial. The distinction between the two subspecies, *M. incognita incognita* and *M. incognita acrita* Chitwood, 1949, has been amended (7), the subspecies have been raised to the species level (5), and their assignment to species has been rejected (19,21). In addition to the two subspecies, two races were recognized (8), one of which was later described as *M. grahami* Golden & Slana, 1978 (10) and the other raised to subspecies (9).

Attempts have been made to relate nematode morphology to the pattern of parasitism on host differentials to distinguish intraspecific forms of *M. incognita.* Originally, *Gossypium hirsutum* L. and *Lycopersicon peruvianum* (L.) Mill. were reported to be parasitized only by the subspecies *M. incognita acrita* (15). Later, *M. incognita acrita* and *M. incognita incognita* were considered to be morphologically indistinguishable and no relation was evident between their morphology and parasitism on *G. hirsutum* or *L. peruvianum* (19). Some researchers still contended, however, that *M. incognita acrita* and *M. incognita incognita* were morphologically different and that *Capsicum annuum* L. (pepper) was parasitized by *M. incognita acrita* but not by *M. incognita incognita* and that *Rhododendron obtusum* Planch. (azalea) was parasitized by *M. incognita incognita* but not by *M. incognita acrita* (7).

Our objectives were to determine 1) the

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TABLE 1. Percentages of perineal pattern types in populations A and B of *Meloidogyne incognita*.

Origin of population*	Types		
	Incognita	Acrita	Atypical
OP-A	91	9	0
SP-A	63	4	33
OP-B	0	95	5
SP-B	0	96	4

* OP = original population. SP = single egg mass population.

reliability of certain morphological characters and the reaction of host differential plants in distinguishing *M. incognita* and *M. incognita acrita* and 2) the relation between morphology and parasitism in two populations of *M. incognita*.

MATERIALS AND METHODS

Two populations of *M. incognita* were maintained in the greenhouse on *L. esculentum* Mill. cv. Rutgers. Population A originated from North Carolina, and population B originated from Georgia. Both populations were originally collected from tomato. To obtain perineal patterns, egg-laying females were dissected from tomato roots and processed (18). About 25 perineal patterns were examined from each of the original populations and 25 additional patterns from subpopulations of the originals started from single egg masses. To study male head shape, number of head annules, and stylet length, males were extracted from tomato roots using a mechanical shaker and processed according to Hooper (11). About 25 males of each population and subpopulation were observed in lateral position. Race 2 of *M. incognita* obtained from the International Meloidogyne Project (IMP) was compared with populations A and B.

For host differential tests, seeds of the differentials were planted in 1,000-cm^3 pots containing a mixture of recycled potting compost, sand, and peat (2:1:1) and grown in a greenhouse at 23–28 C. The potting mixture for azalea (*R. obtusum* 'Hino Crimson') was sand, peat, vermiculite, and perlite (5:1:1:1). Seedlings of the differential hosts were inoculated with 10,000 eggs per pot. Eggs for inoculum were obtained from tomato roots using NaOCl (12). Nematode reproduction was determined 50 days after inoculation. Roots were immersed in water, gently washed, and weighed, and eggs were extracted with NaOCl. Numbers of eggs per gram of root and final population/initial population (Pf/Pi) ratios were used to determine host efficiency. If Pf/Pi was more than one, the plants were considered susceptible.

RESULTS

Morphology: Original population A had predominantly *M. incognita incognita* type perineal patterns (Table 1). In the single egg mass subculture of population A, 33% of the perineal patterns were atypical and could not be classified as either incognita or acrita type. The original culture and subcultures of population B had predominantly acrita type perineal patterns with a small percentage of patterns atypical of either subspecies.

Head shapes of males of all populations were mainly incognita type, but some atypical head shapes were observed. There were three head annules in males of all populations; however, annules varied from faint to very pronounced within a population. Male stylet lengths were not different among populations: 22.4 ± 1.20 μm in population A, 22.2 ± 0.89 μm in population B, and 22.1 ± 1.01 μm in race 2.

Host differential test: Reactions of the North Carolina host differentials to populations A and B are shown in Table 2. Pepper, tomato, and watermelon (*Citrullus lanatus* (Thunb.) Mansf.) were susceptible hosts for both populations, whereas peanut (*Arachis hypogaea* L.), cotton, and tobacco (*Nicotiana tabacum* L.) were nonhosts. Host response of azalea and pepper is shown in Table 3. Pepper was a susceptible host for both the original and the single egg mass populations of populations A and B. Although the Pf/Pi ratio with the single egg mass population of population A was only 1.1, the number of eggs per gram of root clearly indicated that pepper is a suscep-

TABLE 2. Reproduction of populations A and B of *Meloidogyne incognita* on the North Carolina differential hosts.

Differential plant	Pf* (eggs/ plant)	Eggs/g root	Pf/Pi*
Population A			
Pepper 'California Wonder'	348,000	49,714	34.8
Tomato 'Rutgers'	265,920	20,614	26.6
Watermelon 'Charleston Grey'	191,760	14,638	19.2
Peanut 'Florunner'	0	0	0
Cotton 'Deltapine 16'	0	0	0
Tobacco 'NC95'	0	0	0
Population B			
Pepper 'California Wonder'	509,040	33,489	50.9
Tomato 'Rutgers'	212,560	15,982	21.3
Watermelon 'Charleston Grey'	122,640	8,823	12.3
Peanut 'Florunner'	0	0	0
Cotton 'Deltapine 16'	0	0	0
Tobacco 'NC95'	0	0	0

* Pf = final population. Pi = initial population.

TABLE 3. Reproduction of populations A and B of *Meloidogyne incognita* on azalea and pepper.

Nematode population*	Pf† (eggs/plant)	Eggs/g root	Pf/Pi†
Population A			
Pepper (OP)	33,280	5,456	3.3
Pepper (SP)	11,360	7,100	1.1
Azalea (OP)	4,800	1,714	0.5
Population B			
Pepper (OP)	96,880	31,252	9.7
Pepper (SP)	80,560	30,985	8.0
Azalea (OP)	13,100	1,795	1.3

* OP = original population. SP = single egg mass population.
† Pf = final population. Pi = initial population.

tible host. The Pf/Pi ratio was greater for the B than the A populations. Even though populations A and B reproduced on azalea, it was not a very good host for either population. Mature females protruded from the roots, but galls on the thin azalea roots were not conspicuous; some roots had small galls, whereas others had none.

DISCUSSION

On the basis of perineal patterns, original population A would be classified as *M. incognita incognita*, and the single egg mass subpopulation of population A would be classified as a mixture of subspecies, in which *M. incognita incognita* predominated, but with a high percentage of atypical patterns. Our results agree with earlier findings (19) that the two types of perineal patterns can be present in a single egg mass population. Perineal patterns of the original and single egg mass populations of population B were less variable than were patterns of population A; they also were typical of *M. incognita acrita*. Whitehead (21) found similar variability in perineal patterns of *M. incognita acrita* populations.

According to male head shape, all populations we studied would be classified as *M. incognita* with a small percentage of atypical head shapes. We could not differentiate these populations by the degree of annule distinctiveness in the male head.

Reaction of populations A and B was similar to that of *M. incognita* on the North Carolina differential hosts. Based on the reaction of the host differentials, populations A and B were identified as race 1 of *M. incognita*. In a controlled temperature study, however, these two populations differed significantly in parasitism on potatoes (1), indicating differences in parasitism within a single race. Races of *M. incognita* are differentiated according to their ability to parasitize specific cultivars of tobacco and cotton, but there are reports of differences in parasitism of *M. incognita* on tomatoes (13), sweet potatoes (6), soybean (9), alfalfa (20), cowpea (17), pepper (17) and lima bean (20). We believe that separate race schemes should be established for each crop for which breeding for resistance to *M. incognita* is a high priority.

Clear distinction of populations A and B was not possible with host tests on azalea and pepper. Population A reproduced well on pepper and moderately on azalea indicating that it was *M. incognita acrita*. By perineal patterns, however, population A was identified as *M. incognita incognita*. Host response of azalea and pepper for popu-

lation B was typical of subspecies *M. incognita acrita*; but the Pf/Pi ratio on azalea was only ca. 1.0.

We conclude that if the acrita and incognita type perineal patterns are considered together as a single type characteristic of *M. incognita,* perineal patterns are useful to identify this species. The fact that both acrita and incognita type perineal patterns were present in a single egg mass population indicates that the perineal pattern is not a good character for subspecies identification in *M. incognita.* Also, there was no relation between perineal pattern and plants parasitized. Male head shape is a reliable character for species identification even though atypical shapes occur. Because we found no reliable relationship between any morphological characters and pattern of plant parasitism, we support the rejection of *M. incognita acrita* as a subspecies of *M. incognita* and the species status of *M. acrita* (19).

Literature Cited

1. Canto-Saénz, M., and B. B. Brodie. 1986. Host efficiency of potato to *Meloidogyne incognita* and damage threshold densities on potato. Nematropica, 16: 109–116.

2. 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.

3. Christie, J. R., and F. E. Albin. 1944. Host–parasite relationships of the root-knot nematode *Heterodera marioni.* I. The question of races. Proceedings of the Helminthological Society of Washington 11: 31–37.

4. Eisenback, J. D. 1985. Diagnostic characters useful in the identification of the four most common species of root-knot nematodes (*Meloidogyne* spp.). Pp. 95–112 *in* J. N. Sasser and C. C. Carter, eds. An advanced treatise on *Meloidogyne,* vol. 1. Biology and control. Raleigh: North Carolina State University.

5. Esser, R. P., V. G. Perry, and A. L. Taylor. 1976. A diagnostic compendium of the genus *Meloidogyne* (Nematoda: Heteroderidae). Proceedings of the Helminthological Society of Washington 43:138–150.

6. Giamalva, M. J., W. J. Martin, and T. P. Hernandez. 1963. Sweet potato varietal reaction to species and races of root-knot nematodes. Phytopathology 53:1187–1189.

7. Golden, A. M. 1974. *Meloidogyne incognita*: A single, homogenous species or a complex of two or more taxa? Journal of Nematology 6:141 (Abstr.).

8. Golden, A. M. 1977 Subspecific forms of the *Meloidogyne incognita* complex. Journal of Nematology 9:268–269 (Abstr.).

9. Golden, A. M., and W. Birchfield. 1978. *Meloidogyne incognita wartelli* n. subsp. (Meloidogynidae) a root-knot nematode on resistant soybeans in Louisiana. Journal of Nematology 10:269–277.

10. Golden, A. M., and L. J. Slana. 1978. *Meloidogyne grahami* n.sp. (Meloidogynidae) a root-knot nematode on resistant tobacco in South Carolina. Journal of Nematology 10:355–361.

11. Hooper, D. J. 1970. Handling, fixing, staining and mounting nematodes. Pp. 39–54 *in* J. F. Southey, ed. Laboratory methods for work with plant and soil nematodes. Ministry of Agriculture, Fisheries, and Food. London: HMSO.

12. Hussey, R. S., and K. R. Barker. 1973. A comparison of method of collecting inocula of *Meloidogyne* spp. including a new technique. Plant Disease Reporter 57:1025–1028.

13. Linde, W. J. van der. 1956. The *Meloidogyne* problem in South Africa. Nematologica 1:177–183.

14. Lopez-Chavez, R., and D. W. Dickson. 1976. Host response and morphometric variations among three populations of *Meloidogyne incognita* and one of *M. javanica* from Florida. Journal of Nematology 8: 293 (Abstr.).

15. Sasser, J. N. 1954. Identification and host-parasite relationships of certain root-knot nematodes (*Meloidogyne* spp.). Technical Bulletin A-77, University of Maryland Agricultural Experiment Station.

16. Sasser, J. N. 1972. Physiological variation in the genus *Meloidogyne* as determined by differential hosts. OEPP/EPPO Bulletin Number 6:41–48.

17. Southards, C. J., and M. F. Priest. 1973. Variation in pathogenicity of seventeen isolates of *Meloidogyne incognita.* Journal of Nematology 5:63–67.

18. Taylor, D. P., and C. Netscher. 1974. An improved technique for preparing perineal patterns of *Meloidogyne* spp. Nematologica 20:268–269.

19. Triantaphyllou, A. C., and J. N. Sasser. 1960. Variations in perineal patterns and host specificity of *Meloidogyne incognita.* Phytopathology 50:724–735.

20. Viglierchio, D. R. 1978. Resistant host responses to 10 California populations of *Meloidogyne incognita.* Journal of Nematology 10:224–227.

21. Whitehead, A. G. 1968. Taxonomy of *Meloidogyne* (Nematoda: Heteroderidae) with descriptions of four new species. Transactions of the Zoological Society of London 31:263–401.