Preplanting Inoculum Densities of Root-Knot Nematode Related to Carrot Yield in Greenhouse

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ABSTRACT

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Pot experiments showed that preplanting infestation of *Meloidogyne incognita* at densities exceeding 230 juveniles + 2,300 eggs per liter of soil drastically suppressed marketable carrot (*Daucus carota* cv. Nantes) yield. The nematode rendered carrot unmarketable by causing constrictions, digitations, and crackings on the taproots. Only young plants were vulnerable to the nematode-related deformities. At preplanting inoculum densities less than 2,300 juveniles + 23,000 eggs per liter of soil, the nematode did not affect the total weight of the taproots produced.

Additional key words: crop loss of carrot

Relationships between preplanting root-knot nematode densities and crop yield have been studied for many plants (1). Similar information for carrot, however, is scarce. *Meloidogyne hapla* Chitwood is reported to cause detrimental effects on carrot production in Canada at preplanting inoculum density of 2,000 juveniles per liter of soil (5). In Michigan, the same nematode is known to provoke considerable damage on marketable taproots at preplanting inoculum densities as low as 200 juveniles per liter (4). We know of no information of this type available for other species of root-knot nematodes.

Carrot is one of the principal vegetables grown in the Federal District of Brazil, and root-knot nematodes, mainly *M. incognita,* are an important problem. The present investigations were carried out to characterize the relationship between preplanting inoculum densities of the nematode and host performance in pot tests.

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MATERIALS AND METHODS

Dark Red Latosol (Acrustox) with clay texture (approximate composition: 36% sand, 45% clay, and 19% silt) mixed with cow manure (2:1, v/v) was used throughout this work. In addition to a fertilizer mixture of NPK (4:14:8), incorporated at about 15 g/kg, lime was applied to the soil at 1.5 g/kg to correct acidity. After thorough mixing, the soil was treated with a mixture of methyl bromide and chloropicrin at 173 g/m^3 and covered with plastic sheets for 8 wk. Examinations at the end of the period showed that the fumigation eliminated practically all of the nematodes in the soil. No plant-parasitic nematodes were detected after the treatment.

Five liters of the fumigated soil was then put into each plastic pot (20.5 × 20.5 × 26.5 cm) and infested with root-knot nematode, *M. incognita* (Kofoid & White) Chitwood, at predetermined dosages. The top 2 L of the soil mixture from each pot was thoroughly mixed with the desired quantity of the inoculum. Carrot (*Daucus carota* L. cv. Nantes) was then seeded (10 seeds per pot) in the infested soil and maintained in a greenhouse, where the temperature fluctuated between 23 and 28 C during the experimental period. One week after germination, the seedlings were thinned to two plants per pot with a minimum distance of 8 cm between plants.

Eggs of *M. incognita* were extracted from cultures established on okra (*Hibiscus esculentus*) by the sodium hypochlorite method (2). The inocula thus obtained contained approximately 90% viable eggs and 10% second-stage juveniles.

The carrots were harvested 3 mo after seeding, and the effects of the nematode were evaluated. Degree of root-knot nematode parasitism on the carrot was read according to a galling index ranging from 0 to 5, where 0 = plants with no galls on the taproot or secondary roots, 1 = no galls on taproot and ≤10 small galls on secondary roots, 2 = ≤10 small galls on both taproot and secondary roots, 3 = ≤10 small galls on taproot and >10 aggregated galls on secondary roots, 4 = >10 aggregated galls on both taproot and secondary roots, and 5 = >10 aggregated galls on both taproot and secondary roots in addition to taproot deformation.

RESULTS

Although the preplanting inoculum densities of the nematode had no significant influence on the total fresh weight of the taproot produced, pronounced effects on the proportion of nonmarketable roots were evident. Highly significant reductions in marketable root production were observed for those treatments receiving preplanting inocula of more than 230 juveniles (J) + 2,300 eggs (E) per liter of soil (Table 1). Inoculum levels of less than 23 J + 230 E/L had no apparent effects on the quality of carrot.

In addition to galls, the nematode also provoked a significant increase in the incidence of other undesirable characteristics on the infected carrots (Fig. 1). The most frequent was sudden and localized constrictions on the otherwise cylindric taproot, sometimes resulting in twisting of the carrot. The second, referred to as "digitation," was typified by the emergence of thumblike branch roots. The last and least frequent was the exposing of the vascular cylinder on the taproot by cracking of the epidermis. Except for galls, all of the undesirable characteristics were also occasionally detected in uninoculated carrots. However, incidences of constriction, digitation, and cracking were increased in pots receiving preplanting inocula of more than 23 J + 230 E/L, 230 J + 2,300 E/L, and 2,300 J + 23,000 E/L, respectively (Table 2).

To investigate carrot age in relation to susceptibility, soils were infested with the

Table 1. Effects of preplanting inoculum densities of *Meloidogyne incognita* on *Daucus carota* cv. Nates in pot tests

Juveniles + eggs (per liter of soil)	Fresh roots (g/pot) 3 mo after germination[a] — Marketable: No galls	Marketable: Galls[b]	Nonmarketable[c]	Total
2,300 + 23,000	0	0	204	204
230 + 2,300	0	107	100	207
23 + 230	50	143	0	193
2 + 23	168	12	0	180
0	214	0	0	214
$LSD_{0.05}$	38.6	44.5	35.2	NS[d]

[a]Values represent the means of 10 replicates.
[b]Roots with small galls that can be removed without leaving a significant wound.
[c]Taproots with constrictions, digitations, or crackings.
[d]NS = not significant.

Table 2. Effects of preplanting inoculum densities of *Meloidogyne incognita* on *Daucus carota* cv. Nantes taproot deformations

Juveniles + eggs (per liter of soil)	Deformations 3 mo after germination[a] — Galling index[b]	Constrictions (no./root)	Digitation (fingers/root)	Cracking (cm/root)
2,300 + 23,000	4.4	9.2	5.5	0.9
230 + 2,300	2.4	6.2	1.8	0.2
23 + 230	1.4	3.9	0	0.2
2 + 23	0.8	0.9	0	0
0	0.3	0.4	0.2	0.1
$LSD_{0.05}$	0.4	1.0	1.2	0.3

[a]Values represent the means of 10 replicates.
[b]0 = Plants with no galls on taproot or secondary roots, 1 = no galls on taproot and ≤10 small galls on secondary roots, 2 = ≤10 small galls on both taproot and secondary roots, 3 = ≤10 small galls on taproot and >10 aggregated galls on secondary roots, 4 = >10 aggregated galls on both taproot and secondary roots, and 5 = >10 aggregated galls on both taproot and secondary roots in addition to taproot deformations.

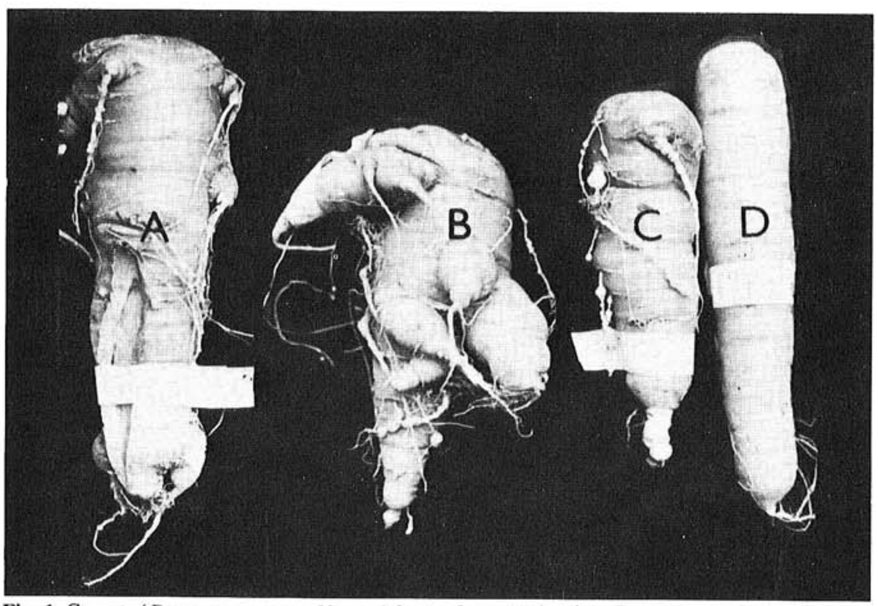

Fig. 1. Carrots (*Daucus carota* cv. Nantes) 3 mo after germination. Roots grown in pots infested with *Meloidogyne incognita* at 2,300 juveniles + 23,000 eggs per liter of soil before planting show **(A)** cracking, **(B)** digitations, and **(C)** constriction. **(D)** Root grown in a noninfested pot is free of the deformities.

Table 3. Effect of time of *Meloidogyne incognita* infestation on *Daucus carota* cv. Nantes yield

Infestation			Yield (g/pot) 3 mo after germinations[b]			
			Marketable			
Time	Juveniles + eggs (per liter of soil)	Galling index[a]	No galls	Galls	Nonmarketable[c]	Total
Preplanting	1,000 + 10,000	3.5	0	0	173	173
Preplanting	200 + 2,000	2.5	0	9	176	185
Preplanting	100 + 1,000	2.8	0	21	177	198
...	0	0	138	0	34	172
30 days post planting	1,000 + 10,000	2.9	15	18	140	172
60 days post planting	1,000 + 10,000	1.8	43	104	51	198
$LSD_{0.05}$		0.8	49.3	48.8	48.3	NS[d]

[a] As given in Table 2, footnote b.
[b] Values represent the means of eight replicates.
[c] Taproots with constrictions, digitations, and crackings.
[d] NS = not significant.

nematode before or after seeding. At an inoculum density of 1,000 J + 10,000 E/L, the nematode caused a substantial reduction in marketable root production, whether infested before or 30 days after seeding (Table 3). Infestations at the same inoculum density 60 days after planting caused no reduction in marketable roots compared with the noninfested controls. Soil infested with 1,000 J + 10,000 E/L 60 days after planting produced more marketable roots than those infested with only 10% of this amount before planting (Table 3). At the inoculum levels tested, the nematode had no effect on the total fresh weight of the carrot produced, whether the soil was infested before or after seeding.

The nematode caused increases in constrictions and digitations only in carrots planted after infestation. Post-planting infestations had no apparent effect on the production of undesirable characteristics, even though they caused increases in galling.

DISCUSSION

Even at preplanting densities of 2,300 J + 23,000 E/L of soil, *M. incognita* had an adverse effect on the quality but not the quantity of the taproot of carrot cv. Nantes (Table 1). Vrain et al (5) reported similar results for *M. hapla* on carrot cv. Goldpack at an inoculum density of 800 J + 1,500 E/L. As the density was elevated to 2,000 J/L, however, the nematode drastically reduced the root weight of the Goldpack carrot (5). Working on cultivar Spartan Premium, Slinger and Bird (4) showed that *M. hapla* is able to delay and reduce carrot growth, in addition to causing other adverse effects, at an inoculum density of more than 50 J/L. This evidence clearly indicates that adverse effects of root-knot nematodes on carrot vary not only with the species and inoculum density but also with the susceptibility of the cultivars involved.

In the state of São Paulo, commercialized carrots are placed into one of three classes, according to quality (3). A 25-kg box of carrots is not allowed to contain more than 5, 10, or 25% deformed or diseased roots for the first, second, or third class, respectively. It is assumed that carrots classified as marketable with galls in the present work are not considered "deformed" or "diseased" in the classification because the galls can be removed without leaving significant wounds on the taproots. Assuming that 10% deformed roots are acceptable, the crop loss at a preplanting inoculum density of 230 J + 2,300 E/L is about 39% (Table 1). Because no significant loss was detected at 10% of this density, the critical preplanting inoculum density of *M. incognita* on the carrot should be found between these concentrations. A more precise estimate of the critical density, however, is not possible based on the data obtained.

Vrain et al (5) suggested that *M. hapla* provokes carrot deformations principally during the period of taproot formation. Results of the present investigations confirmed this opinion, because the infestations made after the first month of seed germination produced many fewer deformed roots than the preplanting infestations (Table 3).

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