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Résumé de l'article

Les effets d'une fumigation du sol de préplantation sur les populations de *Pratylenchus penetrans*, *Xiphinema rivesi* et *Meloïdogyne hapla* et sur la croissance du framboisier (*Rubus idaeus*) ont été étudiés sur une période de quatre ans. Le *P.penetrans* fut le plus abondant et peut être probablement tenu responsable d'une partie importante de la réduction de croissance. La fumigation du sol a accru les rendements du framboisier de 95%, 59% et 18% dans les première, deuxième et troisième années de production, respectivement. L'incidence de la tumeur de collet (*Agrobacterium tumefaciens*) a pu être corrélée avec les populations de *P. penetrans* et de *M. hapla.*

Effects of preplant soil fumigation on nematode population densities and on growth and yield of raspberry

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The effect of preplant soil fumigation on population densities of *Pratylenchus penetrans*, *Xiphinema rivesi*, and *Meloïdogyne hapla* and growth of red raspberry *(Rubus idaeus)* was investigated over a 4-year period. *P. penetrans* was the most abundant and probably accounted for most of the growth reduction. Soil fumigation increased raspberry yields by 98%, 59%, and 18% in the first, second, and third year of production, respectively. The incidence of crown gall *(Agrobacterium tumefaciens)* was not correlated with soil populations of *P. penetrans* or *M. hapla*.

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Les effets d'une fumigation du sol de pré-plantation sur les populations de *Pratylenchus penetrans*, *Xiphinema rivesi* et *Meloïdogyne hapla* et sur la croissance du framboisier *(Rubus idaeus)* ont été étudiés sur une période de quatre ans. Le *P. penetrans* fut le plus abondant et peut être probablement tenu responsable d'une partie importante de la réduction de croissance. La fumigation du sol a accru les rendements du framboisier de 95%, 59% et 18% dans les première, deuxième et troisième années de production, respectivement. L'incidence de la tumeur de collet *(Agrobacterium tumefaciens)* n'a pu être corrélée avec les populations de *P. penetrans* et de *M. hapla*.

Introduction

The root lesion nematode, *Pratylenchus penetrans* (Cobb) Filipjev and Schuurmans-Stekhoven, is a major limiting factor in red raspberry (*Rubus idaeus* L.) production, due to the considerable reductions in replant establishment rate, growth and yield (McElroy 1977). In British Columbia, the dagger nematode, *Xiphinema bakeri* Williams, has been associated with diseased red raspberry plants with populations as low as 50 nematodes per 100 cm^3 of soil (McElroy 1977). The northern root-knot nematode, *Meloïdogyne hapla* Chitwood, has not yet been reported to be associated with a disorder on raspberry, but was shown to increase the incidence of crown gall caused by *Agrobacterium tumefaciens* (E.F. Smith & Townsend) Conn (Griffin *et al.* 1968).

In Quebec, red raspberry is grown as a cash crop on over 600 ha for a total farm value of 4.5 millions dollars annually (Statistics Canada 1989). The standard practice of continuous cropping on intensive small plantations favours population build-up of plant parasitic nematodes. A nematological survey carried out in Quebec (G. Bélair, unpublished data) revealed that *P. penetrans* was the most frequently encountered species, and recorded in 46% of the soil samples. Although less frequent, the dagger nematode, *Xiphinema rivesi* Dalmasso, and the northern root-knot nematode *M. hapla* were also reported in that same survey.

The objectives of this study were to determine the effect of preplant soil fumigation on the population densities of *P. penetrans*, *X. rivesi*, and *M. hapla*, and on growth and yield of red raspberry over a 4-year period.

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Materials and methods

The field trial was initiated at the Experimental farm of Agriculture Canada in Frelighsburg, Quebec on September 1983. The soil, naturally infested with *P. penetrans*, *X. rivesi*, and *M. hapla* was a shist loam (56% sand, 27% silt, 17% clay and 4.0-5.4% O.M.) with a pH (water) of 4.4-5.3. The study site was an established red raspberry plantation of 5 years that exhibited symptoms of decline in vigour, general growth and yield. In the spring of 1983, raspberry plants were dug, large roots and plant debris were removed, and the soil was rototilled several times to allow for a complete breakdown of plant residues.

Soil fumigation was carried out on 19 September 1983 using a John Blue type fumigator. Nematicide treatments were Telone II-B (94% 1,3-dichloropropene) at 150 and 300 L/ha and Vorlex (80% chlorinated C_3 hydrocarbons and 20% methyl isothiocyanate) at 90 and 180 L/ha injected in the soil at the 25-cm depth with chisels spaced 15 cm apart on a 1.65-m band. An untreated check was included. Fumigation dosages were based on broadcast application rates.

On 31 October 1983, raspberry cv. Boyne were transplanted at the one plant per 60 cm density. Plots were a single row 1.65 m wide X 5 m long and treatments were arranged in a randomized complete block design with nine replications. Soil samples (six cores of 5 cm diameter and 20 cm deep) were collected yearly between late September and mid-October, and thoroughly mixed. A 100-cm^3 subsample was assayed for plant parasitic nematodes by the modified Baerman funnel method (Townshend 1963).

Raspberry yield and plant growth were measured along the entire 5-m row. In 1984, all canes were cut to a 15 cm height to promote new growth. From 1985 to 1988, the canes were thinned to 12 canes per meter in early August shortly after harvest. The total number of pruned new canes was recorded, and the length of 25 randomly chosen pruned canes was recorded.

The berries were picked when ripe, every 2-3 days in July of every year. The average weight of berries was measured by recording the weight of 50 marketable berries from each plot at three different times during harvest.

In September 1988, all plants were dug out in order to assess the incidence of the crown gall (*A. tumefaciens*) on the root system. The number and the volume of galls on the entire row were recorded.

Analysis of variance was performed on plant parameter data and log (x+1) transformed nematode counts. The treatment means were compared with Waller-Duncan K-ratio *t*-test and Spearmann's correlation coefficients were determined for all variables recorded.

Results

Nematode densities. *P. penetrans* was the most prevalent plant-parasitic nematode in the soil. The pre-treatment soil densities of *P. penetrans* ranged from 1031 to 1488 nematodes per 100 cm^3 of soil and were uniformly distributed in the field (Table 1). At transplantation time, the mean numbers of *P. penetrans* in the fumigated plots had reduced at or below the detectable level with no significant difference ($P > 0.05$) among the treatments. Densities of lesion nematode in the fumigated plots remained significantly lower ($P \leq 0.05$) than in the control plots in the first three years after treatment (Table 1). In 1986, 1987, and 1988, the numbers of *P. penetrans* increased in the treated plots, so that they were similar to or exceeded the numbers in the control. In 1985, there was a negative correlation between cane numbers ($r = -0.38, P \leq 0.01$), cane

Table 1. Effect of preplant soil fumigation on soil population densities of the root lesion nematode *Pratylenchus penetrans* in raspberry cv. Boyne at Frelighsburg, Quebec

		P. penetrans / 100 cm^3 of soil						
		Pre-treatment	Post-treatment					
Treatment	Rate (L/ha)	1982	1983	1984	1985	1986	1987	1988
Control		1488 a §	16 a	839 a	603 a	83 a	459 a	233 a
Telone II-B	150	1086 a	1 b	319 b	145 a	145 a	409 a	181 a
Telone II-B	300	1163 a	0 b	112 b	24 b	193 a	253 a	291 a
Vorlex	90	1890 a	2 b	142 b	52 b	231 a	486 a	388 a
Vorlex	180	1031 a	1 b	212 b	18 b	109 a	317 a	352 a

§ Means followed by the same letter within a column are not significantly different ($P > 0.05$) according to Waller-Duncan K-ratio *t*-test.

lengths (r = -0.30, $P \leq 0.01$), total yields (r = -0.41, $P \leq 0.01$) and soil populations of *P. penetrans*. There were no relationships (P > 0.05) between growth or yield of raspberry and numbers of *P. penetrans* in the three following years.

Although more heterogenous, pre-treatment soil populations of *X. rivesi* ranged from 2 to 133 nematodes per 100 cm^3 of soil. In the first three years of the experiment, the densities of *X. rivesi* decreased below the detectable level in both treated and untreated plots. In 1986 and 1987, the dagger nematode was isolated from the controls only with population densities less than 14 per 100 cm^3 of soil. In 1988, *X. rivesi* was recovered from all treatments and the average soil populations ranging from 2 to 20 per 100 cm^3 of soil were not different ($P > 0.05$) between treated and control plots. Correlation coefficients indicated negative relationships between population densities of *X. rivesi* and cane numbers (r = -0.39, $P \leq 0.01$), total yields (r = -0.34, $P \leq 0.05$) in 1986, and cane lengths (r = -0.28, $P \leq 0.05$) in 1988.

Population densities of *M. hapla* juveniles were generally below the detectable level in all experimental plots, except in 1985 and 1987 where mean numbers ranged from 25 to 717 per 100 cm^3, and from 11 to 66 per 100 cm^3, respectively. In 1985, all treated plots had significantly higher numbers of *M. hapla* than the control, except for the Telone II-B 150 L/ha treatment. Correlation coefficients indicated a negative correlation between numbers of *M. hapla* and *P. penetrans* in 1985 (r = -0.30, $P \leq 0.05$) and 1987 (r = -0.32, $P \leq 0.05$).

Cane growth and yield. The raspberry plants were established successfully in 1984 but growth measurements were not recorded since all plants were severely pruned at mid-season in order to promote cane production. In 1985, 1986 and 1987, all the fumigant treatments had significantly increased ($P \leq 0.05$) the number of new canes in comparison to the control by an average of 112%, 46% and 56%, respectively (Table 2). Similarly, all the fumigant treatments were followed by significant increases ($P \leq 0.05$) in cane length in comparison to the control by an average of 48%, 16% and 18% in 1985, 1986 and 1987, respectively. However, no significant differences were detected ($P > 0.05$) among the treatments, except for the Telone 150 L/ha treatment in 1985 which exhibited less cane growth (Table 2).

Total raspberry yields in treated plots were significantly increased ($P \leq 0.05$) by an average of 98%, 59% and 18% in 1985, 1986, and 1987 respectively when compared with the control (Table 3). In 1985, the Telone 150 L/ha treatment provided a 55% increase in total yield which was significantly less than the other treatments. In each of the four years in which harvests were taken, the average berry weight was not significantly influenced ($P > 0.05$) by preplant soil fumigation.

Table 2. Effect of preplant soil fumigation on the growth of raspberry cv. Boyne in Frelighsburg, Quebec from 1985 to 1988

		Cane growth							
		1985		1986		1987		1988	
Treatment	Rate (L/ha)	Density (number /5m)	Length (cm)	Density (number /5m)	Length (cm)	Density (number /5m)	Length (cm)	Density (number /5m)	Length (cm)
Control		41.3 a§	71.2 a	49.6 a	89.5 a	38.3 a	82.0 a	39.4 a	60.9 a
Telone II-B	150	78.6 b	98.2 b	69.3 b	100.6 ab	56.6 b	97.9 b	46.6 a	60.4 a
Telone II-B	300	88.3 b	109.8 c	69.8 b	102.9 ab	59.6 b	95.9 b	51.1 a	65.2 a
Vorlex	90	87.9 b	108.1 c	75.0 b	101.3 ab	59.1 b	94.3 ab	43.6 a	65.0 a
Vorlex	180	95.0 b	105.7 bc	74.3 b	109.1 b	63.2 b	99.7 b	54.8 a	64.3 a

§ Means followed by the same letter within a column are not significantly different ($P > 0.05$) according to Waller-Duncan K-ratio t-test.

Table 3. Effect of preplant soil fumigation on the yield of raspberry cv. Boyne in Frelighsburg, Quebec from 1985 to 1988

		Raspberry yield							
		1985		1986		1987		1988	
Treatment	Rate (L/ha)	Fruit weight (g)	Total yield[§] (kg/5 m)	Fruit weight (g)	Total yield (kg/5 m)	Fruit weight (g)	Total yield (kg/5 m)	Fruit weight (g)	Total yield (kg/5 m)
Control		2.29 a[†]	2.2 a	2.13 a	2.3 a	1.92 a	14.3 a	1.80 a	9.5 a
Telone II-B	150	2.32 a	3.4 b	2.18 a	3.7 b	1.89 a	16.5 ab	1.82 a	9.4 a
Telone II-B	300	2.28 a	4.5 c	2.11 a	3.8 b	1.90 a	17.2 b	1.72 a	10.6 a
Vorlex	90	2.32 a	4.7 c	2.13 a	3.4 b	1.92 a	17.5 b	1.79 a	9.6 a
Vorlex	180	2.28 a	4.8 c	2.12 a	3.7 b	2.00 a	16.6 ab	1.76 a	10.7 a

§ Total of eight harvests.

† Means followed by the same letter within a column are not significantly different ($P > 0.05$) according to Waller-Duncan K-ratio *t*-test.

Crown gall incidence. In 1988, the number and volume of *A. tumefaciens* galls were positively correlated with total raspberry yield ($r = 0.30, P \leq 0.01$; $r = 0.26, P \leq 0.01$). No correlation were established between the numbers of *P. penetrans, X. rivesi,* and *M. hapla* and the incidence of crown gall.

Discussion

This field trial provide evidence that the root lesion nematode *P. penetrans* is a damaging pest of raspberry in Quebec. *P. penetrans* was the most abundant plant-parasitic nematode, and its control probably accounted for most of the large growth and yield increases obtained following preplant soil fumigation. These results are consistent with other reports where *P. penetrans* infested plots had been treated before planting (Seipp 1986; Trudgill 1986). The compound methyl isothiocyanate contained in Vorlex is known to be effective against a larger spectrum of soil micro-organisms than the one covered by dichloropropene, the major active ingredient in Telone II-B. Because Vorlex did not exhibit a definite edge on Telone II-B, it is believed that no soil-borne fungi or bacteria has caused any significant damage to raspberry plants at this particular site and that nematode control was the main effect recorded in this experiment. Because both rates of each fumigant provided the same level of *P. penetrans* control which were translated in similar increases in growth and yield of raspberry, it is suggested to use the single application rates on similar soil type.

There was some slight evidence that *X. rivesi* had contributed to the decline of the raspberry plantation as revealed by significant correlation coefficients in 1986 and 1988. Nematode counts recorded in October 1982 on the 5-year-old raspberry plantation showed that populations of *X. rivesi* (average= 47 nematodes per 100 cm^3) were then negatively correlated with total raspberry yields ($r = -0.61; P \leq 0.05$) and cane lengths ($r = -0.70; P \leq 0.01$). Because the extraction method used throughout this study has a low efficiency level for large nematodes such as *Xiphinema*, the exact incidence of this plant-parasitic nematode may have been overrun by the detection level of the technique.

This study also demonstrated the benefit of preplant soil fumigation where replant problems and heavy infestations of plant-parasitic nematodes such as *P. penetrans* may occur. Based on these results, a 3.6 t/ha average yield increase was extrapolated from the total yields of 1985 to 1987. With a crop value of 3200$/t and fumigation costs (1989, canadian prices), the increase in crop return from preplant soil treatment would be of 11 220$ per hectare.

The incidence of crown gall *A. tumefaciens* was not correlated with soil populations of *P. penetrans.* The results of this study do not support the findings of Vrain and Copeman (1987) where this nematode was shown to have a predisposing effect on this disease in short-term greenhouse experiments. Also, no correlation could be established between gall production by *A. tumefaciens* and the presence of *M. hapla* as suggested by greenhouse works by Griffin *et al.* (1968).

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