Races of the Barley Root-Knot Nematode, Meloidogyne naasi. II. Developmental Rates[1]

R. E. MICHELL, R. B. MALEK, D. P. TAYLOR and D. I. EDWARDS[2]

Abstract: The developmental rates of the five newly designated races of *Meloidogyne naasi* were compared on barley, oat and sorghum. Races 1, 2, 3 and 4 developed and reproduced on both barley and oat but not on sorghum. Race 5 developed and reproduced readily on sorghum but poorly on oat. A more rapid rate of development of Race 5 on both barley and sorghum than that of other races on barley demonstrated that Race 5 has a shorter life cycle than do Races 1-4.

Five physiological races within *Meloidogyne naasi* Franklin, the barley root-knot nematode, were designated in the first paper of this series (3). The races differed in ability to reproduce on certain plant species reported as hosts of *M. naasi*.

Rates of nematode development have been reported to differ among populations of the same species. Minton (4) found that second-stage larvae from two populations of *Meloidogyne arenaria* (Neal) Chitwood penetrated roots of Early Runner peanuts in equal numbers, but there were differences between populations in rate of larval development. Comparing two biotypes of *Tylenchulus semipentrans* Cobb, Baines et al. (2) showed that one was more infective and matured faster than the other on two citrus hosts.

The purpose of this study was to determine whether the known races of *M. naasi* differ in their developmental rates on three plant species of varying susceptibility.

MATERIALS AND METHODS

Developmental rates of the five races of *M. naasi* were compared on barley, *Hordeum vulgare* L. 'Traill'; oat, *Avena sativa* L. 'Wintok'; and sorghum, *Sorghum bicolor* (L.) Moench 'RS-610'. Barley, the type host of *M. naasi*, and oat are susceptible to all races (3); oat, however, has shown varying degrees of resistance to Race 3, at least (7). Sorghum supports reproduction only for Race 5 (3).

Single egg mass isolates of *M. naasi* populations, representing the known races, were maintained in a greenhouse on Traill barley. Populations originated from England,

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[2] Former Graduate Research Assistant in Plant Pathology; Assistant Professor of Nematology; and former Professor of Nematology, respectively; University of Illinois, Urbana 61801; and Nematologist, Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, Urbana, Illinois 61801. Addresses of first and third authors, respectively: Environmental Protection Agency, Pesticide Regulation Division, Washington, D.C. 20250; East African Agricultural and Forestry Research Organization, Nairobi, Kenya.

California, Illinois, Kentucky and Kansas (Races 1, 2, 3, 4 and 5, respectively). Nematode storage, extraction, disinfestation and inoculation techniques were the same as those described by Michell et al. (3).

Seedlings were established in 10-cm plastic pots containing a steam-pasteurized mixture of sandy loam soil and quartz sand (2:1) and thinned to one/pot. One week after plant emergence, nine pots of each plant species/nematode race were inoculated with a 10-ml aqueous suspension of 2000 second-stage larvae/pot. Pots were arranged randomly on a greenhouse bench where ambient temperatures averaged 27 C. One hundred ml of a 23-19-17 fertilizer solution were applied to each pot at 3-week intervals.

Three replications of each treatment were removed at intervals of 15, 30 and 50 days after inoculation to determine nematode development. Roots were washed free of soil and stained in 0.1% acid fuchsin in lactophenol. Wherever possible, at least 50 galls containing the most advanced nematode stages were removed from the root system of each plant and placed in 60-mm petri dishes of lactophenol. Individual galls from 15-day samples were carefully dissected and the nematodes mounted in lactophenol on glass slides. At 30 and 50 days, galls were mounted directly on slides. The developmental stage and sex of individual nematodes were determined under a compound microscope.

RESULTS

Data on rates of development of the races of *M. naasi* on barley, oat and sorghum are summarized in Table 1. On individual hosts, developmental rates of Races 1, 2, 3 and 4 were essentially the same. Moreover, progress on barley was similar to that on oat. The predominant forms at 15 days after inoculation were third- and fourth-stage larvae. At 30 and 50 days, females with eggs predominated the population. All four races had produced second-generation, second-stage larvae at 50 days. Males rarely were detected in these hosts and no differences in male:female ratios (ca. 1:30) were found among the races. On sorghum, which was a host for only Race 5, larvae of Races 1-4 penetrated roots but failed to develop beyond the second stage or to induce galling.

Race 5 developed somewhat faster on barley

TABLE 1. First-generation development of five races of *Meloidogyne naasi* on barley, oat and sorghum.

Plant species and cultivar	Days after inoculation	Nematode race[a]	No. nematodes examined per race	2nd-stage larvae (%)	3rd- and 4th-stage larvae (%)		Adults (%)		
					Females	Males	Females Without eggs	Females With eggs	Males
Barley Traill	15	1-4	150	26	71	2	<1	0	0
		5	150	12	64	5	19	0	1
	30	1-4	158	0	0	0	10	85	5
		5	152	0	0	0	1	98	1
	50	1-4	156	0[b]	0	0	0	96	4
		5	152	0[b]	0[b]	0	0	99	1
Oat Wintok	15	1-4	150	34	65	<1	<1	0	0
		5	69	51	23	10	16	0	0
	30	1-4	162	0	0	1	12	81	6
		5	64	0	2	36	9	30	23
	50	1-4	127	0[b]	0	0	2	94	4
		5	0	0[b]	0	0	0	0	0
Sorghum RS-610	15	1-4	10	100	0	0	0	0	0
		5	150	10	40	5	44	0	1
	30	1-4	0	0	0	0	0	0	0
		5	152	0[b]	0	0	0	99	1
	50	1-4	0	0	0	0	0	0	0
		5	153	0[b]	0[b]	0	0	98	2

[a]Races 1-5 represented by populations from England, California, Illinois, Kentucky and Kansas, respectively.
[b]Second-generation nematodes present.

than did the other races. At 15 days, 19% of the population were adult females compared to 2% for Races 1-4. Differences were slightly less at 30 days, where 99% of Race 5 females had reached the egg-producing stage in contrast to 89% in Races 1-4. Although no egg counts were made, Race 5 egg masses were noticeably larger than those of other races, and were the only ones to contain fully embryonated eggs. At 50 days, only Race 5 had proceeded past the second stage in the second generation.

Wintok oat was a poor host for Race 5, and induced a high degree of maleness in the nematode population. Development appeared to be somewhat slower than in other races. At 15 days, there was an average of only 23 nematodes/plant; half were still in the second larval stage. At 30 days, 59% of the remaining individuals were males and only 30% of the population were egg-bearing females. A few second-generation infective larvae were present 50 days after inoculation, but no first-generation nematodes were detected in the roots.

Only Race 5 developed and reproduced on sorghum, which appeared to be the most suitable of the three hosts for this race. Development was more rapid than was that of any race on barley; 45% of individuals were adults by 15 days after inoculation, compared with 20% of Race 5 and less than 1% of Races 1-4 on barley. Second-generation, second-stage larvae were present as early as 30 days after inoculation, and all first-generation individuals were adults. All stages of second-generation larvae were present at 50 days.

DISCUSSION

Differences in developmental rates between populations of the same nematode species have been shown for *Meloidogyne arenaria* (4) and *Tylenchulus semipenetrans* (2). No distinct differences were observed in rates of development among Races 1-4 of *M. naasi* on either barley or oat. Development was approximately 1 week faster than that reported by Siddiqui and Taylor (6) for an Illinois population (Race 3) on wheat, which also is a host for all races (3). The shorter life cycle in our study probably was due to the higher average ambient temperature (27 C), which was determined by Radewald et al. (5) to be the optimum for a California population from creeping bentgrass. Siddiqui and Taylor (6) reported that population increase of Race 3 was lower on oat than on several varieties of wheat and barley. In our study, galls were somewhat less abundant on oat than on barley, particularly at 50 days, but rate of nematode development was the same.

In contrast, Race 5 of *M. naasi* appears to be quite distinct physiologically from Races 1-4. Not only was it the only race to develop and reproduce on sorghum, but its development was faster on barley and markedly dissimilar to that of the other races on oat. The report of Aytan and Dickerson (1) that their population (Race 5) completed its life cycle on sorghum in 31 days at 30 C is in close agreement with our findings where second-generation, second-stage larvae were present within eggs and in new infection sites in roots at 30 days. These results demonstrate that Race 5 is capable of more rapid development than are Races 1, 2, 3 and 4.

LITERATURE CITED

1. AYTAN, S., and O. J. DICKERSON. 1969. *Meloidogyne naasi* on sorghum in Kansas. Plant Dis. Rep. 53:737.
2. BAINES, R. C., T. MIYAKAWA, J. W. CAMERON and R. H. SMALL. 1969. Infectivity of two biotypes of the citrus nematode on citrus and some other hosts. J. Nematol. 1:150-159.
3. MICHELL, R. E., R. B. MALEK, D. P. TAYLOR and D. I. EDWARDS. 1973. Races of the barley root-knot nematode, *Meloidogyne naasi*. I. Characterization by host preference. J. Nematol. 5:41-44.
4. MINTON, N. A. 1963. Effects of two populations of *Meloidogyne arenaria* on peanut roots. Phytopathology 53:79-81.
5. RADEWALD, J. D., L. PYEATT, F. SHIBUYA and W. HUMPHREY. 1970. *Meloidogyne naasi*, a parasite of turfgrass in southern California. Plant Dis. Rep. 54:940-942.
6. SIDDIQUI, I. A., and D. P. TAYLOR. 1970. The biology of *Meloidogyne naasi*. Nematologica 16:133-143.
7. SIDDIQUI, I. A., and D. P. TAYLOR. 1970. Symptoms and varietal reaction of oats to the Illinois isolate of the barley root-knot nematode, *Meloidogyne naasi*. Plant Dis. Rep. 54:972-975.