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Effet d'une rotation avec le millet perlé grain sur *Pratylenchus penetrans* et les rendements subséquents de pommes de terre au Québec

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Article abstract

A field study was conducted in Quebec to determine the effect of crop rotation with grain pearl millet (*Pennisetum glaucum*) on *Pratylenchus penetrans* populations and the subsequent yields of two potato cultivars (*Solanum tuberosum*) when compared with rye and continuous potato with and without fumigation. Pearl millet had a suppressive effect on *P. penetrans* populations compared with rye but not as much as continuous potato with fumigation. In 2002, total potato yields of cv. Superior and cv. Hilite Russet were negatively correlated with *P. penetrans* densities at harvest. Total yields of potato cv. Superior were increased by 123 and 229% following pearl millet and fumigation, respectively, compared with rye. Total yields of potato cv. Hilite Russet increased by 26 and 17% following pearl millet and fumigation. Grain pearl millet CGPM H-1 reduced *P. penetrans* densities and improved potato yields in Quebec.

Effect of crop rotation with grain pearl millet on *Pratylenchus penetrans* and subsequent potato yields in Quebec

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A field study was conducted in Quebec to determine the effect of crop rotation with grain pearl millet (*Pennisetum glaucum*) on *Pratylenchus penetrans* populations and the subsequent yields of two potato cultivars (*Solanum tuberosum*) when compared with rye and continuous potato with and without fumigation. Pearl millet had a suppressive effect on *P. penetrans* populations compared with rye but not as much as continuous potato with fumigation. In 2002, total potato yields of cv. Superior and cv. Hilite Russet were negatively correlated with *P. penetrans* densities at harvest. Total yields of potato cv. Superior were increased by 123 and 229% following pearl millet and fumigation, respectively, compared with rye. Total yields of potato cv. Hilite Russet increased by 26 and 17% following pearl millet and fumigation. Grain pearl millet CGPM H-1 reduced *P. penetrans* densities and improved potato yields in Quebec.

Keywords: Crop rotation, cultural practices, pearl millet, *Pennisetum glaucum*, potato, *Pratylenchus penetrans*, root-lesion nematode, *Solanum tuberosum*.

[Effet d'une rotation avec le millet perlé grain sur *Pratylenchus penetrans* et les rendements subséquents de pommes de terre au Québec]

L'effet d'une rotation avec le millet perlé grain (*Pennisetum glaucum*) sur les populations de *Pratylenchus penetrans* et les rendements subséquents de deux variétés de pommes de terre (*Solanum tuberosum*) a été comparé à des rotations avec le seigle, la pomme de terre et la pomme de terre suivie d'une fumigation. Le millet a eu un effet suppressif sur les populations de *P. penetrans* comparativement au seigle, mais à un degré moindre que la fumigation. En 2002, les rendements de pommes de terre cv. Superior et cv. Hilite Russet étaient négativement corrélés avec les densités à la récolte du *P. penetrans*. Les rendements de pomme de terre cv. Superior ont été accrus respectivement de 123 et de 229 % après la culture de millet et la fumigation comparativement au seigle. Les rendements de pomme de terre cv. Hilite Russet ont été accrus respectivement de 26 et de 17 % après la culture de millet perlé et la fumigation. Le millet perlé grain CGPM H-1 a réduit les densités du *P. penetrans* et accru les rendements de pommes de terre au Québec.

Mots clés : Millet perlé, nématode des lésions, *Pennisetum glaucum*, pomme de terre, pratiques culturales, *Pratylenchus penetrans*, rotation, *Solanum tuberosum*.

INTRODUCTION

In eastern Canada, the root-lesion nematode, *Pratylenchus penetrans* (Cobb) Filipjev & Schuur. Stekh., causes substantial yield reductions in potato (*Solanum tuberosum* L.) (Ball-Coelho *et al.* 2003; Bélair 2005; Bernard and Laughlin 1976; Olthof 1986, 1987, 1989; Olthof and Potter 1973). In Quebec, damaged population densities have been recorded by Vrain and Dupré (1982), and potato yield losses due to *P. penetrans* have recently been reported by Bélair *et al.* (2005).

Traditionally, rye (*Secale cereale* L.) has been used by Quebec potato growers as a rotation crop. Unfortunately, rye is a good host of *P. penetrans* (Bélair *et al.* 2002; Dunn and Mai 1973; Olthof 1980; Thies *et al.* 1995); therefore, when used as a rotation crop, rye may increase nematode damage and yield losses on subsequent crops. Soil fumigation with chemicals such as metam sodium is commonly used in Quebec potato production to control *P. penetrans* populations and increase potato yields. The use of crops that are unsuitable for the build-up of *P. penetrans* in soils may help to reduce or eliminate the

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need for costly nematicide applications in these soils. In a previous study, Bélair *et al.* (2005) showed that forage (FPM) and grain pearl millet (GPM) (*Pennisetum glaucum* L.) could be efficient and economically viable alternatives to fumigation for controlling *P. penetrans* and improving potato yields.

Forage and grain hybrids of pearl millet have been developed by Agriculture Environmental Renewal Canada (AERC Inc., Nepean, Ontario), and are well adapted to the climatic and soil conditions of eastern Canada. Many studies have shown that pearl millet hybrids are poor hosts of *P. penetrans* under greenhouse and field conditions (Ball-Coelho *et al.* 2003; Bélair *et al.* 2002, 2005; Jagdale *et al.* 2000). However, some studies have shown that grain hybrids were less effective than CFPM 101 (a forage hybrid commonly used by growers) in reducing *P. penetrans* populations and improving potato yields (Ball-Coelho *et al.* 2003; Bélair *et al.* 2005). On the other hand, a crop rotation experiment performed in microplots in Quebec showed that CGPM H-1 was as effective as CFPM 101 in controlling *P. penetrans* and improving potato yields (Bélair *et al.* 2003). Due to these conflicting results, further research was needed to confirm the potential of CGPM H-1 as a rotation crop for potato. The objective of this study was to assess the impact of rotating grain pearl millet cv. CGPM H-1 (GPM) on *P. penetrans* populations in potato.

MATERIALS AND METHODS

From 2001 to 2002, a field experiment on crop rotation was conducted at L'Assomption (lat. 45°50' N, long. 73°25' W) in Quebec. The soil type was a sand that averaged 87% sand, 7% silt, 6% clay, and 3.3% organic matter, with a pH range of 6.3 to 7.3. Potato was cropped on this site in summer 2000 and seeded with fall rye cv. Laurier in October 2000. Rye was ploughed under at the beginning of spring 2001. In 2001, the three rotation crops were: GPM, potato cv. Superior, and rye cv. Laurier.

The experimental design was a strip plot, also known as sub-unit treatments in strips (Cochran and Cox 1957), with four replicates. Strips were 10 m wide x 80 m long. In 2001, crops were sown on June 7 and were managed using standard cultural practices. The seeding rate of GPM was 5.8 kg ha^{-1} (35.56 cm between rows) and it received 230 kg N ha^{-1} in a 19-19-19 fertilizer before sowing. Rye was sown at the rate of 120 kg ha^{-1} with 15 cm between rows, and potato was planted at the rate of 2313 kg ha^{-1}, 30 cm apart within a row, with 90 cm between rows. Weeds were controlled manually several times during the season.

In 2002, each strip was split into two sub-plots 5 m wide x 80 m long, and one sub-plot was planted with potato cv. Superior and the other with cv. Hilite Russet. Both cultivars were planted on May 6, 2002, 30 cm apart within a row, with 90 cm between rows. In each strip previously grown in potato, half of the area was fumigated with a band application of metam sodium (Vapam®) at 155-160 L ha^{-1} in the fall of 2001. In 2002, the potato crop was managed according to the recommendations for conventional potato production in Quebec (Conseil des Productions Végétales du Québec 1992). Soil analyses were performed to determine N-P-K levels in each of the rotation crops and fertilization was adjusted to standard recommended rates. Potato tubers were harvested on September 16 and 17, 2002 from two 3-m rows per replicate. All potato tubers were graded as follows according to Canadian standards: J-size > than 8.89 cm tuber diam, B-size between 2.22 and 4.76 cm tuber diam, and A-size between 4.76 and 8.89 cm tuber diam. Tuber yields were expressed as weight in metric tons per hectare.

Each year, soil samples were collected twice to assess *P. penetrans* population density. Soil sampling was carried out prior to sowing and after harvest. In 2002, spring and fall soil samples were collected in each sub-plot to assess population density under each cultivar. For each sample, 12 soil cores (5 cm diam x 20 cm deep) per plot or sub-plot were arbitrarily collected on the row. For the 2002 fall sampling, soil samples were collected in the potato bed of each 3 m of row harvested. The soil samples were placed in plastic bags and stored at 4°C until nematodes were extracted.

Nematode population density was estimated by processing two sub-samples of 50 cm^3 from each soil sample by the modified Baermann pan method (Townshend 1963). Nematodes were counted using a stereo-microscope and expressed as numbers kg^{-1} of soil.

Nematode counts were transformed using ($\log_{10}$ [x+1]) before statistical analysis, but nematode data are presented as back-transformed means in the tables. Data were analyzed through an analysis of variance using the General Linear Model procedure of SAS (SAS Institute Inc., Cary, NC). The Waller-Duncan

Table 1. *Pratylenchus penetrans* populations under rotation crops in 2001 at L'Assomption

	Number of *P. penetrans* kg^{-1} soil	
Crops	Apr. 27	Oct. 22
CGPM H-1	413 a[a]	867 b
Potato cv. Superior	200 a	467 b
Rye	320 a	8533 a

[a] Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$), as determined by the Waller-Duncan test.

Table 2. ***Pratylenchus penetrans*** **populations under two potato cultivars in 2002 at L'Assomption**

	Number of *P. penetrans* kg^{-1} soil			
	Potato cv. Superior		Potato cv. Hilite Russet	
Crops in 2001	May 6	Sept. 17	May 6	Sept. 17
CGPM H-1	348 b[a]	2 515 b	350 b	5 765 b
Potato	63 c	1 188 b	128 b	848 b
Potato (fumigated)	0 d	80 c	5 c	108 c
Rye	3 150 a	7 867 a	1 400 a	13 567 a

[a] Means in the same column followed by the same letter are not significantly different ($P \le 0.05$), as determined by the Waller-Duncan test.

test was used to compare treatments when the analysis of variance showed significant differences among means ($P \le 0.05$). Pearson's correlation coefficients (r) were calculated between potato yields and nematode numbers, and simple linear regressions between total potato yield and *P. penetrans* density at harvest in 2002 were derived for data from both cultivars (SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION

In 2001, the field was infested by *P. penetrans* with an average initial nematode density of 311 kg^{-1} soil and there were no significant differences among treatments (Table 1). In the fall of 2001, *P. penetrans* density in soil had increased ($P \le 0.05$) after rye when compared with GPM and potato (Table 1).

In 2002, pre-planting nematode soil densities in plots with both potato cultivars differed ($P \le 0.01$) among previous rotation crops (Table 2). Nematode densities observed following rye for both potato cultivars were significantly higher than those following GPM and potato. The number of *P. penetrans* was the lowest in the fumigated plots. In the fall of 2002, *P. penetrans* densities were low under fumigation, intermediate under GPM and potato, and high under rye ($P \le 0.001$) (Table 2).

Based on pre-planting populations in 2002, nematode densities in rye plots were above the damage threshold of 1000 *P. penetrans* kg^{-1} soil (Barker and Olthof 1976; Bernard and Laughlin 1976; Kimpinski 1982; Olthof and Potter 1973) (Table 2). Yields of potato cv. Superior were affected ($P \le 0.05$) by previous rotation crops (Table 3). Marketable and total yields were the highest in the fumigation and the lowest in the rye rotation treatment. Fumigation and GPM reduced ($P \le 0.05$) the production of grade B potatoes of cv. Superior when compared with potato and rye (Table 3). The highest total yield was recorded in the fumigation and the lowest in the rye treatment (Table 3). Marketable ($r = -0.645$) and total ($r = -0.632$) yields of potato cv. Superior were negatively correlated with *P. penetrans* densities recorded at harvest in 2002. Yield of B-size potatoes was positively correlated ($r = 0.403$, $P \le 0.01$) with nematode densities observed at harvest in 2002.

Yields of potato cv. Hilite Russet were significantly affected by previous rotation crops (Table 3). The highest marketable ($P \le 0.01$) and total potato yields ($P \le 0.01$) were observed following GPM, and the lowest yields were observed in plots previously grown in potato (Table 3). The production of grade B potatoes was greater ($P \le 0.05$) after fumigation when compared with GPM and rye (Table 3).

Hilite Russet produced a higher number of grade B potatoes than Superior (Table 3). This could be explained by the fact that these two cultivars have different tuber shapes (Hilite Russet is oblong and Superior is round). Consequently, the diameter of oblong shaped potatoes is smaller than that of round potatoes. Correlation analyses revealed that grade B ($r = -0.363$, $P \le 0.05$), marketable ($r = -0.303$, $P \le 0.05$), and total ($r = -0.409$, $P \le 0.01$) potato yields of Hilite Russet were negatively correlated with *P. penetrans* densities observed at harvest in 2002.

Total yields of potato cv. Superior were increased by 229% following fumigation and by 123% following GPM when compared with rye (Table 3). On the other hand, total yields of potato cv. Hilite Russet were increased by only 17% following fumigation and by 26% following GPM when compared with rye (Table 3). Linear regression analyses were performed and provided the following regression equations between fall densities of *P. penetrans* (x) and total potato yields (y): $y = -2.24x + 35.21$ ($P \le 0.001$) for cv. Hilite Russet, and $y = -4.21x + 33.56$ ($P \le 0.001$) for cv. Superior. Although no significant difference was detected between slopes and intercepts of these regression equations (t test, $P > 0.05$), the slopes suggested that cv. Hilite Russet could be less susceptible to damage by *P. penetrans*.

These results demonstrated that *P. penetrans* reduces potato yields under Quebec conditions and confirmed findings from previous work (Bélair *et al.* 2005). Traditionally, rye has been used by Quebec potato growers as a rotation crop. Rye was previously recognized to be a good host for *P. penetrans* (Bélair *et al.* 2002; Dunn and Mai 1973; Olthof 1980; Thies *et al.* 1995). Our results demonstrated that rotation with rye increased *P. penetrans* population densities in soil and, in addition, reduced potato yields.

Table 3. Potato yields in 2002 on two cultivars at L'Assomption

	Fresh weight of tubers (tons ha^{-1})		
	Grade B[a]	Grade A+J	Total
Crops in 2001	Potato cv. Superior		
CGPM H-1	1.8 b[b]	22.2 b	24.1 b
Potato	3.2 a	18.5 b	21.8 b
Potato (fumigated)	1.6 b	33.9 a	35.5 a
Rye	3.3 a	7.4 c	10.8 c
Crops in 2001	Potato cv. Hilite Russet		
CGPM H-1	6.7 bc[b]	25.2 a	31.9 a
Potato	7.9 ab	14.3 c	22.2 c
Potato (fumigated)	9.8 a	19.9 b	29.6 ab
Rye	5.6 c	19.8 b	25.4 bc

[a] Tuber classification: Grade B between 2.22-4.76 cm tuber diam; Grade A between 4.76-8.89 cm; Grade J > 8.89 cm.
[b] Values in the same column and within each potato cultivar followed by the same letter are not significantly different ($P \le 0.05$), as determined by the Waller-Duncan test.

In our study, *P. penetrans* populations following potato were lower than those following rye. Similar results were obtained by Florini *et al.* (1987). They suggested that the lower populations of *P. penetrans* in potato compared with rye was due to the decrease in potato root mass with time, especially in early maturing cultivars such as Superior. Another study demonstrated that the cultivation of potatoes for three consecutive growing seasons did not lead to a statistically significant increase in the number of root-lesion nematodes in soils (Kimpinski and Willis 1980). These observations suggest that potato is a host of *P. penetrans*, but not as good a host as rye.

Our work did not confirm the results obtained by Ball-Coelho *et al.* (2003) which showed that grain pearl millet did not reduce *P. penetrans* when compared with rye. In contrast, our results support previous studies which demonstrated that grain pearl millet is a poor host of *P. penetrans* when compared with rye (Bélair *et al.* 2004; Jagdale *et al.* 2000).

Pearl millet is well adapted to Quebec potato soils, which are of light texture, with low fertility and a low water-holding capacity. Because this crop needs warm temperatures for establishment in the spring, sowing is recommended for late May and/or early June, when the probability of frost is low. Hybrids of grain pearl millet are early maturing dwarfs, and produce 5 to 10 head-bearing tillers per plant. Potential grain yields vary from 2.5 to 3.5 tons ha^{-1}. Grain millet has several potential uses, such as feed for beef and dairy cattle, and in poultry rations.

Differences in susceptibility to damage by *P. penetrans* exist among potato cultivars (Bernard and Laughlin 1976; Bird and Vitosh 1978; Olthof 1983, 1986). Potato cv. Superior was shown to be susceptible to root-lesion nematodes (Bernard and Laughlin 1976; Bird and Vitosh 1978; Olthof 1986). It is unclear whether cultivar Hilite Russet is more tolerant to *P. penetrans* than cultivar Superior. No information is currently available on the tolerance of Hilite Russet, a cultivar recently licensed in Canada (1995) and used in Quebec potato production. Further studies are needed to confirm the relative susceptibility of various potato cultivars to *P. penetrans* under Quebec's production system.

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