Relationship Between Population Densities of Pratylenchus penetrans and Crop Losses in Flue-Cured Tobacco in Ontario[1]

Th. H. A. OLTHOF[2], C. F. MARKS[2] and J. M. ELLIOT[3]

Abstract: Flue-cured tobacco was grown in microplots consisting of concrete drainage tiles, 40-cm (i.d.), infested with 0; 666; 2000; 6000 or 18,000 root-lesion nematodes, *Pratylenchus penetrans* /kg of soil. Yield and grade index decreased with preplant soil population densities in excess of 2000/kg of soil. At initial densities of 6000 and 18,000/kg of soil losses in crop returns were 11.0% and 27.5%, respectively. Decreases in the maturity index and in percentage dry stalk weight with increasing densities showed that the nematode delayed maturity. Increases in population densities of nematodes were correlated with decreases in weights of tops and roots and in plant height. All final population densities in soil were lower than the initial densities except at the lowest pre-plant density. All soil populations at midseason were lower than those at the beginning and end of the growing season. Populations of *P. penetrans* at harvest were in excess of half a million per root system with the 18,000/kg initial soil population density. The results suggest that fumigation, which costs $75/ha, or approximately 2% of the crop value, is economically warranted at preplant densities in excess of 2000/kg of soil. *Key Words: Nicotiana tabacum*, microplots.

In 1970, more than 90 million kg of flue-cured tobacco, worth $130 million (Canadian), was produced by 4000 growers in southwestern Ontario (10). Over 70% of the 33,000 ha were fumigated to control root-lesion nematodes which cause brown root rot (2). In 1967, only 10% of the tobacco acreage was fumigated and the average yield per ha was 30% less than in 1971 (5). Probably at least part of this large increase in yield was due to increased use of soil fumigants (13). Recently, the question has arisen whether the use of such quantities of chemicals is economically warranted. Information was needed, therefore, on the population densities at which the root-lesion nematode caused economic loss.

For many years it has been recommended that *Pratylenchus penetrans* (Cobb), the principal cause of brown root rot (1), be controlled in Ontario flue-cured tobacco at densities of 500 or more per 454 g of soil (9). In Germany, Lange et al. (3) found that densities higher than 500/250 ml of soil damaged the crop. Olthof (6) found a significant difference in height of tobacco plants grown in soil that contained 3397 and 20,231 *P. penetrans*/kg of soil at harvest.

The paucity of information prompted an investigation of the relationship between five preplant population densities of the root-lesion nematode and damage to flue-cured tobacco grown in microplots under field conditions. A discussion of the merits of the method employed in this study has been published elsewhere (8). A brief report of this work has been made (7).

MATERIALS AND METHODS

The root-lesion nematode, *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* DC., 'Utah') in a greenhouse. Large soil populations of *P. penetrans* were reared on 'Tetra Petkus' rye grown for 6 months in infested Vineland loam in a ground bed in a greenhouse. After removing all coarse roots by screening and carefully mixing the infested soil, the population density was determined by processing ten 50-g samples by a modified Baermann funnel technique (12). Appropriate portions of the infested soil, which contained an average of 35,660 *P. penetrans*/kg, then were mixed thoroughly with steamed Fox loamy sand from Delhi for 5 min in a cement mixer to yield 666; 2000; 6000 or 18,000 nematodes/kg of soil. Soil for the control plots consisted of steamed Fox loamy sand. To simulate field conditions, 50 kg of steamed subsoil from the Fox loamy sand were placed in the bottom half of each concrete drainage tile, 40 cm (i.d.) and

Received for publication 14 July 1972.

[1]Contribution No. 80, Tobacco Research Station, Canada Department of Agriculture, Delhi, Ontario.
[2]Nematologists, Canada Department of Agriculture, Research Station, Vineland Station, Ontario.
[3]Plant Nutritionist, Canada Department of Agriculture, Research Station, Delhi, Ontario.

60 cm long, which previously had been buried vertically to a depth of 55 cm in rows in a tobacco field at the Research Station, Delhi. The upper half of each tile was filled with 50 kg of mixed soil, which contained the various populations of the nematode, or the control soil.

Moisture-temperature sensors were placed in four tiles, located throughout the plot, at depths of 15 cm and 30 cm. To determine actual nematode population densities, soil samples were taken from all tiles immediately after filling. In an attempt to ensure the presence of the same microflora in the control tiles as in the nematode-infested ones, each received 50 ml of air-dried soil from the nematode-infested greenhouse ground bed. One seedling of tobacco (*Nicotiana tabacum* L. 'Delhi 34') was transplanted to each tile within 6 days after filling the tiles with soil. Immediately after transplanting, each tile received 90 g of 2-12-16 tobacco fertilizer, equivalent to 1346 kg/ha. A randomized block design was used with five nematode population densities (treatments) and ten replicates of each treatment. Plants were grown in two rows 24 m long and 1.05 m apart with plants spaced 0.9 m in the row. The two experimental rows were separated and surrounded by tobacco guard rows not in tiles.

Normal management practices, such as insect control, irrigation, topping and hand suckering were used during the growing season. Soil moisture and temperature at 15- and 30-cm depths were determined once a week during this period. To determine the nematode populations at midseason, soil samples were taken to a depth of 20-30 cm from each tile 49 days after transplanting. Each sample then was processed by the method referred to above. Individual plant heights were also measured at 44 and 80 days after transplanting. A plastochron index of growth (4), adapted for use in tobacco by Dr. N. Rosa of Delhi (*personal communication*), was determined 49 days after transplanting.

Harvest started 72 days after transplanting and was completed 1 month later. Five pullings (two to three leaves each) were harvested and cured in the conventional manner. To cure and obtain agronomic indices, the leaves of the ten plants were bulked into two replicates of five plants each and the tobacco was sorted into grades according to the Ontario Farm Products Grades and Sales Act (11). Grade index was based on the average market price of each grade for the previous five years. Crop index was calculated by multiplying the yield per hectare by the grade index. Maturity index was the percentage of the tobacco harvested in the first three pullings. Fresh and dry weights of stalks, suckers and roots were determined and the final soil nematode population in each tile established as before. Root populations of the nematode were determined after extracting them from 25-g samples of fibrous roots in a mist chamber for 2 weeks.

RESULTS

Yields and crop indices were significantly reduced at initial population densities of 6000 and 18,000 *P. penetrans*/kg of soil and, although not statistically significant, also reduced at the 2000 density (Table 1). Grade and maturity indices and percentage dry weight of stalks tended to decrease with increasing

TABLE 1. Effect of five preplant population densities of *Pratylenchus penetrans* on yield and quality of flue-cured tobacco.

Preplant population/kg of soil	Yield[a] (kg/ha)	Grade index (cents/kg)	Crop[a] index (dollars/ha)	Maturity[b] index (%)	Dry wt. of stalks (% dry matter)
0	2287	161	3673	46.5	18.84
666	2282	162	3705	45.0	18.41
2000	2164	160	3458	45.5	17.89
6000	2090	157	3270	44.0	17.16
18,000	1845	144	2663	38.0	16.32
LSD 0.05	178	11	300	3.4	0.86
0.10	144	9	243	2.7	0.72

[a]Based on 9633 plants/ha.
[b]Percentage of tobacco harvested in first three pullings.

TABLE 2. Effect of five preplant population densities of *Pratylenchus penetrans* on fresh weight of flue-cured tobacco other than leaves[a].

Preplant population/kg of soil	Fresh weights (g)				
	Tops		Roots		
	Stalks	Suckers[b] and debris	Tap	Fibrous	Total[c] plant
0	983	546	335	183	2049
666	910	526	349	174	1959
2000	863	543	326	175	1907
6000	777	499	269	185	1731
18,000	703	447	209	192	1553
LSD 0.05	98	N.S.	47	N.S.	177

[a]Average of 10 plants.
[b]Exclusive of suckers removed prior to harvest.
[c]Exclusive of harvested leaves, inflorescence and suckers removed prior to harvest.

nematode densities; however, only the highest density significantly decreased the indices, and the three highest densities significantly decreased the stalk weight. Only the two highest densities significantly decreased the weight of the tap roots and total plant weight (Table 2). The two highest densities decreased plant height, relative to the controls, by mid-July, but by mid-August the differences, though still present, were less pronounced (Fig. 1A).

All soil nematode populations at midseason were significantly lower than those either at the beginning or end of the growing season. Also, at harvest, all soil populations of *P. penetrans* were significantly lower than the initial densities, except the smallest (Table 3). The numbers of *P. penetrans* extracted from the roots increased as the initial population density increased, and amounted to 19,000/g of dry fibrous root at the highest density (Table 4).

Soil moisture and temperature in the microplots (Fig. 1B, C) were comparable to those recorded in a nearby field (*unpublished records*, Research Station, Delhi, Ontario). Weather conditions during the growing season were favorable for growth of the tobacco crop.

Temperature was above average in June and although rainfall during May, June and July was considerably below average (14), irrigation was provided when necessary to maintain soil moisture.

DISCUSSION

Because the root-lesion nematodes used in this study were reared in Vineland loam, the proportion of Vineland loam to Fox loamy sand increased with increasing preplant densities of nematodes and constituted 54% at the highest density. The difference in these two soils (61 and 85% sand and 2.21 and 1.20% organic matter, respectively) perhaps accounted for some of the differences in growth of the tobacco in the microplots. In the greenhouse, no significant differences in top weights were observed, however, when Delhi 34 tobacco plants were grown in similar mixtures of the two soils in the absence of nematodes.

Data on plant heights and root weights support the view that the root-lesion nematode causes most of its damage by destroying parts of the young root systems. Although in many cases infected plants form new roots which may compensate for those destroyed, growth early in the season is slow resulting in less total plant growth and delayed maturity (2). Because nematode infestations usually occur in patches in a field, the less mature leaves will be harvested along with the bulk of the crop thereby lowering the grade index.

The data show that soil populations of *P. penetrans* are lowest at mid-season (Table 3), the time when samples are usually taken to confirm brown root rot. In this experiment, statistically significant crop losses occurred when nematode population densities at mid-season were between 500 and 1200/kg of soil (250-600/lb). These densities are somewhat lower than those of 1000/kg in Ontario (9) and 2000/kg in Germany (3), previously suggested as causing economic damage. In the present study, crop losses at a mid-season density of 480 *P. penetrans*/kg of soil amounted to $215/ha or 5.9% of the value of the crop. Although not statistically significant, these losses far exceeded the cost of fumigation at $75/ha.

With one exception, the soil population densities at harvest were lower than those initially present but the root systems were heavily infested. As these roots decay, it is possible that many of the nematodes enter the soil and infest the rye plants that are grown in rotation with tobacco. Additional research is needed to further determine the critical initial density requirẹd for economic loss.

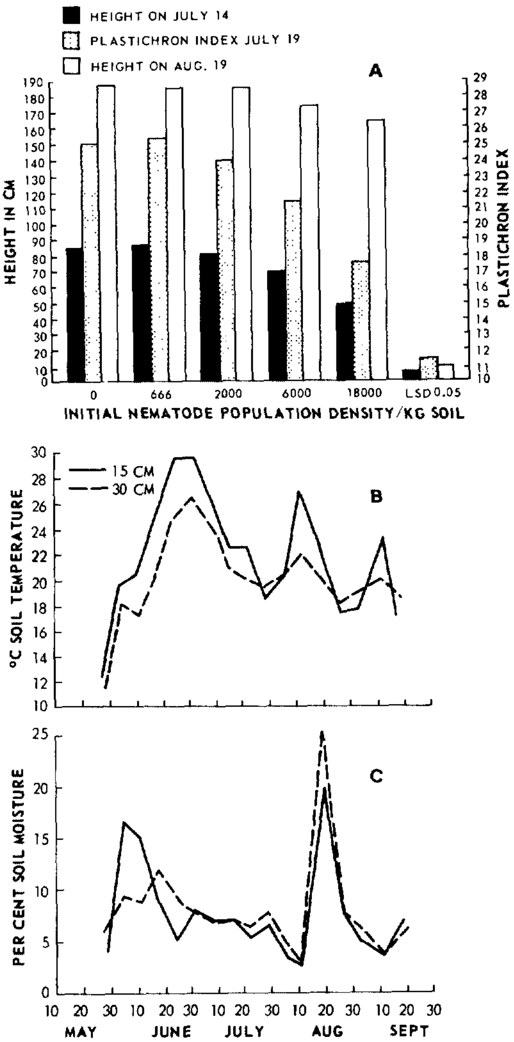

FIG. 1. The relation between five preplant population densities of *Pratylenchus penetrans* and growth of flue-cured tobacco at Delhi, Ontario: **A.** Effect on height and development. **B.** Soil temperature in microplots, monitored weekly. **C.** Soil moisture in microplots, monitored weekly.

TABLE 3. Soil population densities of *Pratylenchus penetrans* under flue-cured tobacco.

Time of sampling	Intended preplant population densities/kg of soil			
	666	2000	6000	18,000
	Actual population densities/kg of soil			
Initial	440	1500	5800	18,000
Mid-season	190	480	1200	4500
Final	450	1000	3100	14,000
LSD 0.05	140	600	1300	4000
0.10	120	500	1100	3400

TABLE 4. Populations of *Pratylenchus penetrans* in roots of flue-cured tobacco at harvest.

Preplant population density/kg of soil	Number of *P. penetrans*/root system	Number of *P. penetrans*/g of dry fibrous root
666	64,000	2600
2000	180,000	6800
6000	300,000	12,000
18,000	580,000	19,000
LSD 0.05	100,000	2500
0.10	83,000	2100

LITERATURE CITED

1. ELLIOT, J. M. and C. F. MARKS. 1972. Control of nematodes in flue-cured tobacco in Ontario. Can. Dep. Agr. Publ. 1465. 10 p.
2. ELLIOT, J. M., C. F. MARKS and C. M. TU. 1972. Effects of nematicides on *Pratylenchus penetrans*, soil microflora, and flue-cured tobacco. Can. J. Plant Sci. 52:1-11.
3. LANGE, B., J. MEYER und P. BURMEISTER. 1964. Vorläufige Ermittlungen über Schäden an Tabak durch freilebende Nematoden und Versuche zu ihrer Bekämpfung. Mitt. Biol. Bundesanst. Berlin-Dahlem 111:85-93.
4. MICHELINI, F. J. 1958. The plastochron index in developmental studies of *Xanthium italicum* Moretti. Amer. J. Bot. 45:525-533.
5. OLTHOF, Th. H. A. 1967. Economics of fumigation in flue-cured tobacco. Can. Dep. Agr. Information for Extension Personnel, Agdex No. 181.2/628.
6. OLTHOF, Th. H. A. 1971. Seasonal fluctuations in population densities of *Pratylenchus penetrans* under a rye-tobacco rotation in Ontario. Nematologica 17:453-459.
7. OLTHOF, Th. H. A., C. F. MARKS and J. M. ELLIOT. 1972. Relations between population densities of *Pratylenchus penetrans* and crop losses in flue-cured tobacco in Ontario. J. Nematol. 4:231 (Abstr.).

8. OLTHOF, T. H. A. and 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, Th. H. A., J. L. TOWNSHEND, J. W. POTTER and H. D. FRANCIS. 1967. Plant-parasitic nematode genera associated with crops in Ontario in 1967. Can. Plant Dis. Surv. 47:110-111.

10. ONTARIO DEPARTMENT OF AGRICULTURE & FOOD. 1970. Agricultural statistics for Ontario. Publ. 20, Farm Economics, Co-operatives & Statistics Branch, Toronto, Ontario. 107 p.

11. QUEEN'S PRINTER AND PUBLISHER. 1965. Ontario farm products grades and sales act and regulations respecting flue-cured tobacco. Toronto, Ontario p. 10-25.

12. TOWNSHEND, J. L. 1963. A modification and evaluation of the apparatus for the Oostenbrink direct cottonwool filter extraction method. Nematologica 9:106-110.

13. VICKERY, L. S. 1971. Progress of the Canadian tobacco crop. Ontario. The Lighter 41(3):7.

14. VICKERY, L. S. 1971. Progress of the Canadian tobacco crop. Ontario. The Lighter 41(4):8.