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Interrelationship of *Heterodera schachtii* and *Meloidogyne hapla* on Tomato[1]

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Abstract: Invasion of tomato (*Lycopersicon esculentum* L.) roots by combined and sequential inoculations of *Meloidogyne hapla* and a tomato population of *Heterodera schachtii* was affected more by soil temperature than by nematode competition. Maximum invasion of tomato roots by *M. hapla* and *H. schachtii* occurred at 30 and 26 C, respectively. Female development and nematode reproduction (eggs per plant) of *M. hapla* was adversely affected by *H. schachtii* in combined inoculations of the two nematode species. Inhibition of *M. hapla* development and reproduction on tomato roots from combined nematode inoculations was more pronounced as soil temperature was increased over a range of 18–30 C and with prior inoculation of tomato with *H. schachtii. M. hapla* minimally affected *H. schachtii* female development, but there was significant reduction in the buildup of *H. schachtii* when *M. hapla* inoculation preceded that of *H. schachtii* by 20 days.
Key words: northern root-knot nematode, sugarbeet cyst nematode, invasion, soil temperature, populations, inoculum density, development, reproduction, *Lycopersicon esculentum.*

Researchers are becoming increasingly aware of the combined effects of two or more nematodes on plant growth. One nematode species may adversely affect or enhance the invasion, development, and reproduction of another nematode species (1,5,11–16); in addition, the effect of one nematode species on another nematode species may be different on different host plants (3,4).

A previous study (7) showed that the combination of a *Heterodera schachtii* Schmidt (Hs) population pathogenic to tomato and a population of *Meloidogyne hapla* Chitwood (Mh) cultured on tomato significantly suppressed the growth of tomato more than the additive suppression caused by either nematode alone. Since a synergistic effect between *H. schachtii* and *M. hapla* on tomato has been observed, my objectives were to study the effects of each nematode species on invasion, development, and reproduction of the other as well as the influence of soil temperature and sequential inoculations on the concomitant relationships.

Materials and Methods

The Hs population used in this study was collected originally from tomato (*Lycopersicon esculentum* Mill.) planted at Ogden, Utah, and cultured over eight periods of 60 days each on 'Stone Improved' tomato (7). Mh was collected from lettuce (*Lactuca*

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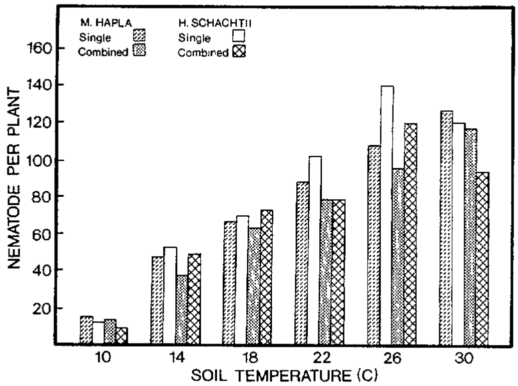

FIG. 1. Effect of soil temperature on the invasion of tomato seedlings with *Meloidogyne hapla* and *Heterodera schachtii* juveniles singly and in combination (LSD [$P = 0.05$] = 12).

sativa L.) and cultured on Stone Improved tomato.

Cysts of Hs and egg masses of Mh were collected from culture plants and surface sterilized in 0.5% sodium hypochlorite. Hs eggs were hatched in a 3 mM/liter $ZnCl_2$ solution, and *M. hapla* eggs were hatched in deionized water in an oxygenator; second-stage juveniles (J2) were used for inoculum. Stone Improved tomato was used as the host plant.

Effect of temperature on nematode invasion of tomato seedlings: Fourteen-day-old tomato transplants (four per 10-cm-d container) were inoculated by pipetting suspensions of 200 Mh and 200 Hs J2 singly, or in combination, around the roots at planting. Plants were grown in greenhouse water baths at soil temperatures of 10, 14, 18, 22, 26, and 30 C and an air temperature of 22 ± 5 C. Treatments were replicated five times. Plants were grown for 14 days with a 16-hour light period. Roots were stained in lactophenol–acid fuchsin and the number of nematodes inside the roots were counted with a microscope.

Effect of temperature on nematode reproduction on tomato: The effect of combined inoculations of Hs and Mh on the development of females of each species was determined in another study. Twenty-eight-day-old tomato plants were inoculated with the same numbers of nematodes as stated earlier and were grown at the same temperatures and light conditions, except inoculations consisted of 1) single inoculations of each species, 2) simultaneous inoculations of both species, 3) Mh inoculated 20 days prior to Hs, and 4) Hs inoculated 20 days prior to Mh. Treatments were replicated eight times. After 100 days, plants were harvested and nematode reproduction (eggs per plant) was determined. Roots were then macerated and stained and nematode development (females per plant) determined.

RESULTS

Effect of soil temperature on nematode invasion of roots: Invasion of 14-day-old tomato seedling roots by either Hs or Mh was affected more by soil temperature than by competition between the two nematode species (Fig. 1). Invasion of roots by J2 increased directly with soil temperature. No differences were observed in numbers of J2 invading roots in single species inoculations between 10 and 18 C, but significantly ($P = 0.05$) more Hs than Mh invaded roots at 22 and 26 C. Maximum invasion by Hs J2 occurred at 26 C, whereas maximum invasion by Mh was at 30 C. Combined inoculations did not affect *M. hapla* invasion of tomato seedlings, but there was a significant reduction ($P = 0.05$) in the invasion by Hs at 22, 26, and 30 C.

Effect of temperature on nematode development: Numbers of females per plant were affected by both soil temperature and inoculation combinations (Fig. 2). Females per plant of both Mh and Hs increased with an increase in soil temperature; the greatest number of females per plant of both species were found at 30 C. Greater numbers of Mh than Hs developed per plant from single species inoculations at all soil temperatures. Combined inoculations of Mh and Hs significantly reduced the number of developing Mh females, while only prior invasion by Mh affected Hs development.

Effect of temperature on egg reproduction: Egg production by Hs was much lower than by Mh. Egg production by both nematode species increased with an increase in temperature from 18 to 26 C. Maximum Mh egg production occurred at 26 C and maximum Hs egg production at 30 C (Fig. 3).

Mh egg production was significantly ($P = 0.05$) reduced at all soil temperatures by Hs when inoculated simultaneously with Mh, but especially when Hs was added 20

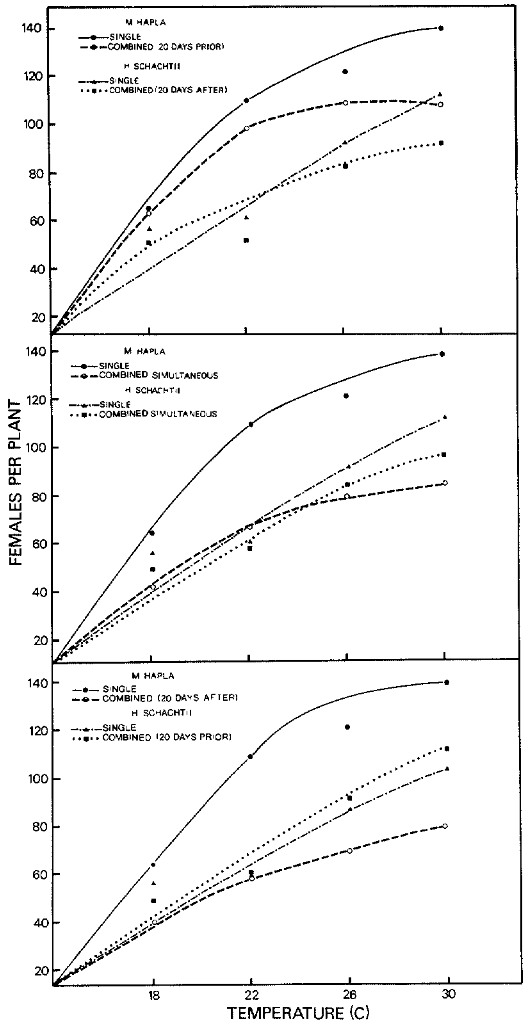

FIG. 2. Effect of soil temperature on development of *Meloidogyne hapla* and *Heterodera schachtii* singly and in combination in tomato (LSD [$P = 0.05$] for *M. hapla*—18 C = 14, 22 C = 18, 26 C = 15, 30 C = 12; *H. schachtii*—18 C = 11, 22 C = 10, 26 C = 12, 30 C = 9).

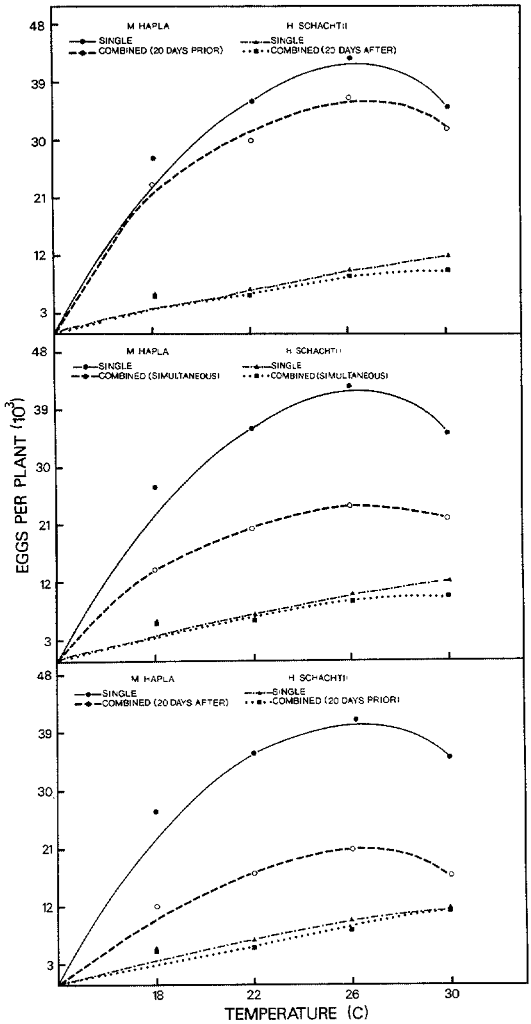

FIG. 3. Effect of soil temperature on egg production of *Meloidogyne hapla* and *Heterodera schachtii* singly and in combination in tomato (LSD [$P = 0.05$] for *M. hapla*—18 C = 5.9, 22 C = 6.7, 26 C = 5.8, 30 C = 6.3; *H. schachtii*—18 C = 2.5, 22 C = 3.0, 26 C = 2.6, 30 C = 2.8).

days before Mh. Mh did not adversely affect egg production of Hs.

DISCUSSION

This study substantiates results of a previous study (7) where combined inoculations with Mh and Hs reduced the galling index of Mh on tomato. Since simultaneous inoculation of tomato seedlings with Hs and Mh had little effect on the numbers of invading Mh J2, results from this study indicate that any adverse affect of Hs on Mh was generated within the plant tissue following invasion; Hs adversely affected the availability or access of Mh to appropriate feeding sites and subsequent egg production. Although Mh had less effect on Hs, egg production of Hs was always lower than that of Mh. This agrees with a previous study (7) that showed tomato was a poor host of this Hs population; nematode reproduction was similar to reproduction in that study.

This study confirms other studies indicating that concomitant relationships involving a *Meloidogyne* sp. usually results in depression of the root-knot nematode species population (3,4,6,11,12,14). Root-knot nematodes are considered the most economically important single genus of plant parasitic nematodes because of their geographical distribution, wide host range, pathogenicity, and environmental adaptability. However, they are generally poor competitors. For example, Bird et al. (1) reported *M. incognita* was unable to compete with *Hoplolaimus columbus* on cotton under field conditions. Jatala and Jensen (12) also showed that Mh was unable to compete with Hs on sugarbeet, agreeing with Inserra et al. (11). The poor ability of Mh to compete with Hs was again demonstrated in this study.

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