Effects of Population Densities of Meloidogyne hapla on Growth and Yield of Tomato

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Abstract: Growth and yield of 'Veebrite' tomato were studied in 20-cm (i.d.) clay-tile microplots containing initially 260, 1,840, 6,120, or 27,950 *Meloidogyne hapla* larvae/kg of soil. Low nematode numbers stimulated, and the highest nematode population suppressed, vegetative plant growth. More tomatoes, with a higher total weight, were harvested from plants infested with 260 and 1,840 nematode larvae at planting than from those with initial densities of 6,120 and 27,950 larvae. At the two highest densities, the cumulative fruit production (weight) was suppressed by 10% and 40%, respectively. The increase in growth and yield at the lower densities appeared to be due to an increase in the size of the root system. However, at the higher densities, yield was no longer directly related to root weight. The reproduction factor of *M. hapla* was negatively correlated with initial density; for the lowest and highest initial densities, it was 96X and 7X at midseason, and 354X and 3X at harvest, respectively. The equilibrium density was 63,000 larvae/kg of soil; initial densities larger than 2,000 larvae/kg of soil may require control. *Key Words:* root-knot nematode, crop losses, *Lycopersicon esculentum.*

The northern root-knot nematode, *Meloidogyne hapla* Chitwood, is widely distributed in southwestern Ontario, but rarely in large numbers (11). Chitwood's microplot trial (2) provided the first quantitative data to show that *M. hapla* suppresses growth and yield of tomatoes. An earlier study by Ficht (5) is of limited value as the identity of the root-knot nematode involved is uncertain. Later, Sayre and Toyama (13) provided data from field tests showing that low and medium densities of *M. hapla* (220 and 1,980 larvae/kg of soil) increased numbers and weights of processing tomatoes. In the Netherlands, *M. hapla* caused severe damage to greenhouse tomatoes, on which the nematode increased greatly (Oostenbrink, pers. comm.; 8). In recent microplot experiments, Barker *et al.* (1) demonstrated suppression of yields of field tomatoes by *M. hapla*. Moreover, the yield suppression at given initial densities depended on abiotic environmental conditions prevailing at two different locations in North Carolina.

Research in other countries has demonstrated the extent of damage *M. hapla* can cause to tomato. Because this nematode occurs widely in Ontario (11) and tomato is an important crop (7), the objectives of this study were: *(i)* to determine the relationship between nematode densities and crop loss; *(ii)* to establish whether *M. hapla* also causes delays in fruit ripening as was found with *Pratylenchus penetrans* (10); and *(iii)* to establish the rate of reproduction of *M. hapla* on this crop.

MATERIALS AND METHODS

The root-knot nematode, *M. hapla,* was a local isolate maintained for 6 years on celery (*Apium graveolens* L. var. *dulce* DC. 'Utah') and reared on peanut (*Arachis hypogaea* L. 'NC-2') in Vineland loam soil in greenhouse groundbeds. In May 1972, nematode-infested soil was mixed with steam-sterilized soil to yield four different initial nematode densities (P_i); steam-sterilized loam served as a noninfested check soil (10). Microplots consisted of 20-cm i.d. x 30-cm long clay drainage tiles installed in a field (10); they were filled with the experimental soils, and included moisture-temperature sensors. The experimental design was a randomized block with four P_i's and a check; each was replicated 20 times.

A single tomato seedling (*Lycopersicon esculentum* Mill. 'Veebrite'), 6 weeks old and 10-15 cm high, was transplanted into each microplot. Procedures for P_i determination, microfloral restoration, fertilization, and insect control followed previously-described practices (10). At midseason, 44 days after transplanting, the nematode population densities were determined in

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soil samples (10). Straw mulch was applied when needed to prevent spoiling of the ripening fruits.

Commencing 10 weeks after transplanting (August 8), the ripe fruits were harvested twice weekly, and were weighed and graded by using official standards (12). At the end of the 8-week picking period, all remaining fruits were removed, weighed, and graded. The top weight and root weight were recorded for each replicate.

The final larval nematode population in the soil (P_f) was determined for each microplot by the Baermann pan method (16), and the degree of galling of each root system was rated by the Daulton-Nusbaum index (4). Plant growth data and nematode counts were analyzed as before (10); data on numbers and weights of fruit were related to size of fruit, time of picking, and P_i. Soil populations of fungi and bacteria were determined at harvest (6, 9).

RESULTS

Population densities of 260, 1,840, 6,120, and 27,950 *M. hapla* larvae/kg of soil had increased many times by midseason (Table 1). At harvest, further increases in larval soil populations were noted, except at the highest P_i. All the nematode-infested tomatoes were galled severely.

Both top weight and root weight were significantly increased at the 260/kg P_i, whereas top weight was lowest at the 27,950 per kg P_i (Table 2). Top and root weight tended to be higher in the 1,840 P_i treatment than in the control. In the 6,120 P_i treatment, top weight tended to be lower than in the control, but root weight was higher ($P < 0.05$).

In all size ranges, the numbers of fruits (Fig. 1) and the total weights (Fig. 3) tended to be highest in the presence of the fewest nematodes. Generally, fewer tomatoes, weighing less, were picked each week from plants infested with the highest number of nematodes (Fig. 2, 4).

Although the two highest nematode densities resulted in fewer tomatoes in all size ranges, the loss in yield was mainly due to the appearance of fewer fruits over 44 mm diam (Fig. 5) and thus a lower total weight (Fig. 7). From the second week (Fig. 6, 8), a suppression of the cumulative yield, in terms of numbers and weights of fruits, became evident at the highest P_i. Differences in cumulative yield became apparent among the other treatments after 6 weeks.

All 18 fungal genera isolated from the soil were common saprophytes; *Trichurus, Penicillium,* and *Cephalosporium* accounted for 64% of the incidence. The bacterial count was 12.1 X 10^6/gm of soil. No difference in microflora was apparent among the treatments, nor was any evidence of fungal pathogenesis observed.

Soil temperature was generally favorable for tomato growth (Fig. 9). In dry periods from late June to mid-July and from mid-

TABLE 1. Population densities of *Meloidogyne hapla* under Veebrite tomato[w].

Initial larval density/kg soil (P_i)	Sampling Time: Midseason[x] no/kg soil (in 1000s)	Final[y] No/kg soil (in 1000s)	Final[y] Gall Index[z]
260	25	92a	3.7a
1,840	50	152b	4.8b
6,120	90	130b	5.0b
27,950	198	84a	5.0b

[w]Column means followed by a letter in common do not differ, according to Duncan's Multiple Range Test ($P = 0.05$).
[x]Based on samples from 5 replicates.
[y]Based on samples from 20 replicates.
[z]Index modified from Daulton-Nusbaum rating scheme (4), in which 5 is a maximum for *M. hapla* galling.

TABLE 2. Effects of *Meloidogyne hapla* on vegetative growth of Veebrite tomato[y].

Initial larval density/kg soil (P_i)	Plant weights (gm) at harvest: Tops[z]	Roots	Total[z]
Check	1,170a	70a	1,240a
260	1,480b	85b	1,565b
1,840	1,210a	80ab	1,290a
6,120	1,140a	100c	1,240a
27,950	750c	95c	845c

[y]Column means followed by a letter in common do not differ, according to Duncan's Multiple Range Test ($P = 0.05$). Means of 20 replicates.
[z]Excluding fruit weight.

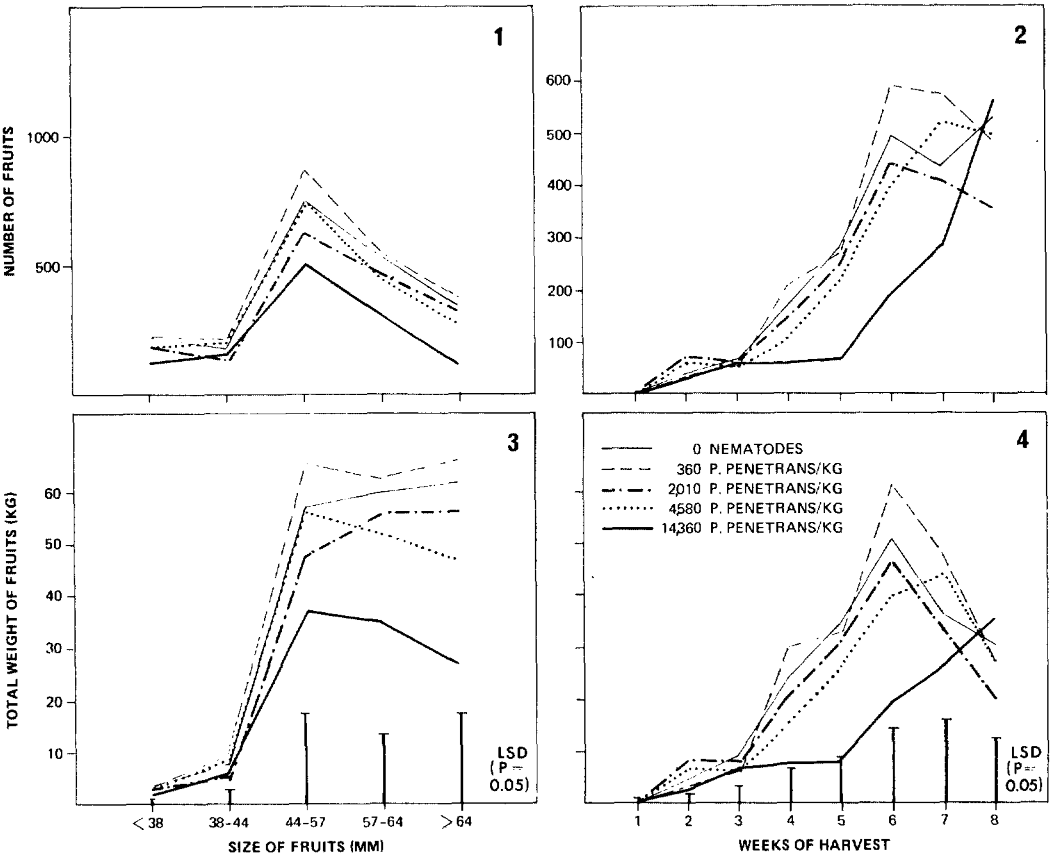

FIG. 1-4. Average yield of Veebrite tomato. *1)* Number fruits in each size range for each P_i of *Meloidogyne hapla*. *2)* Number of fruits per week of harvest at each P_i of *M. hapla*. *3)* Total weight of fruits in each size range for each P_i of *M. hapla*. *4)* Total weight of fruits per week of harvest at each P_i of *M. hapla*.

August to mid-September, soil moisture ranged between 15 and 10% (Fig. 9), substantially below field capacity (22%).

DISCUSSION

Three major effects of *Meloidogyne hapla* on fruit production of Veebrite tomato became apparent in this study. First, fruit-ripening was delayed noticeably, at the highest P_i, from the second week of harvest onward. Second, with less than 2,000 nematodes/kg of soil, total yield of fruit was greater than in the check, a suggestion of the stimulatory influence of the nematode. Third, at densities above 2,000 larvae/kg, total yield of fruit was depressed.

Any delay in ripening, resulting in a delayed harvest, could be financially detrimental for the fresh-market grower because prices tend to be highest for the earliest tomatoes. The delay in onset of fruit-ripening, associated with high densities of *M. hapla*, was also noted before with *P. penetrans* (10), and was probably part of a suppressed maturation rate of the plants, as suggested previously (10). However, the delay caused by *M. hapla* was evident after 1 week of picking, whereas with *P. penetrans* the delay did not become apparent until 3 weeks after the beginning of harvest. With *M. hapla*, the rate of ripening increased between the second and third week, reached a peak at the sixth week, and then declined; whereas with *P. penetrans*, a rapid increase in ripening began during the fifth week and continued unabated to the end of harvest. These differences can be partly explained on the basis of differences in the mode of parasitism and the relative multiplication rates of the two

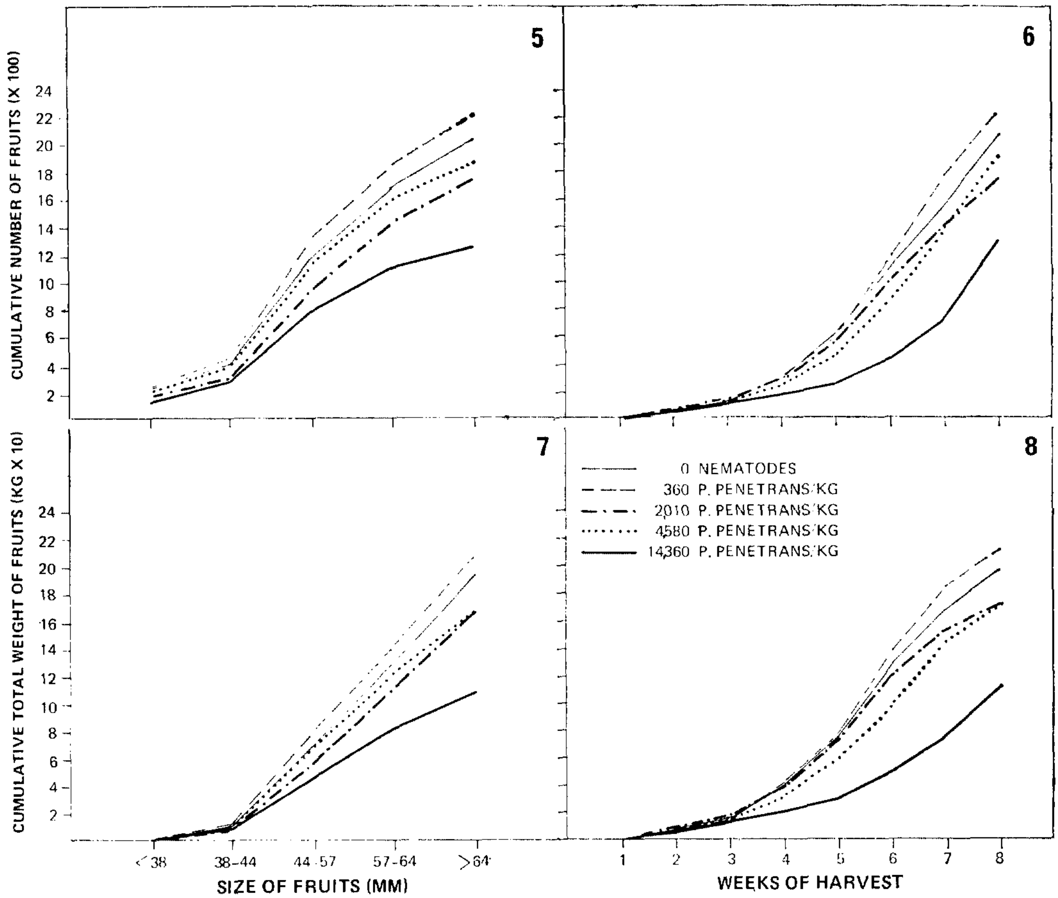

FIG. 5-8. Cumulative yield of Veebrite tomato. *5)* Number of fruits over all sizes for each P_i of *Meloidogyne hapla*. *6)* Number of fruits over all weeks of harvest for each P_i. *7)* Total weight of fruits over all sizes for each P_i. *8)* Total weight of fruits over all weeks of harvest for each P_i.

nematodes. The root-lesion nematode, unlike *M. hapla*, is very destructive to roots (3) but has a low reproductive rate. Thus, plants attacked by *P. penetrans* are more likely to outgrow the damage. Our data supported this view for *P. penetrans* (10). In contrast, at the highest densities in our experiment, the rate of multiplication of *M. hapla* apparently exceeded the rate of root expansion and resulted in a lower yield with no indication of recovery.

The stimulation of fruit production at a P_i of less than 2,000 larvae/kg of soil has been noted previously by others (2, 13). Sayre and Toyama (13) suggested that the more vigorous growth of plants at low and medium nematode densities in their work and in that of Chitwood (2) might be the result of the many adventitious roots formed in the galled root areas. In our experiment, root weight, top weight, and fruit production were greatest at the two lower P_i's. Our weekly harvest records showed that stimulation of fruit production continued over most of the harvest period at low nematode levels. Our results generally support the hypothesis of Wallace (17) in which he explains the effect of *M. javanica* on its host plants in terms of a balance between stimulatory and inhibitory processes. Although root weights were higher with the two highest P_i's, yield losses were comparable to those reported by other workers (1, 2, 8, 13).

At midseason, the number of nematodes in the soil at the highest P_i had increased greatly but, at the end of harvest, the P_f was lower than the midseason population. Although root weights were increased by nematodes at the highest P_i, much of the increased root weight was probably unsuitable for nematode repro-

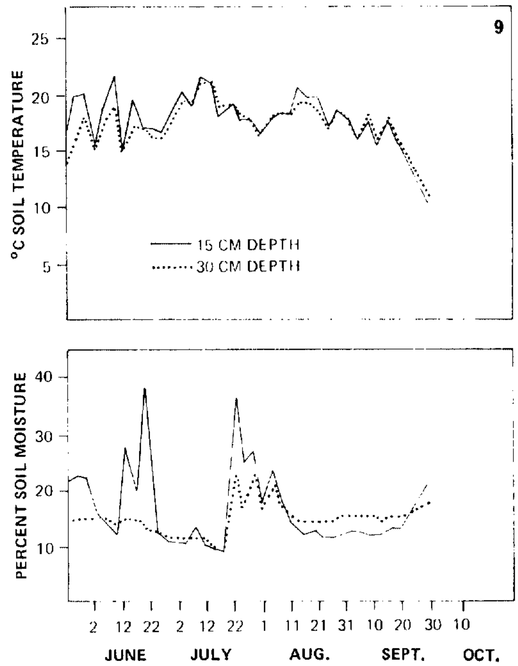

FIG. 9. Average biweekly soil temperature and moisture at two depths under Veebrite tomato.

duction because *Meloidogyne* larvae only penetrate root tips (15). This fact could well account for the decline in soil larval population from midseason to harvest. By graphing log P_f vs. log P_i, the value of the equilibrium density E (14) was extrapolated to be 63,000 larvae/kg of soil. This value was exceeded by the two higher densities at midseason, and by all densities at termination of the experiment. The maximum reproduction observed was 198,000 at midseason with $P_i = 27{,}950$; maximum reproduction of *M. hapla* observed by Barker et al. (1) was also near 200,000, although with $P_i = 4{,}000$ to 8,000. Reproduction in our experiment and in that of Barker et al. (1) was comparable at low and moderate P_i, in spite of differences in experimental materials, procedures, and locations.

This study has shown that the multiplication factor of *M. hapla* on tomato is negatively correlated with initial density; that delay in fruit ripening accounts for a large part of the yield loss at the highest P_i; and that initial densities larger than 2,000 larvae/kg of soil may require control.

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