The Relationship between Population Densities of Pratylenchus penetrans and Crop Losses in Summer-Maturing Vegetables in Ontario

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ABSTRACT

Six vegetable crops were grown in microplots infested with *Pratylenchus penetrans*. In general, marketable yields were inversely correlated with preplant nematode population densities. Losses in marketable yields of sweet corn and onions ranged from 30% and 14% at a preplant density of 666 nematodes/kg of soil, to 49% and 71% at 18,000 nematodes/kg of soil, respectively. At preplant densities of 6,000 and 18,000 nematodes/kg of soil, the reductions in marketable yields of cabbage, lettuce, cauliflower, and potatoes were 17% and 25%; 18% and 33%; 19% and 59%; and 35% and 43%, respectively. With the exception of potatoes and onions at the 18,000 density, soil nematode populations under all crops at harvest were higher than at planting. Nematode populations in the roots at harvest were positively correlated with preplant nematode densities, except with potatoes and onions at the two highest densities. Largest nematode numbers/g of fresh root occurred at the 18,000 density with cabbage (450/g), lettuce (1,460/g), cauliflower (1,710/g), and sweet corn (350/g); at the 6,000 density with onions (1,230/g); and at the 2,000 density with potatoes (1,320/g).

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Additional key words: population dynamics, economic loss threshold.

RÉSUMÉ

Six légumes furent cultivés dans des micro-parcelles infestés de *Pratylenchus penetrans*. En général, le rendement des légumes vendable sur le marché était inversement relié aux populations initiales de nématodes. Les pertes de mais sucré et d'oignons vendable sur le marché étaient respectivement de 30% et 14% à une densité initiale de 666 nématodes/kg de sol et de 49% et 71% à une densité de 18,000 nématodes/kg de sol. Aux densités de 6,000 et 18,000 nématodes/kg de sol, les réductions respectives du rendement du chou, laitue, chou-fleur, et des pommes de terre vendables sur le marché étaient de 17% et 25%; 18% et 33%; 19% et 59%; et 35% et 43%. À la récolte de toutes les cultures, à part les pommes de terre et les oignons cultivés aux densités de 18,000 nématodes, les populations des nématodes du sol étaient plus larges qu'à la plantation. Les populations des nématodes des racines étaient positivement reliées aux populations initiales, à l'exception des cultures de pommes de terre et d'oignons aux deux densités les plus larges. Le plus grand nombre de nématodes/g de racines fraîches fut trouvé à la densité de 18,000 pour le chou (450/g), la laitue (1,460/g), le chou-fleur (1,710/g), et mais sucré (350/g); à la densité de 6,000 pour les oignons (1,230/g); et à la densité de 2,000 pour les pommes de terre (1,320/g).

In a previous paper (8) we outlined the need for reliable data on the relation between numbers of plant parasitic nematodes and crop losses in vegetables in Ontario and described a microplot method to assess crop damage at several preplant densities of *Meloidogyne hapla* under field conditions without using fumigants.

Subsequently, attention was turned to crop losses associated with the root-lesion nematode, *Pratylenchus penetrans* (Cobb). In Ontario, Townshend (17) found this nematode responsible for stunting and root discoloration of celery, and large numbers were found associated with stunted plants in fields of snap beans, cabbage, cauliflower, sweet corn and onions (9). Hawkins & Miller in Connecticut (5) and Ferris in Indiana (3) found correlations between numbers of *P. penetrans* and damage to potatoes and onions, respectively. In Wisconsin, *P. penetrans* reduced yield of potatoes and growth of corn (2).

In view of the widespread occurrence of *P. penetrans* in Ontario and its suspected economic importance in vegetable production, microplot studies were undertaken as before (8), relating five preplant population densities to crop losses in six common vegetable crops.

MATERIALS AND METHODS.—The population of *P. penetrans* used in this study, was isolated from rye (*Secale cereale* L. 'Tetra Petkus') growing in rotation with tobacco at the Canada Department of Agriculture, Research Station, Delhi, Ontario, and was maintained on celery (*Apium graveolens* L. var. *dulce* 'Utah') in the greenhouse. Large soil populations were reared on rye grown for 6 months in infested Vineland loam in a 3 × 6 m ground bed in the greenhouse. After removing all coarse roots and carefully mixing the infested soil, the population density was determined by processing ten 50-g samples by a modified Baermann funnel technique (18). Portions of the infested soil, which contained an average of 35,660 *P. penetrans*/kg, were then thoroughly mixed with steam-treated (1.5 to 2 hr at 82 to 104 C) Vineland loam for 5 min in a cement mixer to yield ca. 666, 2,000, 6,000 or 18,000 nematodes/kg of soil. The soil for the control plots consisted of steam-treated Vineland loam. Ten kg of soil of each infestation level were placed in clay drainage tiles of 20 cm internal diameter and 30 cm long, which had previously been plunged in the field soil on 1.2-m centers. A randomized block design in a 12- × 12-m plot with 20 tiles (replicates) for each of the five nematode population densities (treatments) was used for each kind of vegetable. While filling the tiles, resistance-block moisture-temperature sensors (Soiltest, Inc., Evanston, Illinois) were placed in one tile in each plot at depths of 15 and 30 cm to indicate when additional moisture was required.

Within 4 days after filling the tiles with soil, one 5- to 6-week-old seedling of cabbage (*Brassica oleracea* L. var. *capitata* L. 'Market Prize'), cauliflower (*Brassica oleracea* L. var. *botrytis* L. 'Idol'), or lettuce (*Lactuca sativa* L. 'Pennlake') was transplanted to each tile in the appropriate plot. Three 5- to 6-week-old seedlings of onion (*Allium cepa* L. 'Copper Gem') were transplanted per tile. Two weeks later one seed-potato eye (*Solanum tuberosum* L. 'Sebago') was planted per tile and sweet corn (*Zea mays* L. var. *rugosa* Bonaf. 'Veecrop') was seeded at three seeds per tile.

To determine actual nematode population densities, soil samples were taken from all treatments immediately after transplanting. To ensure that all the tiles had, qualitatively and initially, the same microflora present, each received 40 to 50 ml of air-dried soil from the nematode-infested greenhouse ground bed. On the same day, 8-32-16 fertilizer was added to each tile at the rate of 560 kg/ha; ammonium nitrate at 168 kg/ha was added to each crop 4 weeks after transplanting.

To control root maggots on cabbage, cauliflower, and onions, the respective tiles received a 230 ml drench of Diazinon W50, 0.06 kg/100 liters, at transplanting and 2 weeks later, following commercial practices. Aphids and loopers on cabbage and cauliflower were controlled as before (8).

To determine the population densities of the nematode at approximately midseason, soil samples were taken to a depth of 15 to 20 cm from five microplots of each treatment and crop 40 days after filling the tiles; samples were processed by the method indicated above.

Marketable yields (14) and other growth data were obtained at crop maturity which took 57, 65,

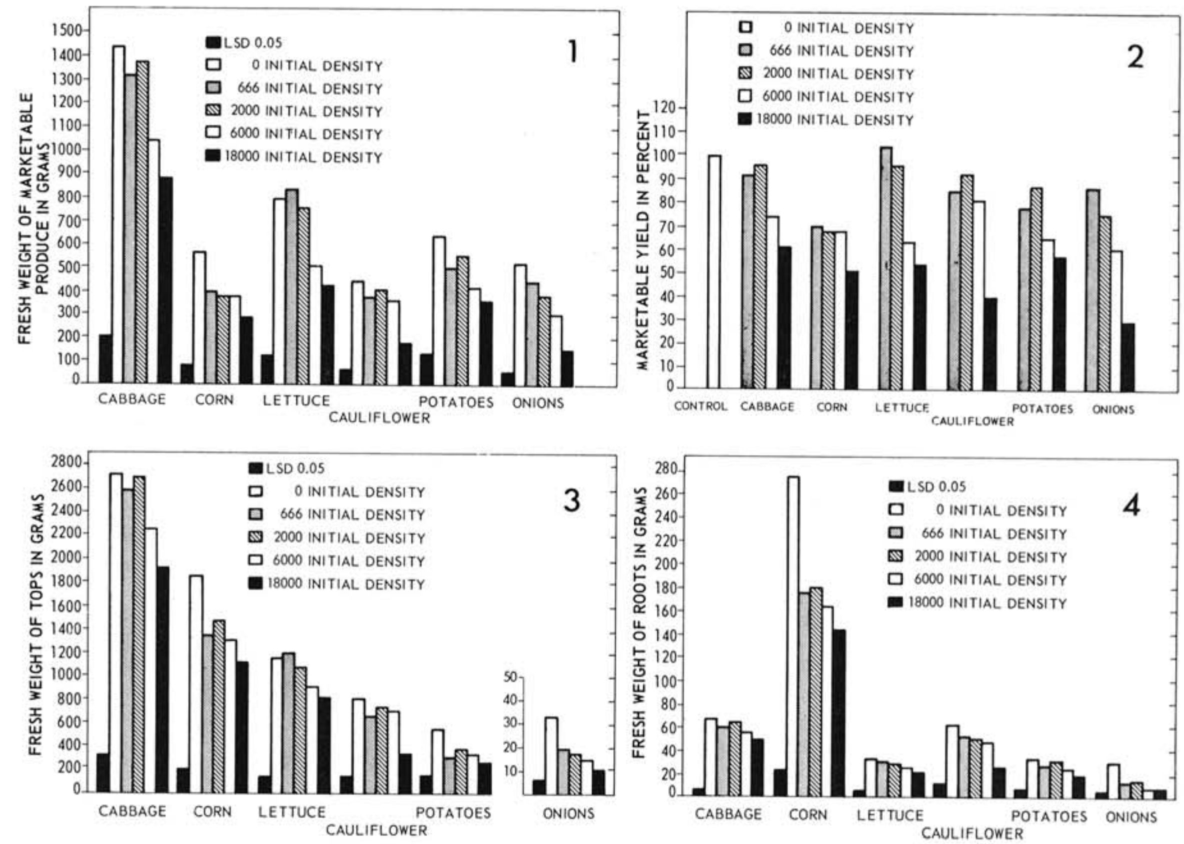

Fig. 1-4. The relationship between five population densities of *Pratylenchus penetrans* and growth and marketable yield of six field-grown vegetables in Ontario. **1)** Marketable yields in grams. **2)** Marketable yields expressed as percent of control. **3)** Effect on fresh weight of tops. **4)** Effect on fresh weight of roots.

72, 78, 120, and 121 days from transplanting or seeding, respectively, for lettuce, cauliflower, cabbage, corn, onions, and potatoes. The final soil nematode population in each microplot was determined as before (18). A composite soil sample was taken from potato microplots and suitable dilutions of this soil were plated with glucose-peptone agar containing rose bengal and chlortetracycline (12) for isolation of fungi and with soil extract agar (6) for determination of bacterial numbers. Root populations of the nematode were determined by extracting them for 1 week from each entire root system (or a 50-g sample of corn root) in a mist chamber and counting them.

RESULTS.–Marketable yields of corn and onions were reduced at all preplant densities of *P. penetrans*, whereas reductions in yield of cabbage, lettuce, cauliflower, and potatoes only became evident at 6,000 *P. penetrans*/kg of soil (Fig. 1). Losses in marketable yields of corn and onions ranged from 30% and 14% at the lowest density to 49% and 71% at the highest density, respectively. At the 6,000 and 18,000 densities, marketable yields of cabbage were down by 26% and 38%, respectively, relative to the uninfested control; lettuce was reduced by 36% and 46%; cauliflower by 19% and 61%; and potatoes by 35% and 43% (Fig. 2). With the latter crop, the number of marketable tubers was reduced at the two high densities; the number of unmarketable tubers was reduced only at the highest density.

Total top weights of corn, potatoes, and onions were reduced by all initial nematode densities; a density of 6,000/kg of soil was required to cause such a decrease in cabbage and lettuce, and 18,000 in cauliflower (Fig. 3). Root weight of corn and onions

TABLE 1. Midseason[a] soil population densities of *Pratylenchus penetrans* under six vegetables in Ontario

	Initial *P. penetrans* densities/kg of soil			
Crop	666	2,000	6,000	18,000
Cabbage	520	1,400	5,060	18,500
Corn	570	2,160	5,920	18,300
Lettuce	1,090	2,370	6,720	19,100
Cauliflower	690	1,480	6,060	17,000
Potatoes	280	2,140	4,710	20,300
Onions	480	1,720	5,300	12,400

[a] Thirty-six days after transplanting cabbage, cauliflower, lettuce and onions; 22 days after seeding corn and potatoes.

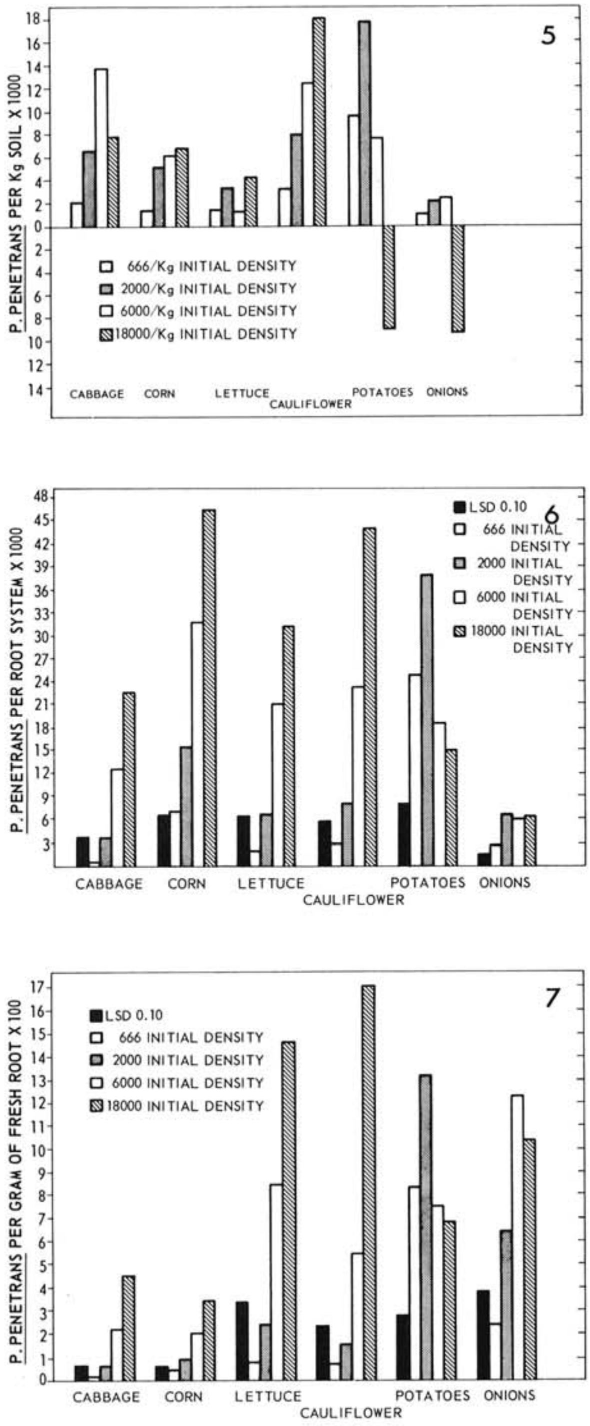

Fig. 5-7. 5) Changes in populations of *Pratylenchus penetrans* on six field-grown vegetables in Ontario, based on the difference between initial and final densities. Columns above the base line signify more nematodes and those below the base line fewer nematodes in the soil at harvest than at planting. **6-7)** Number of nematodes in roots of six vegetables grown with five preplant population densities of *Pratylenchus penetrans* in Ontario. **6)** Number of *P. penetrans* per root system. **7)** Number of *P. penetrans* per gram of fresh root.

decreased at all densities; that of lettuce and cauliflower was down at the 2,000 density and root weight of cabbage and potatoes required 6,000 nematodes/kg of soil to be reduced (Fig. 4).

Average midseason nematode population densities in all vegetables are presented in Table 1. The change in nematode population densities in the soil, based on the difference between initial and final densities, is shown in Fig. 5. Except for potatoes and onions at the 18,000 density, soil nematode populations were higher at harvest than at planting. Final root populations increased with increasing preplant population densities, except for potatoes and onions at the two highest densities (Fig. 6). A positive correlation between final populations per gram of fresh root and preplant densities occurred in all crops, except in potatoes at the 6,000 and 18,000 density and in onions at the 18,000 density (Fig. 7).

A total of 124 fungal isolates, belonging to 12 genera, were obtained from the potato soil sample. *Trichurus* sp. was most prevalent (45.2% incidence), followed by *Penicillium* (15.3%); *Cladosporium* (10.5%); *Chaetomium* (6.5%); sterile sp. (5.6%); *Chrysosporium* and *Trichoderma* (each 4.0%); *Mucor*, *Myrothecium* and unidentified sp. (each 2.4%); and *Fusarium* and *Phialophora* (each 0.8%). Bacteria were present at 13.2×10^6/g of soil.

Soil moisture and temperature data at 15- and 30-cm depths in potato microplots are presented in Fig. 8. Natural rainfall, supplemented with irrigation when necessary, maintained moisture near field capacity in the root zone.

DISCUSSION.–In a previous paper we introduced the concept of the economic loss threshold as being a percentage of the total value of a crop equivalent to the cost of nematode control and related to nematode density (8). In this relationship, the economic loss threshold is associated with an initial nematode density, beyond which control of nematodes by fumigation would become economically feasible. In the present investigation, the economic loss thresholds for corn (25%), onions (10%), cabbage (5%), lettuce (11%), cauliflower (4%), and potatoes (7%), were derived from the crop values and the known costs of fumigation. The farm values/ha of the crops were averaged over the 1969 to 1970 crop seasons (10). The cost of fumigation in the case of onions and lettuce is \$200/ha (\$80/acre) for broadcast treatment, but only \$100/ha (\$40/acre) for row fumigation with corn, cabbage, cauliflower, and potatoes. Fumigation would be economically feasible with corn and onions at initial densities below 666 *P. penetrans*/kg of soil and with cabbage, lettuce, cauliflower, and potatoes at densities between 2,000 and 6,000/kg, as the economic loss thresholds of the first two crops were exceeded at 666/kg and those of the latter four at 2,000/kg. Cauliflower and potatoes were included in the latter group because yield reductions at the 2,000 density, though exceeding the economic loss thresholds, were not statistically significant; this was probably due to experimental variation that tended to depress these weights at the 666 density.

Cabbage, lettuce, cauliflower, and potatoes appear to be tolerant to *P. penetrans* as decreases in marketable weights of all four crops occurred only at the two highest initial densities (Fig. 1). Acedo & Rohde (1) showed in aseptic studies that *P. penetrans* is capable of causing wilting and death of cabbage. The results support field observations associating high root-lesion nematode populations with stunting of cabbage in Ontario (9). In Dutch greenhouses, lettuce is apparently more sensitive as the Advisory Manual, used by the Bedrijfslaboratorium voor Grond- en Gewasonderzoek, Oosterbeek, The Netherlands, describes densities of 500 to 1,000 *P. penetrans*/kg of soil as moderately damaging to this crop. Root-lesion nematode damage to potatoes was reported as early as 1889 (15). Several workers have shown that the potato is a good host for this nematode (2, 11, 19); others (5) found in field experiments that populations of about 1,700/kg of soil reduced tuber yield by 14%. The Advisory Manual, referred to above, suggests moderate damage at population densities of 750 to 2,000/kg of soil. In contrast with *Meloidogyne hapla*, which caused a decrease in the number of undersized culls (8), *P. penetrans* reduced the number of both. Possibly the stolons, like the feeder roots, are caused to proliferate by the former nematode or destroyed by the latter.

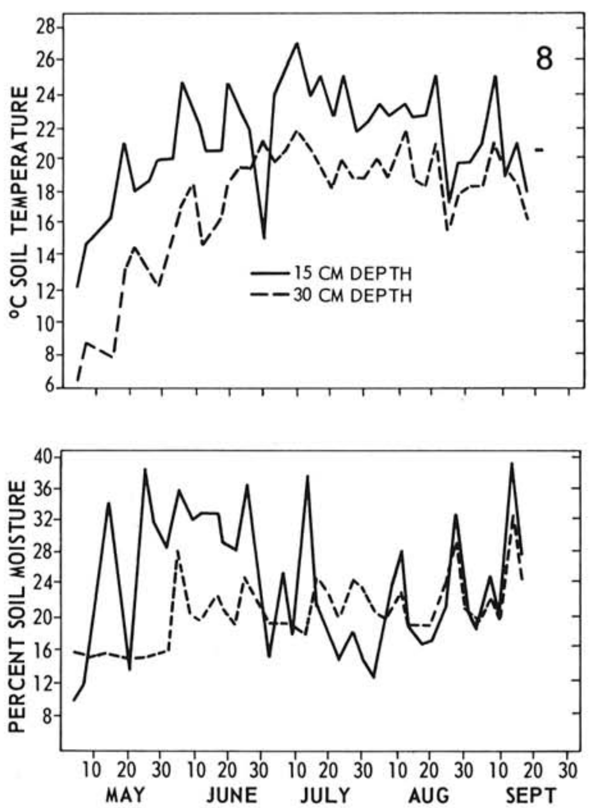

Fig. 8. Soil moisture and temperature in microplots cropped to potatoes at Vineland Station, Ontario, monitored twice weekly.

Corn and onions are quite sensitive to *P. penetrans*, as even the lowest density caused appreciable losses (Fig. 1); the results also support observations of damage to these crops in the field by this nematode (9). Damage to corn has been noted in South Carolina (4) and significant reductions in top- and root growth at one nematode density were reported in Wisconsin (2). Losses in onions resulted only from a reduction in size of mature bulbs and not, as with *M. hapla* (8), in failure of the bulbs to fill out and mature. Other workers (19) have shown that onion is a very good host for *P. penetrans*. Ferris (3) showed that root-lesion nematode populations larger than 10/liter of soil resulted in injury to onions; in our study, even the lowest density, 666 *P. penetrans*/kg of soil, resulted in significant losses.

Midseason sampling, done 3 to 5 weeks after seeding or transplanting, showed little change from the initial densities (Table 1). Apparently, migration of the nematode into the roots did not appreciably reduce the soil population at the sampling site (2 to 3 cm away from suspected root zone), and the time lapse was insufficient to allow much natural decline in populations or little, if any, reproduction. This sampling provided some insight into changes in the soil population, at a time when differences in top growth became apparent in our plots, and presumably would be observable in commercial fields. The relatively small differences between nematode counts from initial and midseason samples suggest that either the former or the latter may be used to anticipate crop damage and aid in deciding whether to apply measures to mitigate nematode damage, such as fertilizer side-dressing or irrigation. The midseason sampling in our study also provided a check on the relative population sizes of the various initial densities.

Soil populations at harvest were much larger than the initial populations, except with potatoes and onions at the 18,000 density (Fig. 5). Final root populations increased with increasing initial densities, except with potatoes where a significant decrease took place at the 6,000 density and with onions where the maximum number per root system was reached at the 2,000/kg initial density (Fig. 6). Final populations/g of root also increased with increasing initial densities for all crops, except with potatoes and onions (Fig. 7). The decrease in numbers/g of root beyond initial densities of 6,000 with potatoes and onions indicate that the "equilibrium density" (16) for these crops must be in the order of 1,200 to 1,300/g of root. With the other crops, not even an initial density of 18,000/kg caused reproduction in the roots to exceed the "equilibrium" or "maximum density".

The fungi present in the potato soil were mainly common saprophytes. Although some fungi are known to interact with plant parasitic nematodes in causing plant disease (13), careful root examination revealed no visual evidence of fungal attack in the present study. The fungi cited are believed to be representative of the microflora in all microplots because the nematode inoculum soil was all from one ground bed and was mixed thoroughly, and the microplots were all in the same field where any introduction presumably would have affected all microplots similarly. In addition, the microflora from soil in a parallel experiment with tomatoes was similar to that in the potato soil.

Stress factors, such as periods of drought, low temperature, or low soil fertility, aggravate the damage caused by the root-lesion nematode and affect population densities. Cultural practices and environmental conditions were favourable to growth of the vegetables in this study (Fig. 8) and crop damage by *P. penetrans* may be greater when growing conditions are more adverse.

The initial densities in our studies were similar to those commonly encountered in grower's samples from muck and sandy soils in Ontario (7). This study has shown that such densities of *P. penetrans* are capable of causing damage to a variety of vegetables. It appears, therefore, that this nematode is of major importance in Ontario vegetable production.

LITERATURE CITED

1. ACEDO, J. R., & R. A. ROHDE. 1968. Lesion nematode injury to cabbage. Nematologica 14:1 (Abstr.).
2. DICKERSON, O. J., H. M. DARLING, & G. D. GRIFFIN. 1964. Pathogenicity and population trends of Pratylenchus penetrans on potato and corn. Phytopathology 54:317-322.
3. FERRIS, J. M. 1962. Some observations on the number of root lesion nematodes necessary to cause injury to seedling onions. Plant Dis. Reptr. 46:484-485.
4. GRAHAM, T. W., & Q. L. HOLDEMAN. 1951. Nematode injury to tobacco, cotton, and corn in relation to populations of root-knot and meadow nematodes. Phytopathology 41:14 (Abstr.).
5. HAWKINS, A., & P. M. MILLER. 1971. Row treatment of potatoes with systemics for meadow nematode (Pratylenchus penetrans) control. Amer. Potato J. 48:21-25.
6. LOCHHEAD, A. C., & F. E. CHASE. 1943. Qualitative studies of soil microorganisms. V. Nutritional requirements of the predominant bacterial flora. Soil Sci. 55:185-195.
7. MARKS, F., J. L. TOWNSHEND, J. W. POTTER, T. H. A. OLTHOF, & A. CORNELISSE. 1971. Plant-parasitic nematode genera associated with crops in Ontario in 1970. Can. Plant Dis. Surv. 51:127-128.
8. OLTHOF, T. H. A., & J. W. POTTER. 1972. Relationship between population densities of Meloidogyne hapla and crop losses in summer-maturing vegetables in Ontario. Phytopathology 62:981-986.
9. OLTHOF, T. H. A., J. L. TOWNSHEND, J. W. POTTER, & C. F. MARKS. 1969. Plant parasitic nematodes of economic importance in Ontario. Entomol. Soc. Ontario, Proc. 100:8-9.
10. ONTARIO DEPARTMENT OF AGRICULTURE & FOOD. 1970. Agricultural statistics for Ontario. Pub. 20, Farm Economics, Co-operatives & Statistics Branch, Toronto, Ontario. 107 p.
11. OOSTENBRINK, M. 1958. An inoculation trial with Pratylenchus penetrans in potatoes. Nematologica 3:30-33.
12. PETERSON, E. A. 1958. Observations on fungi associated with plant roots. Can. J. Microbiol. 4:257-265.
13. POWELL, N. T. 1971. Interaction of plant parasitic nematodes with other disease-causing agents. p. 119-136. *In* B. M. Zuckerman, W. F. Mai & R. A. Rohde [ed.]. Plant parasitic nematodes, Vol. II. Academic Press, New York.
14. QUEEN'S PRINTER & PUBLISHER. 1970. The farm products grades and sales act and regulations respecting fruit and vegetables. Farm Products Inspection Branch, Ontario Dept. Agr. & Food, Toronto, Ontario. 144 p.
15. SCRIBNER, F. L. 1889. Diseases of the Irish potato. Tenn. Agr. Exp. Sta. Bull. 2:27-43.
16. SEINHORST, J. W. 1966. The relationships between population increase and population density in plant parasitic nematodes. I. Introduction and migratory nematodes. Nematologica 12:157-169.
17. TOWNSHEND, J. L. 1962. The root-lesion nematode, Pratylenchus penetrans (Cobb, 1917) Filip. & Stek. 1941, in celery. Can. J. Plant Sci. 42:314-322.
18. TOWNSHEND, J. L. 1963. A modification and evaluation of the apparatus for the Oostenbrink direct cottonwool filter extraction method. Nematologica 9:106-110.
19. WONG, K. Y., & J. M. FERRIS. 1968. Factors influencing the population fluctuation of Pratylenchus penetrans in soil. III. Host plant species. Phytopathology 58:662-665.