Development of Four Populations of Meloidogyne hapla on Two Cultivars of Cucumber at Different Temperatures

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Abstract: The infectivity and development of four populations of *Meloidogyne hapla* were compared, at three temperatures, on tomato and two varieties of cucumber. A population from Canada produced few root-galls on cucumber and, except at 24 C, no larvae developed into adult females and produced egg masses. In contrast, a population with 45 chromosomes from America produced many galls on cucumber and small proportions of larvae became females and produced egg masses at 20 and 24 C. At 18 C this population produced no egg masses on cucumber, but a population from Britain and one from America with 17 chromosomes produced more egg masses at this temperature than at 20 or 24 C. Dissection of the galls showed that on cucumber many larvae died or their growth and development was slowed. *Key words:* temperature, root-knot nematodes, cucumber, tomato. Journal of Nematology 14(4):545-549. 1982.

The northern root-knot nematode, *Meloidogyne hapla,* has a wide host range. Within the family Cucurbitaceae, some species are regarded as resistant while others are susceptible (9). Cucumber was first reported as being resistant to *M. hapla* in 1956 (12). However, differences in the resistance of cucumber varieties and in the ability of populations of *M. hapla* to develop on them have been reported (4). Stephan (10) found that a population of *M. hapla* from Canada failed to produce egg masses on cucumber, and Winstead (12) and Panayi (8) claimed that cucumber cultivars are less susceptible to *M. hapla* than to other *Meloidogyne* species. However, Zimmer and Walkof (13) reported that seedlings of different cucumber varieties frequently were severely galled and died.

Temperature is a major factor governing the distribution and importance of root-knot nematodes and may alter the host range. Holtzmann (6) reported that the resistance of tomatoes to *M. incognita* increased at temperatures above 25 C. Griffin (5) found that maximum reproduction of *M. hapla* occurs on resistant and susceptible alfalfa at 25 C, but that the incidence of galling is greatest at 30–35 C. Berge et al. (1) and Cardin (3) reported that temperature affects the resistance of cucumber to populations of *M. hapla.*

In the study reported here, the ability of four populations of *M. hapla* to reproduce on two varieties of cucumber at different temperatures was compared.

MATERIALS AND METHODS

Four populations of *M. hapla* were tested: one from Montreal, Canada; one from Suffolk, England; and two from North Carolina, USA, one with 17 and one with 45 chromosomes. The egg masses used in these experiments were obtained from roots of tomato (*Lycopersicon esculentum* Mill. var. Rutgers) grown in nematode-infested soil for 6 wk in a greenhouse at 20 ± 2 C. The eggs were separated from the gelatinous matrix by agitation of the egg masses in 0.5% chloros (sodium hypochlorite) for 4 min and collected on a 25-μm-pore screen. The eggs were rinsed with water for 8 min to remove any residual chloros.

Seedlings (2 wk old) of tomato (var. Rutgers) and cucumber (vars. National Pickling and Market More 70) were transplanted into 10-cm-d pots filled with a loam soil and immediately inoculated with 1,000 eggs. All experiments were completely randomized with four replicates.

The plant roots were washed free of soil 8, 16, 20, 30, 40, 50, and 60 days after inoculation and the number of galls counted. Each gall was then dissected under a stereobinocular microscope, and any larvae found were measured (length and breadth at center). The volume of each larvae was calculated from its length and breadth on the assumption that it is cone shaped. Data were subjected to an analysis of variance, and significant differences amongst the means were determined by Duncan's multiple-range test.

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The influence of temperature on the development of the four populations of *M. hapla* infecting the two varieties of cucumber was studied by growing inoculated potted plants in water baths maintained at 18, 20, or 24 C. The roots were harvested 30, 45, and 60 days after inoculation, and the number of galls and egg masses was determined.

RESULTS

At 20 C egg masses were produced on tomato after 30–40 days. On the two cucumber varieties, the production of egg masses was greatly restricted. The Canadian nematode population produced none on either variety, and the English and n = 17 populations from America produced none on National Pickling. On Market More the English and the two American populations produced only a single egg mass per plant, but on National Pickling the 45-chromosome population from America produced moderate numbers (Table 1).

The suppression of egg-mass formation on the cucumbers was due partly to there being fewer larvae in the cucumber roots (Table 2) and partly to the restricted rate of development of the larvae, as measured by their volume 30 days after inoculation (Table 3).

Except with the 45-chromosome American population, significantly fewer galls were formed on cucumber than on tomato (Table 4). On tomato the numbers of larvae found exceeded the numbers of galls formed, but on cucumber the reverse was obtained except with the Canadian population (compare Tables 2 and 4). Dissection of larvae from the roots 8, 16, 20, and 30 days after inoculation showed that on tomato the numbers of larvae and galls progressively increased. On cucumber, however, the numbers of galls also progressively increased, but the numbers of larvae did not (Table 5).

When the experiments with the two cucumber varieties were repeated at 18 and

Table 1. Numbers of *Meloidogyne hapla* egg masses produced 30–40 days (tomato) or 60 days (cucumber) after inoculation by four populations. The results are means from four plants.

Host	Population of *Meloidogyne hapla*			
	Canadian	English	American n = 17	American n = 45
Tomato				
'Rutgers'	53 (30)*	51 (40)	56 (30)	82 (40)
Cucumber				
'National Pickling'	0	0	0	10 (40)
'Market More'	0	1 (40)	1 (30)	1 (40)

*Figures in brackets give day after inoculation when egg masses were first observed.

Table 2. Numbers of larvae per root system 30 days after inoculation of tomato or cucumber with four populations of *Meloidogyne hapla* at 20 C. Means of four replicates.

Host	Population of *Meloidogyne hapla*			
	Canadian	English	American n = 17	American n = 45
Tomato				
'Rutgers'	104 a*	51 a	155 a	201 a
Cucumber				
'National Pickling'	7 b	25 b	11 b	21 b
'Market More'	13 c	19 b	25 c	7 c

*The results for each population are from separate experiments; therefore, the result within each column cannot be directly compared. Within columns, values followed by the same letter are not significant at (P = 0.05) according to Duncan's multiple-range test.

Table 3. Calculated volume of larvae of *Meloidogyne hapla* from four populations in the roots of tomato and two varieties of cucumber 30 days after inoculation. Results are means from four plants.

Host/variety	Population of *Meloidogyne hapla*			
	Canadian	English	American n = 17	American n = 45
	(Volume in 1,000 μm^3)			
Tomato 'Rutgers'	1,440 a*	752 a	1,759 a	1,215 a
Cucumber				
'National Pickling'	211 b	176 b	385 b	865 a
Market More'	277 b	191 b	1,356 a	413 b
Undeveloped Second-stage larvae	70	99	89	86

*The results for each population are from separate experiments; therefore, the result within each column cannot be directly compared. Within columns, values followed by the same letter are not significant at ($P = 0.05$) according to Duncan's multiple-range test.

Table 4. Numbers of galls produced by four populations of *M. hapla* on tomato and cucumber 30 days after inoculation. Means of four replicates.

Host/variety	Population of *Meloidogyne hapla*			
	Canadian	English	American n = 17	American n = 45
Tomato 'Rutgers'	73 a*	27 a	144 a	195 a
Cucumber				
'National Pickling'	7 b	56 b	25 b	139 a
'Market More'	10 b	31 c	59 c	173 a

*The results for each population are separate experiments; therefore, the result within each column cannot be directly compared. Within columns, values followed by the same letter are not significant at ($P = 0.05$) according to Duncan's multiple-range test.

Table 5. Means for all four populations* of *Meloidogyne hapla* of the numbers of larvae and galls 8, 16, 20, and 30 days after inoculation on tomato and cucumber. Means of four replicates.

Host/variety	Days after inoculation			
	8	16	20	30
	Mean number of larvae/galls			
Tomato 'Rutgers'	9/8	23/16	33/22	128/110
Cucumber				
'National Pickling'	2/2	11/15	9/25	16/57
'Market More'	4/4	14/17	16/28	16/28

*Populations obtained from Montreal, Canada; Suffolk, England; and North Carolina, USA, (n = 17 and n = 45).

24 C, somewhat different results were obtained. At 18 C the Canadian and the n = 45 population from America produced no females on either variety while the English and the n = 17 American population produced moderate numbers, Market More being somewhat less resistant than National Pickling. At 24 C all populations produced some egg masses; with the two American populations, National Pickling was con-

siderably less resistant than Market More (Table 6).

DISCUSSION

All populations attacked and invaded cucumber, but most of the larvae failed to develop into adult females. Overall, cucumber was most resistant to the Canadian population and least resistant to the n = 45 American population. Few larvae of the Canadian population were able to grow and initiate gall formation. In contrast, many galls were formed by the larvae of the n = 45 American population, and a small proportion of larvae were able to develop sufficiently to become adult females and form egg masses. However, even with this population many of the galls dissected 30 days after inoculation were empty or contained dead or poorly fed larvae. Stephan (10) found that some larvae of the Canadian population of *M. hapla* did induce giant cells in cucumber (Market More) 16 days after inoculation, but that after 70 days these giant cells had degenerated, thereby supporting the suggestion by Cardin et al. (3) that resistance may operate after a larva has started to develop. McClure et al. (7) made a similar observation in relation to development of *M. incognita* in resistant cotton in which resistance may be due to terpenoid aldehydes (11).

The differences among populations in ability to reproduce on cucumber, the differences in resistance of the two cucumber varieties, and the modification of resistance by temperature support previous findings by Berge et al. (1) and Cardin (3) and point to a complex interaction among host, environment, and nematode.

The high percentage of empty galls observed at 18 and 24 C in both cucumber varieties inoculated with the Canadian population could be because the temperatures are at the limits of its range of tolerance. Stephan (10) indicated that at 17.5 C tomato roots were only slightly infected when inoculated with this population and that its development was depressed at 25 C. The American population with 45 chromosomes was well developed at 24 C, and more females and egg masses were found than at 18 and 20 C. The English and the American n = 17 populations were more aggressive at 18 C than at 20 or 24 C. So the host nematode inter-relationship is affected not only by the genetic qualities of the host but also by the temperature, which acts both on the nematode and on the plant.

Our results support the suggestion by Bogert (2), Berge et al. (1), and Cardin (3) that cucumber may be useful as a trap crop for many populations of *M. hapla*. The durability of this resistance is unknown, but it seems possible that many populations will possess the capacity to adapt.

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Table 6. Numbers of galls, nematodes, and egg masses formed by four populations of *Meloidogyne hapla* at two temperatures on two varieties of cucumber. Means of four plants. Data taken on the day when egg masses were first observed; where no egg masses formed, data taken 60 days after inoculation.

Temperature	Population	Cucumber Variety: 'National Pickling' Galls	'National Pickling' Nematodes	'National Pickling' Egg-mass	'Market More 70' Galls	'Market More 70' Nematodes	'Market More 70' Egg-mass
18 C	Canadian	42	0	0	113	13	0
	English	39	9	4	107	21	7
	American (n = 17)	31	20	13	114	81	38
	American (n = 45)	0	0	0	0	0	0
24 C	Canadian	18	2	0	48	9	2
	English	58	19	3	80	25	2
	American (n = 17)	44	22	7	76	30	2
	American (n = 45)	83	45	33	78	23	19

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