Supplement to Journal of Nematology 24(4S):656–661. 1992.

Effects of Fumigant Nematicides on Yield and Quality of Paste Tomatoes Grown in Southwestern Ontario[1]

L. B. Reynolds,[2] Th. H. A. Olthof,[3] and J. W. Potter[3]

Abstract: Field trials were conducted at the Delhi Research Station, Ontario, Canada, on a Fox loamy sand soil during 1987 and 1988 to evaluate the effects of row application of the fumigants Telone II, Telone C-17, Vorlex Plus, and Vorlex Plus CP on the yield and quality of paste tomato (*Lycopersicon esculentum* Mill. cv. Ferry Morse 6203). The four fumigants were equally effective in controlling the natural field populations of root lesion nematodes (*Pratylenchus penetrans* Cobb). A significant reduction in marketable red fruit yield due to different nematode densities at time of transplanting was observed in 1988. Fumigation did not significantly affect the yield of nonmarketable fruit, the relative maturation rate, or the processing quality in either year.
Key words: chloropicrin, 1,3-dichloropropene, fumigation, *Lycopersicon esculentum,* methyl isothiocyanate, nematode, paste tomato, *Pratylenchus penetrans,* tomato.

The root lesion nematode (*Pratylenchus penetrans* Cobb) is an important plant-parasitic nematode in southwestern Ontario (7,17). Stunting of field tomatoes (*Lycopersicon esculentum* Mill.) due to injury from *P. penetrans* in the Leamington area of southwestern Ontario was first reported in 1954 (9). In clay tile microplots inoculated with *P. penetrans,* preplant population densities greater than 2,000/kg soil caused a significant reduction in plant top weights and root weights of the fresh-market tomato cv. Veebrite (16). A reduction in plant height of 66% was observed in the fresh-market tomato cv. Bonny Best after 2 months of growth in a greenhouse in a soil containing a preplant population density of 550 *P. penetrans*/kg soil (8). Yield reductions due to feeding injury by *P. penetrans* have also been reported on other vegetable crops such as sweet corn (*Zea mays* L. var. *rugosa* Bonaf. cv. Veecrop) and onions (*Allium cepa* L. cv. Copper Gem) at preplant population densities of 666/kg and on lettuce (*Lactuca sativa* L. cv. Pennlake) at a preplant population density of 2,000/kg (12,18). In a survey of Kent and Essex counties in Ontario, Pitblado and Olthof reported that 11.2% and 13.5% of the tomato fields with coarse-textured soils contained *P. penetrans* population densities greater than 2,000/kg of soil in 1988 and 1989, respectively (15).

This report describes the effects of row fumigation on the yield and quality of paste tomato cv. Ferry Morse 6203 grown in field plots at the Delhi Research Station, Ontario, Canada, in 1987 and 1988.

Materials and Methods

Field plots of the processing tomato cv. Ferry Morse 6203 were established in 1987 and 1988 at the Delhi Research Station on a Fox loamy sand soil (86% sand, 7% silt, 7% clay; 1% organic matter; pH 6.4). A plot consisted of a single row 1.25 m × 10 m in 1987 and three rows 1.25 m × 10 m in 1988. All data were collected from the single row in 1987 or the middle row of the three-row plots in 1988. Plots were arranged in a randomized complete block design with four replications. A 2-year rotation was followed with winter rye (*Secale cereale* L.) used as a plow-down cover crop in the year previous to each year's tomato crop.

Fumigants were applied on 1 May 1987 and 5 May 1988, by single shank injection to a depth of 15 cm immediately followed by hilling, which resulted in a total soil coverage of about 30 cm. The fumigants used were Telone II (94% 1,3-dichloropropene) at 8.5 ml of formulation/m of row (68 liters/ha), Vorlex Plus (20% methyl isothio-

Received for publication 19 December 1991.
[1] Contribution number 221.
[2] Agriculture Canada, Research Branch, Research Station, P.O. Box 186, Delhi, Ontario, N4B 2W9, Canada.
[3] Agriculture Canada, Research Branch, Research Station, P.O. Box 6000, 4902 Victoria Ave. North, Vineland Station, Ontario, L0R 2E0, Canada.

cyanate + 40% 1,3-dichloropropene and other related C_3 hydrocarbons) at 3.5 ml of formulation/m of row (28 liters/ha), Telone C-17 (78% 1,3-dichloropropene + 16.5% chloropicrin) at 8.5 ml of formulation/m of row (68 liters/ha), and Vorlex Plus CP (17% methyl isothiocyanate + 34% 1,3-dichloropropene and other related C_3 hydrocarbons + 15% chloropicrin) at 5.5 ml of formulation/m of row (44 liters/ha).

Tomato seedlings were grown on a muck seedbed in an unheated greenhouse located at the Delhi Research Station. Seedlings 15–20 cm tall were pulled and transplanted with a Holland-type vegetable planter into the field plots at a spacing of 0.3 m in the row and 1.25 m between rows on 27 May 1987 and 24 May 1988. Fertilizer was applied at transplanting in 10-cm bands on either side and 8 cm below the soil surface at a rate of 30 kg N + 60 kg P_2O_5 + 180 kg K_2O/ha. Approximately 3 weeks later, an additional 45 kg N + 135 kg K_2O/ha was applied as a banded side-dressing on either side of the seedlings. Normal cultural practices and procedures as recommended annually were followed in regards to cultivation, diseases, insects, growth regulators, and weed control (14). Plots were irrigated (2.5 cm per irrigation) with overhead sprinklers three times in 1987 and twice in 1988.

In 1987, the nematode population density before fumigation was determined from 16 samples taken at random from the entire plot area. Each sample consisted of 10 soil cores 2.5 cm in diameter and 20 cm in depth. All subsequent nematode densities were determined from individual plots, and were based on samples consisting of 10 soil cores taken from the plot rows, excluding guard rows. Nematodes were extracted from 50-g subsamples for 1 week by the Baermann pan method (20).

Plant height and fresh green weight, including fruit, were determined on 7 July 1988. Three consecutive plants, excluding the end plant, were selected at one end of a plot row and the height measured from soil surface to the top of the leaf canopy. The same three plants were then cut off at the soil surface and weighed.

The maturity rating was an adaptation of a method published for field corn (2). Heat unit values based on the average of a nonlinear growth response relationship for daytime maximum temperature with a threshold temperature of 10 C and a linear growth response relationship for nighttime minimum temperature with a threshold temperature of 4.4 C. The heat unit values were accumulated starting from the day following transplanting and continuing through the day on which 15% of the fruit 2.5 cm in diameter or larger showed red coloration. All plots were then sprayed with the ripening agent ethephon (Ethrel) at 4.0 liters/ha, and the fruit was harvested 2–3 weeks later when judged to have reached optimum ripeness.

Yield was estimated by hand picking all fruit with a diameter $\geq$ 2.5 cm from eight consecutive plants, excluding end plants, from each plot row. The fruit was sorted into marketable, green, and defect categories and weighed.

The Agtron color rating and the Brix value for each plot were determined on a 3.0-kg subsample of the marketable fruit. The tomatoes were washed and processed in a commercial duty blender (Model CB-6, Waring Commercial, New Hartford, CT) under a vacuum of 87 kPa for 1 minute at low speed (15,500 rpm free running). The puree was strained through a US #14 mesh screen and 175 ml was transferred to a glass petri dish. The reflected color was determined on a Agtron Model E-5 spectrophotometer (Filper Magnuson, Reno, NV). Brix was determined by straining approximately 2 ml of puree through a disposable paper wiper (Kimberly-Clark, Mississauga, Ontario) and measuring the serum refraction on a Abbé refractometer (Reihert Scientific, Buffalo, NY).

Nematode count data were subjected to a $\log_{10}(x + 200)$ transformation prior to analysis using the ANOVA procedure of the Statistical Analysis System (19,21). Where a significant F-value was found, separation of treatment means was performed using a Duncan's multiple-range test (6).

Results

1987: The nematode population density at transplanting averaged 680/kg of soil in the untreated check plots (Table 1). Significantly lower population densities were observed in fumigated treatments compared to the nonfumigated check at transplanting (26 days after fumigation) and at harvest (129 days after fumigation). All fumigants were equally effective in controlling nematode populations. The Telone II and Vorlex Plus CP treatments required less time to reach the 15% red fruit stage of maturity than did the Telone C-17 treatment in 1987; however, none of the fumigated treatments were significantly different from the check in maturity rating. Green and defect fruit yield, Agtron rating, and Brix were not affected by fumigation treatment. Although not significant ($P \leq 0.05$), the average yield difference between fumigated and nonfumigated treatments was 5.5 t/ha.

1988: The nematode density at transplanting was 4,760/kg of soil in the untreated check plots (Table 2). Lower ($P \leq 0.05$) population densities were observed in the fumigated treatments at transplanting (19 days after fumigation), at midseason (53 days after fumigation), and at harvest (125 days after fumigation). Both plant height and plant weight were lower ($P \leq 0.05$) in the check than in any of the fumigated treatments. Yield of marketable fruit from the treatments fumigated with Telone II, Vorlex Plus, and Telone C-17 were greater ($P \leq 0.05$) than the check. Green and defect fruit yield, Agtron rating, and Brix were not affected by fumigation treatments. The average yield increase of fumigated vs. nonfumigated treatments was 12.7 t/ha.

Discussion

In this study, densities of *P. penetrans* in the spring were inconsistent from year to year, even within the confines of a 1.6-ha field plot area. Thus, high *P. penetrans* populations in the previous year and the presence of a good host crop such as winter rye or tomato do not guarantee high nematode populations in the following year. Previous work at this site monitoring nematode populations in a rye–tobacco rotation indicated that early spring populations of *P. penetrans* typically range between 500 to 8,000/kg soil (3,4,10,11).

The results of this field trial both support and confirm the observations made by Potter and Olthof in their clay tile microplot study conducted in 1977 (16). The effect of root-lesion nematodes at a density of 680/kg of soil at time of transplanting was not found to have a significant effect on yield at $P \leq 0.05$. However, with a high value crop such as tomatoes, a small increase in yield, even though not significant at $P \leq 0.05$, can be economically viable at the farm level (1). The economic benefit of fumigation (yield increase minus cost of fumigant) based on 1987 values for paste tomatoes ($108/t) and the two least-expensive fumigant materials, Telone II ($3.12/liter) and Vorlex Plus ($7.58/liter), was $1,073/ha and −$417/ha, respectively, in 1987. In 1988, at a population density of 4,760/kg, a significant and positive yield response was observed that would have more than compensated a commercial grower for the cost of the fumigation procedure. The economic benefit of fumigation in 1988 was $1,494/ha and $1,440/ha for Telone II and Vorlex Plus, respectively.

The considerable variability in numbers of *P. penetrans* from year to year and the inconsistent yield response of the tomato crop to fumigation make the decision to fumigate difficult at best. In tomato fields that consistently show low crop vigor and depressed yields, *P. penetrans* densities should be determined. If densities are greater than 4,000/kg, then fumigation is warranted and will probably produce a net economic benefit to the grower. However, at population levels between 680/kg and 4,000/kg of soil, the net economic benefit is likely to be somewhat smaller and probably more inconsistent.

TABLE 1. Effect of fumigation on populations of *Pratylenchus penetrans* and on yield and quality of paste tomatoes in 1987.

		P. penetrans in soil (no./kg)‡				Yield (t/ha)				
						Marketable	Nonmarketable			
Treatment†	Rate of fumigation (ml/m)	Before fumigation	Trans-planting	Harvest	Maturity rating (CHU)§	Red	Green	Defect	Agtron‖	Brix*
Telone II	8.5	560	0 b	200 b	1,954 b	80.3	0.8	14.2	27	4.9
Vorlex Plus	3.5	560	5 b	120 b	2,016 ab	66.5	1.3	14.3	25	4.9
Telone C-17	8.5	560	0 b	1,600 b	2,062 a	71.2	3.6	16.3	26	5.0
Vorlex Plus CP	5.5	560	0 b	20 b	1,954 b	77.4	2.8	14.9	25	5.0
Check	0	560	680 a	2,370 a	2,018 ab	68.4	2.1	13.9	26	5.0

All values are means of four replications. Means within columns followed by the same letter are not different at $P \leq 0.05$ according to Duncan's multiple-range test; letters omitted when no significant differences exist.

† Telone II = 94% 1,3-dichloropropene; Vorlex Plus = 20% methyl isothiocyanate + 40% 1,3-dichloropropene and C_3 hydrocarbons; Telone C-17 = 78% 1,3-dichloropropene + 16.5% chloropicrin; Vorlex Plus CP = 17% methyl isothiocyanate + 34% 1,3-dichloropropene and C_3 hydrocarbons + 15% chloropicrin.

‡ Nematode count data were transformed by $\log_{10}(x + 200)$ prior to statistical analysis; nontransformed means are reported.

§ CHU = Corn heat units, according to Brown (2).

‖ Agtron color reflectance ratings as determined by spectrophotometry.

* Brix value is the serum refraction of filtered tomato puree.

TABLE 2. Effect of fumigation on populations of *Pratylenchus penetrans* and on yield and quality of paste tomatoes in 1988.

Treatment†	Rate of fumigation (ml/m)	P. penetrans in soil (no./kg)‡				Plant height (cm)	Plant weight (g)	Maturity rating (CHU)§	Yield (t/ha)			Agtron‖	Brix*
		Before fumigation	Trans-planting	Mid-season	Harvest				Marketable	Nonmarketable			
									Red	Green	Defect		
Telone II	8.5	6,380	140 b	130 b	1,580 bc	37 a	226 a	1,972	66.3 a	0.5	4.4	23	4.8
Vorlex Plus	3.5	11,160	330 b	300 b	530 c	33 b	183 ab	2,010	65.8 a	0.4	3.8	22	5.0
Telone C-17	8.5	10,600	60 b	140 b	4,270 b	33 b	131 bc	2,034	63.4 a	0.4	3.5	23	5.0
Vorlex Plus CP	5.5	9,980	40 b	170 b	1,680 bc	35 ab	191 ab	2,060	56.1 ab	2.5	4.0	22	4.9
Check	0	9,180	4,760 a	5,360 a	15,730 a	26 c	87 c	2,022	50.5 b	0.5	2.5	21	5.2

All values are means of four replications. Means within columns followed by the same letter are not different at $P \leq 0.05$ according to Duncan's multiple-range test; letters omitted when no significant differences exist.

† Telone II = 94% 1,3-dichloropropene; Vorlex Plus = 20% methyl isothiocyanate + 40% 1,3-dichloropropene and C_3 hydrocarbons; Telone C-17 = 78% 1,3 dichloropropene + 16.5% chloropicrin; Vorlex Plus CP = 17% methyl isothiocyanate + 34% 1,3-dichloropropene and C_3 hydrocarbons + 15% chloropicrin.

‡ Nematode count data were transformed by $\log_{10}(x + 200)$ prior to statistical analysis; nontransformed means are reported.

§ CHU = Corn heat units, according to Brown (2).

‖ Agtron color reflectance ratings as determined by spectrophotometry.

* Brix value is the serum refraction of filtered tomato puree.

Literature Cited

1. Barker, K. R., and Th. H. A. Olthof. 1976. Relationships between nematode population densities and crop responses. Annual Review of Phytopathology 14:327–353.

2. Brown, D. M. 1978. Heat units for corn in Southern Ontario. Factsheet 78-063, Ontario Ministry of Agriculture and Food, Toronto, Ontario.

3. Elliot, J. M., C. F. Marks, and C. M. Tu. 1972. Effects of nematicides on *Pratylenchus penetrans*, soil microflora, and flue-cured tobacco. Canadian Journal of Plant Science 52:1–11.

4. Elliot, J. M., C. F. Marks, and C. M. Tu. 1974. Effects of the nematicides DD and Mocap on soil nitrogen, soil microflora, populations of *Pratylenchus penetrans*, and flue-cured tobacco. Canadian Journal of Plant Science 54:801–809.

5. Kimpinski, J. 1982. The effect of nematicides on *Pratylenchus penetrans* and potato yields. American Potato Journal 59:327–335.

6. Little, T. M., and F. J. Hills. 1978. Agricultural experimentation. New York: Wiley.

7. Marks, C. F., J. L. Townshend, J. W. Potter, Th. H. A. Olthof, P. W. Johnson, and J. Lounsbery. 1972. Plant parasitic nematode genera associated with crops in Ontario in 1971. Canadian Plant Disease Survey 52:102–103.

8. Miller, P. M. 1975. Effect of *Pratylenchus penetrans* on subsequent growth of tomato plants. Plant Disease Reporter 59:866–867.

9. Mountain, W. B., and J. C. Fisher. 1954. Stunting of tomato associated with *Pratylenchus penetrans*, an apparent migrant from an adjoining peach orchard. Plant Disease Reporter 38:809–810.

10. Mountain, W. B., and J. M. Elliot. 1963. Effect of summer fallowing on the root lesion nematode *Pratylenchus penetrans* (Cobb) and yield of flue-cured tobacco in Ontario. Canadian Journal of Plant Science 42:642–645.

11. Olthof, Th. H. A. 1971. Seasonal fluctuations in population densities of *Pratylenchus penetrans* under a rye-tobacco rotation in Ontario. Nematologica 17: 453–459.

12. Olthof, Th. H. A., and J. W. Potter. 1973. The relationship between population densities of *Pratylenchus penetrans* and crop losses in summer-maturing vegetables in Ontario. Phytopathology 63:577–582.

13. Ontario Ministry of Agriculture and Food. 1989. Vegetable production recommendations. Publ. 363, Ontario Ministry of Agriculture and Food, Toronto, Ontario.

14. Ontario Ministry of Agriculture and Food. 1989. Guide to weed control. Publ. 75, Ontario Ministry of Agriculture and Food, Toronto, Ontario.

15. Pitblado, R. E., and Th. H. A. Olthof. 1989. A survey of plant parasitic nematodes in tomato fields throughout Essex and Kent Counties. Pp. 51–52 *in* Fungicide and insecticide trials, Ridgetown College of Agricultural Technology, Ridgetown, Ontario.

16. Potter, J. W., and Th. H. A. Olthof. 1977. Analysis of crop losses in tomato due to *Pratylenchus penetrans*. Journal of Nematology 9:290–295.

17. Potter, J. W., and J. L. Townshend. 1973. Distribution of plant-parasitic nematodes in field crop soils of southwestern and central Ontario. Canadian Plant Disease Survey 53:39–48.

18. Potter, J. W., and Th. H. A. Olthof. 1974. Yield losses in fall-maturing vegetables relative to population densities of *Pratylenchus penetrans* and *Meloidogyne hapla*. Phytopathology 64:1072–1075.

19. Proctor, J. R., and C. F. Marks. 1974. The determination of normalizing transformations for nematode count data from soil samples and of efficient sampling schemes. Nematologica 20:395–406.

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

21. Statistical Analysis System Institute. 1985. SAS users guide: Statistics. Version 5 Edition. Cary, NC: SAS Institute Inc.