Relationship between Population Densities of Heterodera schachtii and Losses in Vegetable Crops in Ontario

T. H. A. Olthof, J. W. Potter, and E. A. Peterson

Nematologists, Research Station, Research Branch, Agriculture Canada, Vineland Station, Ontario, L0R 2E0; and Microbiologist, Chemistry and Biology Research Institute, Research Branch, Agriculture Canada, Ottawa, K1A 0C6.

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ABSTRACT

Five vegetable crops were grown in microplots infested with 0, 666, 2,000, 6,000, or 18,000 sugarbeet nematode larvae (*Heterodera schachtii*) per kg of soil. In general, marketable yields were inversely correlated with preplant nematode population densities, except for cauliflower which was not affected at any preplant density used. Losses in marketable yields of rutabagas were 15%, 22%, and 35%, respectively, at the three highest preplant densities; those of spinach were 29% and 49%, respectively, at the 6,000 and 18,000 densities. At the 18,000 density, losses in marketable weight of cabbage and table beets were, respectively, 24% and 30%. Larval populations in the soil were higher at harvest than at planting under all crops except spinach. At the 18,000 density, there were 210,000 nematodes per kg of soil under cabbage, 98,000 under beets, 90,000 under rutabagas, 46,000 under cauliflower, and 2,900 under spinach. The number of *H. schachtii* cysts in the soil at harvest increased with increasing larval population densities per kg of soil and amounted to 720 under cabbage, 530 under rutabagas, 470 under beets, 400 under cauliflower, and 240 under spinach, for the 18,000 density. The number of *H. schachtii* cysts per root system, and the number of cysts per gram of fresh root, were also positively correlated with preplant densities in all crops.

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RESUME

Cinq légumes furent cultivés dans des micro-parcelles infestés de 0, 666, 2,000 6,000, ou 18,000 larves de nématode de la betterave (*Heterodera schachtii*) par kg de sol. En général, le rendement des légumes vendable sur le marché était inversement relié aux populations initiales de nématodes, à l'exception du chou-fleur qui ne fut affecté, quelque soit la densité initiale utilisée. Les pertes de rutabaga vendable sur le marché étaient respectivement de 15%, 22%, et 35% aux trois densités initiales les plus hautes; celles des épinards étaient respectivement de 29% et 49% aux densités de 6,000 et 18,000 nématodes. A la densité de 18,000, les pertes de chou et de betterave potagère vendable sur le marché étaient respectivement de 24% et 30%. A la récolte de toutes les cultures, à part les épinards, les populations des larves dans le sol étaient plus larges qu'à la plantation. A la densité de 18,000 il y avait 210,000 larves par kg de sol pour le chou; 98,000 pour la betterave; 90,000 pour les rutabagas; 46,000 pour le chou-fleur, et 2,900 pour les épinards. Le nombre de kystes de *H. schachtii* dans le sol à la récolte était positivement relié aux densités de populations de larves par kg de sol et était de 720 pour le chou, 530 pour les rutabagas, 470 pour la betterave, 400 pour le chou-fleur, et 240 pour les épinards, à une densité de 18,000. Le nombre de kystes de *H. schachtii* par système radiculaire et le nombre de kystes par gramme de racine fraîche était aussi positivement relié aux densités initiales pour toutes les cultures.

The relationship between initial population densities of *Meloidogyne hapla* and *Pratylenchus penetrans* and crop losses for some vegetables in Ontario has been established (14, 15). Another nematode associated with vegetables in Ontario, is the sugarbeet nematode, *Heterodera schachtii* Schmidt. This cyst nematode, first found in Canada in 1921 (2), has been a problem on sugarbeets in southern Ontario (1) and in Alberta (10). Serious damage to table beets at Woodbridge, Ontario, in 1964 prompted a survey that showed widespread distribution throughout southern Ontario (25). *H. schachtii* has also been reported from New York (12), Ohio (18), Florida (23), and many other States in the USA (5).

Host range studies in Ontario (13, 25) and elsewhere (7) have shown that several vegetable crops in the Chenopodiaceae and Cruciferae are susceptible to *H. schachtii*. Moreover, greenhouse studies (12, 25) and field trials (3, 6, 9, 22) have indicated that the nematode can cause varying degrees of damage to these crops.

To determine the extent of damage under our conditions, microplots (14, 15) were used to relate five preplant population densities of *H. schachtii* to crop losses in rutabagas, cabbage, cauliflower, beets, and spinach. In addition, an inventory was made of soil microflora which might affect such a relationship.

MATERIALS AND METHODS.—*H. schachtii* used in this study, was isolated from table beets (*Beta vulgaris* L.) at Woodbridge, Ontario, and was maintained in the greenhouse for 5 yr on table beets and a further 3 yr on cabbage (*Brassica oleracea* L. var. *capitata* L.). Large soil populations of larvae were reared on cabbage 'Badger Market' in Vineland loam in a greenhouse ground bed. Portions of the infested soil were then thoroughly mixed with steam-treated (2 h at 104 C) Vineland loam for 5 min in a cement mixer to yield ca. 666, 2,000, 6,000, or 18,000 larvae/kg of soil. The soil for the control plots consisted of steam-treated Vineland loam. The same procedure, experimental design, and moisture-temp sensors were used as before (15).

Two days after filling the tiles with soil (10 kg), one 5- to 6-wk-old seedling of cabbage 'Market Prize' or cauliflower (*Brassica oleracea* L. var. *botrytis* L. 'Idol Original') was transplanted to each tile in the appropriate plot. Two days later table beets 'Detroit Dark Red' were seeded at three seeds per tile, rutabagas (*Brassica napobrassica* Mill. 'Laurentian') at two seeds and spinach (*Spinacia oleracea* L. 'Cold-Resistant Savoy') also at two seeds per tile.

Actual initial nematode population densities were determined from soil samples, taken from all treatments at the time of planting, and extracted for one wk using the Baermann pan method (24). Addition of air-dried ground bed soil to each tile, fertilization, and root maggot control followed previous practice (15). Zolone (2.24 kg/ha) was applied 6 wk after planting to control aphids, plant bugs, and leaf hoppers.

Population densities of the nematode at approximately midseason (35 days after planting) were determined as previously (15). Marketable yields (21) and other growth data were obtained at crop maturity 46, 56, 62, 73, and 80 days after planting, respectively, for spinach, cauliflower, cabbage, beets, and rutabagas. The marketable storage-root portions of the latter two crops were separated from the remainder of the root system. The final population of larvae in the soil of each microplot was determined as before (24). The number of cysts in the soil of each microplot was determined by the Fenwick can method (4); the number of cysts per root system (excluding marketable portions) was determined after separating them ultrasonically from the roots. For microbial determination, composite soil samples, based on soil taken at harvest from each microplot for each crop, were combined and thoroughly mixed. Fungi were isolated from suitable dilutions of a 10-g quantity of each composite sample using Peterson's method (19); bacterial numbers were determined according to Lochhead and Chase (11).

RESULTS.—Marketable yields of rutabagas were reduced at 2,000 *H. schachtii*/kg of soil; of spinach at 6,000/kg and of cabbage and beets at 18,000/kg of soil. Cauliflower yields were not affected by any nematode population density (Fig. 1). Losses in marketable yields of rutabagas were 15%, 22%, and 35%, respectively, at the three highest densities; and those of spinach were 29% and 49%, respectively, at the two highest densities (Fig. 2). Losses for cabbage and beets at the highest nematode density were, respectively, 24% and 30%.

Total top weights of all crops were only reduced at the highest initial nematode density, except for spinach where top weights were down at the two highest densities (Fig. 3). Root weight of cabbage was decreased at the three highest densities; that of cauliflower only by the highest, and that of spinach by the two highest densities (Fig. 4). In contrast, root weight of spinach was increased at 666 *H. schachtii*/kg of soil. Root weight, excluding marketable portions, of beets was increased at the 6,000 density and that of rutabagas at the two highest densities.

Larval population densities of *H. schachtii* in the soil at midseason were much lower than those at the initiation of the experiment. At harvest however, larval populations under all crops, except spinach, exceeded those at planting. The changes in larval populations, based on the difference between initial and final densities, are shown in Fig. 5. The number of cysts in the soil under each crop increased with increasing preplant larval population densities (Fig. 6). Similarly, the number of cysts per root system increased in all crops, except in rutabagas at the highest initial density (Fig. 7). The number of cysts per gram of fresh root of all crops also increased with increasing preplant densities (Fig. 8).

A total of 672 fungal isolates, belonging to over 18 genera were obtained from the soil samples of the five crops (Table 1). Of these genera, *Chrysosporium* was the most prevalent in all crops except rutabagas, followed by *Trichurus* and *Penicillium*; the incidence of all other genera was low. Bacterial counts averaged 13.1×10^6/g of soil. Data on soil moisture and temperature at 15- and 30-cm depths in the rutabaga microplots are presented in Fig. 9. Natural rainfall, supplemented with irrigation when necessary, maintained moisture near field capacity in the root zone.

DISCUSSION.—The economic loss threshold, described earlier (14, 15), is the percentage of the total value of a crop equivalent to the cost of nematode control, and is associated with an initial nematode density beyond which control of nematodes by fumigation becomes

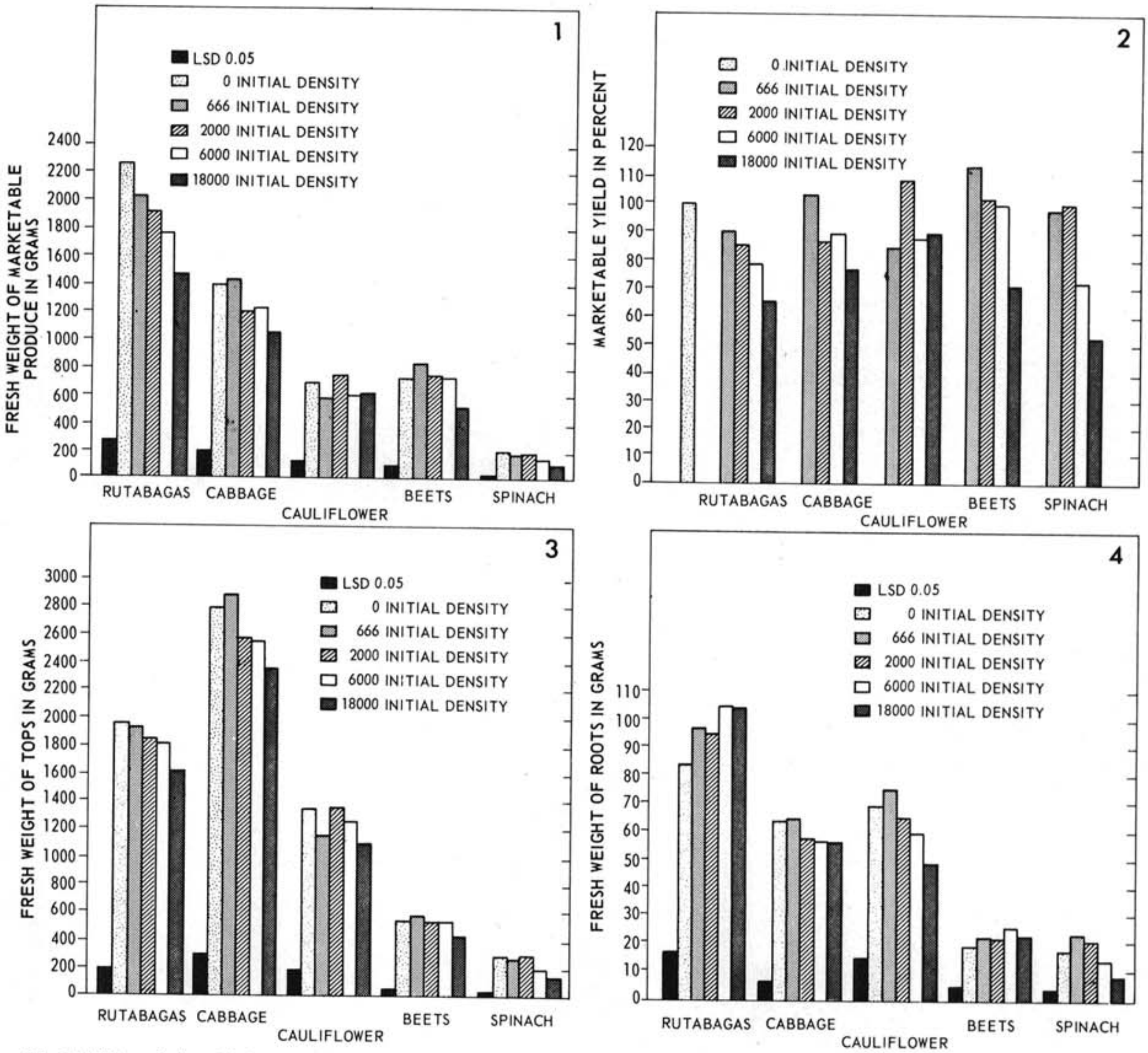

Fig. 1-4. The relationship between five population densities of *Heterodera schachtii* and growth and marketable yield of five field-grown vegetables in Ontario. **1)** Marketable yields in grams. **2)** Marketable yields expressed as percent of control. **3)** Effect on fresh weight of tops. **4)** Effect on fresh weight of roots, excluding marketable portions of rutabagas and beets.

economically feasible. In our work with *Pratylenchus penetrans* (15), we only considered fumigation to be economically feasible at nematode densities where the economic loss threshold was exceeded and where crop losses were statistically significant. In the present study, yield losses sometimes exceeded the economic loss threshold (e.g., in cauliflower); yet, because these losses were not statistically significant, fumigation could not be considered at any of the preplant densities tested for this crop.

The economic loss thresholds, derived from the crop values and the known costs of fumigation, were approximately: for rutabagas, 9%; cabbage, 5%; cauliflower, 4%; beets, 18%; and spinach, 13%. The farm values/ha of the crops were averaged over the 1970 and 1971 crop seasons and totaled \$6.5 million (17). The cost of fumigation in the case of beets and spinach is ca. \$200/ha (\$80/acre) for broadcast treatment, but only \$100/ha (\$40/acre) for row fumigation with rutabagas, cabbage, and cauliflower. Fumigation would be economically feasible with rutabagas at initial larval densities in excess of 666/kg of soil; with spinach, at densities higher than 2,000/kg; and with cabbage and beets, at densities in excess of 6,000/kg of soil.

Because of mortality and penetration of larvae into roots, larval population densities in the soil were very low at midseason, when damage usually becomes evident in the field. This fact must be considered when making diagnoses at midseason, when low nematode populations in the soil do not necessarily mean an absence of a cyst nematode problem.

With the exception of spinach, all crops were good hosts of *H. schachtii* (Fig. 5-8). These results agree with other reports on the reproductive potential of this

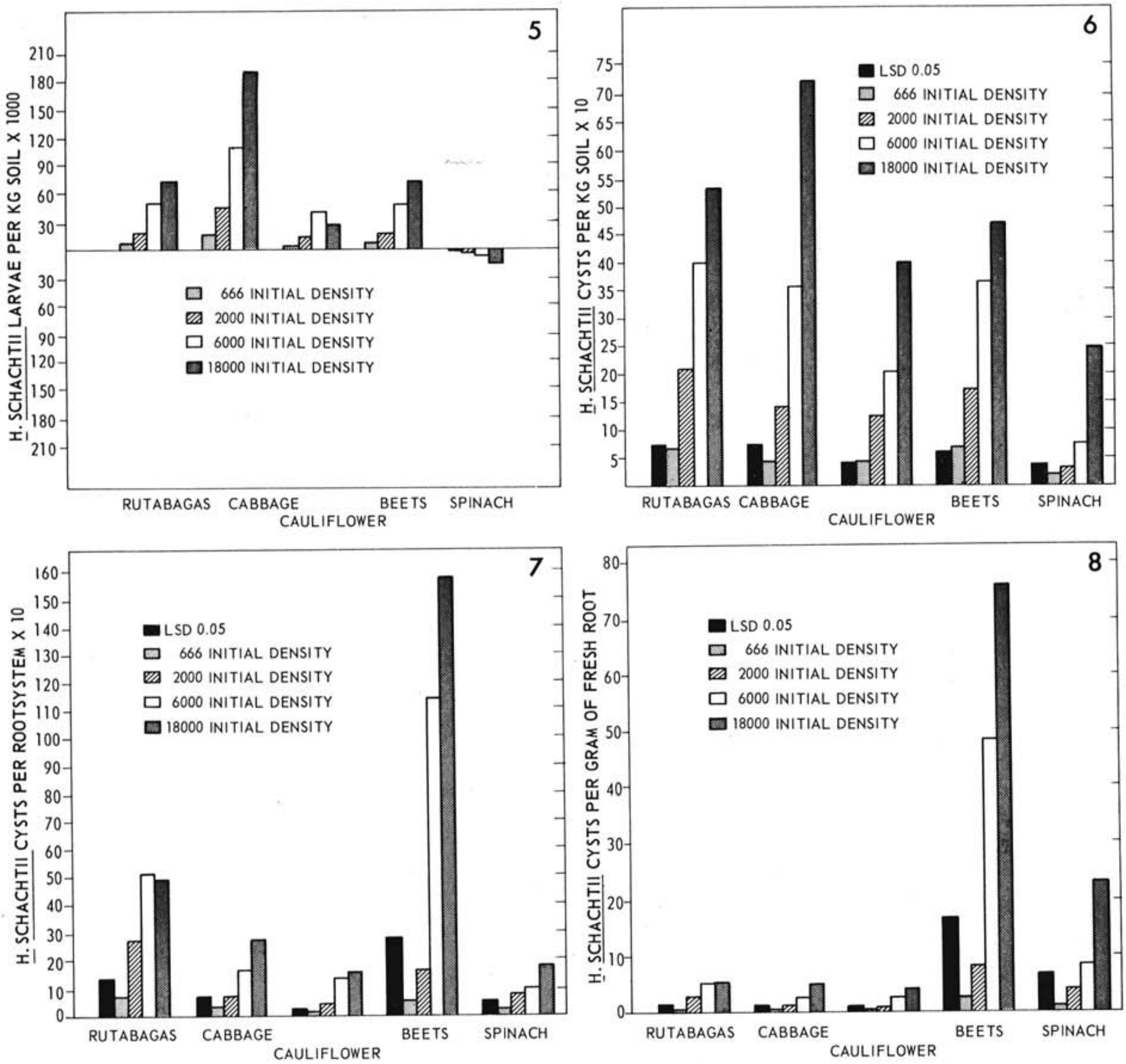

Fig. 5-8. 5) Changes in populations of *Heterodera schachtii* larvae in soil on five field-grown vegetables in Ontario, based on the difference between initial and final densities. Columns above the base line signify more nematodes and those below the base line fewer nematodes at harvest than at planting. **6)** Number of cysts in soil of five vegetables grown with five preplant population densities of *Heterodera schachtii* in Ontario. **7-8)** Number of cysts on roots, excluding marketable portions of rutabagas and beets, of five vegetables grown with five preplant population densities of *Heterodera schachtii* in Ontario. **7)** Number of *H. schachtii* cysts per root system. **8)** Number of *H. schachtii* cysts per gram of fresh root.

nematode (7, 13, 25). As also noted in Germany (8), the time for spinach to mature to harvest was insufficient for cyst maturation or for large-scale hatching to develop high cyst (Fig. 6) or larval numbers in the soil; consequently, the latter at harvest were lower than the initial densities (Fig. 5).

Of the 18 or more genera of common soil saprophytic fungi recognized, relatively few assumed predominant proportions. Although some saprophytic fungi are known to interact with plant parasitic nematodes in causing plant disease (20), careful root examination revealed no visual evidence of fungal attack in the present study. There appeared to be a positive correlation between the number of fungal genera present in the soil and the time required to reach maturity (Table 1). Possibly, the longer growing period presents more opportunity for contamination of the soil, and subsequent fungal development in the microplots. Bacterial numbers were fairly similar in the soil under beets, rutabagas, spinach; no explanation can be offered for the high count in cabbage or the low count in cauliflower.

The initial densities in our experiment were similar to those used in previous studies involving *Meloidogyne*

TABLE 1. Percentage incidence of fungi and total numbers of bacteria in soil infested with different population densities of *Heterodera schachtii*, cropped to five vegetables in Ontario[a]

Fungus genera	Rutabagas (80 days)[b]	Beets (73 days)	Cabbage (62 days)	Cauliflower (56 days)	Spinach (46 days)
Acrostalagmus	2.0	0.0	0.0	0.0	0.0
Alternaria	2.0	0.0	0.0	0.0	0.0
Aspergillus	1.0	3.4	1.9	1.1	2.6
Cephalosporium	2.0	1.7	1.9	0.5	0.9
Chaetomium	0.0	0.9	0.0	0.5	0.9
Chrysosporium	18.0	47.9	66.5	67.2	75.2
Fusarium	0.0	0.9	0.0	0.0	0.0
Gliocladium	1.0	0.0	0.0	0.0	0.0
Humicola	0.0	0.9	4.5	0.5	0.9
Metarrhizium	1.0	0.0	0.0	0.0	0.0
Mortierella	1.0	0.0	0.0	0.0	0.0
Mucor	3.0	6.8	0.6	0.0	0.9
Myrothecium	2.0	0.0	0.0	0.0	0.0
Oidiodendron	1.0	0.0	0.0	0.0	0.0
Penicillium	24.0	11.1	8.4	7.7	6.8
Phialophora	0.0	0.0	0.6	0.5	0.0
Trichoderma	2.0	1.7	1.3	2.7	0.9
Trichurus	38.0	22.2	13.5	19.1	11.1
Sterile spp.	2.0	2.6	0.6	0.0	0.0
Total Fungi	15	11	10	9	9
No. of isolates	100	117	155	183	117
Bacteria counts (millions/g soil)	10.7	13.1	23.9	4.9	13.1

[a]Based on composite samples, comprising five nematode population densities per crop, taken at harvest.
[b]Number of days from planting to maturity.

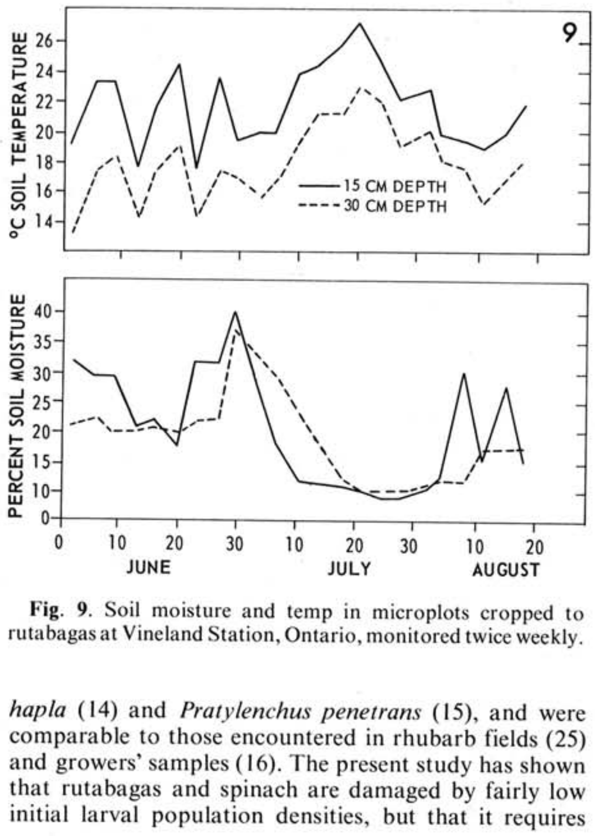

Fig. 9. Soil moisture and temp in microplots cropped to rutabagas at Vineland Station, Ontario, monitored twice weekly.

hapla (14) and *Pratylenchus penetrans* (15), and were comparable to those encountered in rhubarb fields (25) and growers' samples (16). The present study has shown that rutabagas and spinach are damaged by fairly low initial larval population densities, but that it requires much larger populations to damage cabbage, beets, and particularly, cauliflower. In view of the very large population densities at harvest in most crops in this experiment (Fig. 5-8), it is possible that the initial densities used were lower than those naturally occurring in fields with a sugarbeet nematode problem. Nevertheless, these experiments have shown that relatively low initial densities of *H. schachtii* are capable of causing appreciable losses to some crops, and suggest future similar experimentation using higher initial population densities.

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