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THE EFFECT OF DIFFERENT DENSITIES OF *MELOIDOGYNE ARDENENSIS* AND OF THREE POPULATIONS OF *M. HAPLA* ON THE GROWTH OF TOMATO AT FOUR SOIL TEMPERATURES

by

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Comparative studies by Stephan (1982) and Stephan and Trudgill (1982b) have shown that the reproduction of the root-knot nematode *Meloidogyne ardenensis* Santos and *M. hapla* Chitwood on tomato (*Lycopersicon esculentum* Mill.) and Lonicera (*Lonicera nitida* L.) plants is strongly influenced by soil temperature. Oostenbrink (1966) and Seinhorst (1965, 1970) have indicated that crop damage caused by plant parasitic nematodes is related to the preplanting population density and the rate of reproduction of the nematode. *M. hapla* is considered to be a serious pest of many important crops (Barker *et al.*, 1976; Belair and Estey, 1981; Griffin and Jorgenson, 1969; Townshend and Potter, 1978; Wong and Mai, 1973), the amount of damage being directly related to the initial population density. The effect of initial population density of *M. ardenensis* on the growth of tomato under controlled conditions has not been studied. Other research has indicated that, on a given host, populations of *Meloidogyne* species often have different optimum temperature requirements for maximum reproduction (Martin, 1954; Sasser and Nusbaum, 1955; Stephan and Trudgill, 1982a).

Therefore, this study examined the effect of the initial population density of *M. ardenensis* and of three populations of *M. hapla* on the growth of tomato plants grown at different temperatures.

Materials and Methods

A population of *M. ardenensis* from Scotland, and three populations of *M. hapla* from Montreal (Canada), North Carolina (USA) with 17 chromosomes and England with 45 chromosomes were tested. The eggs used in this experiment were obtained from the roots of tomato cv. Rutgers grown in nematode infested soil for 6 weeks in a greenhouse at 20 ± 2°C (Stephan, 1982). Three week old tomato plants were transplanted into 8 cm pots filled with 500 g of sterilized soil (3:1 peat/sand) and inoculated immediately with 0, 100, 1,000, 2,000, 4,000, 8,000 eggs. The influence of soil temperature on the development of the populations of nematodes was studied by immersing the pots into waterbaths maintained at 15, 18, 21 or 24°C. The air temperature ranged between 18 and 25°C. The experiment was compeletely randomized with five replicates. Sixty days after inoculation, fresh plant weight, root weight, plant height and numbers of root galls and eggs formed were determined.

Results

The results show that *M. ardenensis* and the three populations of *M. hapla* had different temperature requirements for optimum reproduction (Table I). Only the American population of *M. hapla* was able to infect tomato plants at all of the temperatures tested. The Canadian population failed to invade and form galls at 15°C, the English at 15 and 18°C and *M. ardenensis* at 21 and 24°C. Temperature also affected the rate of development, *M. ardenensis* failing to complete its life cycle in 60 days at 15°C and the populations of *M. hapla* having a partial second generation at 24°C. At 15 and 18°C an initial inoculum of 4,000 and 8,000 eggs of *M. ardenensis* significantly increased tomato root weight and decreased top weight compared with the untreated (Table II) and decreased plant height (Table III). At 15°C smaller densities of *M. ardenensis* did not effect growth significantly but at 18°C they increased top weight. No invasion by *M. ardenensis* occurred at 21 or 24°C and tomato growth was unaffected at these temperatures.

The effect of *M. hapla* in reducing top weight increased as both the temperature and inoculum density increased. Where infection occurred at the two lower temperatures the top growth was unaffected

Table I - *Invasion and reproduction of* Meloidogyne ardenensis *and three populations of* M. hapla *in tomato roots at different temperatures. (Means of 5 replicates).*

Temperature °C	Initial population densities	NUMBER OF ROOT GALLS AND EGGS OF NEMATODES							
		M. ardenensis		*M. hapla* Canada		*M. hapla* n=17		*M. hapla* n=45	
		Galls	Eggs	Galls	Eggs	Galls	Eggs	Galls	Eggs
15	100	2 a[+]	0	0	0[++]	4 a	0	0	0[++]
	1000	9 b	0	0	0	18 b	0	0	0
	2000	26 d	0	0	0	45 c	0	0	0
	4000	69 f	0	0	0	102 d	0	0	0
	8000	120 g	0	0	0	191 g	0	0	0
18	100	3 a	0 a	9 a	9 a	8 a	2 a	0	0[++]
	1000	21 d	5 b	9 a	79 b	24 b	5 a	0	0
	2000	35 e	21 c	38 b	56 b	56 c	8 a	0	0
	4000	60 f	83 d	81 cd	58 b	110 d	30 b	0	0
	8000	112 g	174 e	66 c	56 b	151 f	87 c	0	0
21	100	0	0[++]	32 b	490 c	41 c	550 d	5 a	490 a
	1000	0	0	87 d	2239 e	105 d	1000 e	28 b	3981 c
	2000	0	0	126 e	3802 f	170 g	1906 f	174 f	6025 e
	4000	0	0	191 f	5754 h	159 f	1862 f	182 f	10233 g
	8000	0	0	182 f	4375 gh	229 h	3802 i	209 g	11220 g
24	100	0	0[++]	33 b	708 d	50 c	794 d	10 a	891 b
	1000	0	0	96 d	3467 f	118 d	5888 j	117 c	6166 e
	2000	0	0	148 e	4169 fg	174 g	2571 g	132 d	5754 d
	4000	0	0	214 g	6310 i	182 g	6026 j	148 e	7862 f
	8000	0	0	205 g	7096 j	135 e	2951 h	155 e	7729 f

[+] Values followed by the same letter within columns are not significantly different according to Duncan's Multiple Range test ($P < 0.05$).
[++] No galls were formed by nematode species.

Table II - *Effects of initial population densities of* Meloidogyne ardenensis *and three populations of* M. hapla *on top and root weights of tomato at different temperatures. (Means of 5 replicates).*

Temperature °C	Initial population densities	TOP AND ROOT WEIGHTS (g) OF TOMATO PLANTS							
		M. ardenensis		*M. hapla* Canada		*M. hapla* n=17		*M. hapla* n=45	
		Top	Root	Top	Root	Top	Root	Top	Root
15	0	20.9	2.7	20.9	2.7 +	20.9	2.7	20.9	2.7 +
	100	20.6	2.4	21.1	2.8	19.5	3.3	21.3	2.7
	1000	19.8	2.8	20.4	2.8	20.0	2.9	21.6	2.8
	2000	19.2	2.6	20.7	2.8	20.0	2.3	21.4	2.8
	4000	14.4 ***	4.1 ***	21.0	2.8	20.0	2.5	21.4	2.6
	8000	15.3 ***	4.0 ***	20.4	2.8	18.7	2.1	21.3	2.7
18	0	18.5	2.5	18.5	2.5	18.5	2.5	18.5	2.5 +
	100	28.2 ***	2.3	23.4 ***	2.3	19.9	2.2	20.0	2.2
	1000	22.4 ***	2.8	23.6 ***	2.8	23.2 **	2.5	20.5	2.2
	2000	23.6 ***	3.1	27.2 ***	2.4	21.7	2.2	20.3	2.0
	4000	13.5 ***	3.4 ***	25.0 ***	2.2	21.5	1.8 *	19.6	2.2
	8000	13.2 ***	3.6 ***	20.0	1.8 **	19.0	2.3	19.3	2.1
21	0	26.3	3.4 +	26.3	3.4	26.3	3.4	26.3	3.4
	100	26.3	3.3	24.7	2.6 ***	24.1	3.3	21.9 **	2.4 **
	1000	26.7	3.5	23.0	2.0 ***	26.6	2.0 ***	23.7	4.2 **
	2000	26.3	3.5	24.4	2.9	23.5	2.0 ***	8.5 ***	2.7
	4000	26.3	3.5	23.7	2.2 ***	16.7 ***	2.0 ***	7.0 ***	3.3
	8000	26.6	3.6	19.1 ***	1.5 ***	12.0 ***	1.9 ***	6.7 ***	3.4
24	0	22.3	2.5 +	22.3	2.5	22.3	2.5	22.3	2.5
	100	24.4	2.4	23.8	2.8	22.9	3.4 ***	27.9 ***	2.7
	1000	24.1	2.4	22.3	2.3	21.8	1.8 *	24.4	4.1 ***
	2000	22.9	2.6	22.4	2.5	21.7	1.8 *	7.3 ***	3.1
	4000	23.1	2.7	24.7	1.7 *	13.7 ***	1.3 ***	7.2 ***	2.9
	8000	23.2	2.5	14.4 ***	0.7 ***	9.9 ***	0.9 ***	5.6 ***	3.2 **

Top weight SED (332) = 1.86.
Root weight SED (332) = 0.38.
*, **, *** Significantly different from untreated $P < 0.05$, 0.01, 0.001 respectively.
+ No infection occurred and tomato growth was unaffected by different densities of nematode species.

or was increased compared with the untreated (Table II). At the higher temperatures top weight tended not to be increased, even by small initial inocula, and to be strongly decreased by large inocula. The Canadian population appeared to be the least damaging, only the 8,000 eggs inoculum significantly decreased final top weight, and the English (N45) population the most damaging, top weight being

Table III - *Effects of initial population densities of* Meloidogyne ardenensis *and three populations of* M. hapla *on plant height of tomato plants at different temperatures. (Means of 5 replicates).*

Temperature °C	Initial population densities	PLANT HEIGHT (cm)			
		M. ardenensis	*M. hapla* Canada	*M. hapla* n=17	*M. hapla* n=45
15	0	37.4	37.4 +	37.4	37.4 +
	100	34.2	37.4	36.6	37.2
	1000	38.0	36.8	37.6	38.4
	2000	34.6	38.2	38.8	36.8
	4000	29.8 ***	37.0	36.0	37.4
	8000	27.4 ***	37.0	29.2 ***	38.0
18	0	45.8	45.8	45.8	45.8 +
	100	42.2	43.6	43.6	46.6
	1000	44.8	45.6	42.0 ***	47.2
	2000	44.4	40.4 **	39.4 ***	46.4
	4000	38.8 ***	40.0 ***	38.0 ***	47.6
	8000	36.6 ***	36.2 ***	29.8 ***	46.4
21	0	45.2 +	45.2	45.2	45.2
	100	45.4	44.6	42.6	47.4
	1000	46.2	43.6	36.8 ***	41.0 ***
	2000	46.8	41.4 ***	36.2 ***	32.0 ***
	4000	46.6	36.2 ***	33.4 ***	28.6 ***
	8000	46.2	32.2 ***	25.6 ***	28.8 ***
24	0	47.8 +	47.8	47.8	47.8
	100	48.6	45.4	41.2 ***	45.0
	1000	49.4	41.8 ***	37.4 ***	43.4 ***
	2000	48.8	43.4 ***	34.0 ***	30.6 ***
	4000	47.8	40.6 ***	32.0 ***	26.8 ***
	8000	48.6	21.8 ***	20.6 ***	25.4 ***

SED (332) = 2.00.
*, **, *** Significantly different from untreated $P < 0.05$, 0.01, 0.001 respectively.
+ No infection occurred and tomato growth was unaffected by different densities of nematode species.

significantly decreased compared with the untreated by as few as 2,000 eggs.

The effect of the three populations of *M. hapla* on root weight tended to be the reverse of that on the tops (Table II). At 21 and 24°C root weight was most strongly decreased by the Canadian population and at 24°C was increased at every inoculum density by the English population.

Plant height was not increased at any of the temperatures by *M. hapla* (Table III) and was increasingly decreased as the temperature and inoculum density were increased. The Canadian population caused the least reduction compared with the uninoculated and the American population the most.

Discussion

M. ardenensis and the three populations of *M. hapla* developed successfully on tomato, but varied in their degree of infestation and pathogenicity. Tomato plants in soil heavily infested with *M. hapla* suffered less root-knot infestation and damage at 15 and 18°C than at 21 and 24°C. The results showed that the effect of temperature on the rates of root invasion (as indicated by gall formation) differed between populations of *M. hapla*. Differences between races or pathotypes on the same host have been observed (Dao, 1970; Daulton and Nusbaum, 1962; Stephan and Trudgill, 1982a; and Sturhan, 1968). The results also indicate that fewer *M. ardenensis* invaded the tomato roots and caused less damage than *M. hapla*, probably because tomato root exudate does not stimulate egg hatching of *M. ardenensis* (Stephan, 1982).

The variation in the pathogenicity between the populations of *M. hapla* is associated with physiological or biochemical differences within the species and primarily probably due to differences in enzymes, either qualitatively or quantitatively (Sturhan, 1968).

The reduction in plant height, even at the lowest level of inoculum, as compared to the control, appears to be unusual as many earlier authors reported stimulation of growth (Olthof and Potter, 1977; Sayer and Toyama, 1964). *M. hapla* produced only small galls on tomatoes, therefore root weights did not increase as numbers of nematodes increased.

This study has shown three major effects: first, at densities above

2,000 eggs/500 g soil, plant growth was depressed significantly. Secondly, temperature influenced nematodes directly. There were temperature differences between species and between populations within species. Thirdly, nematode multiplication on tomato decreased as initial density increased.

SUMMARY

The effect of *Meloidogyne ardenensis* and three populations of *M. hapla* on the growth of tomato were compared at four temperatures. *M. ardenensis* caused greater plant height reduction at 15 than 18°C, the percent reduction was 27 and 20 respectively. Percent reduction in plant height caused by the American population *M. hapla* was 57, 43, 35 and 22 at 24, 21, 18 and 15°C respectively. The American and English populations of *M. halpa* were more damaging to tomato plants than the Canadian population and *M. ardenensis*. The American population was the only one which reproduced on tomato at all temperatures tested. *M. ardenensis* failed to produce at 21 and 24°C, the Canadian at 15°C and the English population at 15 and 18°C. At the higher densities (4,000 and 8,000 eggs), all the nematode species tested caused greater reduction in plant height, plant weight and root weights as compared to the control. The reproduction factor of the nematode species was negatively correlated with initial density.

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