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Reproduction of *Pratylenchus penetrans* on 24 Common Weeds in Potato Fields in Québec

G. Bélair, N. Dauphinais, D. L. Benoit, Y. Fournier

Abstract: Twenty-four weeds commonly found in commercial potato fields in Quebec were evaluated for their host suitability to the root-lesion nematode, *Pratylenchus penetrans*, under greenhouse conditions. Brown mustard (*Brassica juncea*) and rye (*Secale cereale*) were included as susceptible controls and forage pearl millet hyb. CFPM 101 (*Pennisetum glaucum*) as a poor host. *Pratylenchus penetrans* multiplied well on 22 of the 24 weed species tested (Pf/Pi ≥ rye or brown mustard). *Cirsium arvense*, *Leucanthemum vulgare* and *Matricaria discoida* were classified as very good hosts with a Pf/Pi ranging from 1.60 to 2.54, while *Ambrosia artemisiifolia* and *Cyperus esculentus* were classified as poor hosts with a Pf/Pi from 0.01 to 0.15. *Amaranthus powellii*, *A. retroflexus*, *Raphanus raphanistrum*, *Rorippa palustris*, *Cerastium fontanum*, *Spergula arvensis*, *Stellaria media*, *Chenopodium album*, *Vicia cracca*, *Elytrigia repens*, *Digitaria ischaemum*, *Echinochloa crusgalli*, *Panicum capillare*, *Setaria faberii*, *S. pumila*, *S. viridis*, *Polygonum convolvulus*, *P. scabrum* and *P. persicaria* were intermediate hosts with Pf/Pi values ranging from 0.33 to 2.01. The plant species and the botanical family had a significant impact on nematode reproduction. The Brassicaceae family resulted in the greatest reproduction of *P. penetrans*, and the Cyperaceae resulted in the least. The plant life-cycle (annual vs. perennial) had no impact on nematode population.

Key words: brown mustard, host range, pearl millet, potato, *Pratylenchus penetrans*, root-lesion nematode, rye, weed.

The root-lesion nematode, *Pratylenchus penetrans*, is an endoparasitic nematode that causes substantial yield reductions in potato (*Solanum tuberosum* L.) in many production areas in Canada and the US (Olthof and Potter, 1973; Bernard and Laughlin, 1976; Olthof, 1986, 1987, 1989; Ball-Coelho et al., 2003). In Québec, *P. penetrans* is the dominant species in potato fields, and population densities above the damage threshold of 1,000 nematodes/kg soil are common (Vrain and Dupré, 1982; Olthof, 1987). Recently, yield losses by *P. penetrans* have been recorded in commercial potato fields in various areas of Québec (Bélair et al., 2005). This nematode has an extremely wide host range, including most cultivated crops and numerous weeds, which complicates its management with crop rotation (Jensen, 1953; Townshend and Davidson, 1960; Manuel et al., 1980). Traditionally, rye (*Secale cereale* L.) has been grown as a rotation crop by potato growers. Rye is a good host for *P. penetrans*, so its use as a rotation crop increases nematode pressure on subsequent crops, potentially increasing yield losses (Dunn and Mai, 1973; Olthof, 1980; Thies et al., 1995; Bélair et al., 2002). Lately, poor host status was reported for forage and grain pearl millets (*Pennisetum glaucum* L.), and both were demonstrated to be economically viable alternatives to soil fumigation for controlling *P. penetrans* and improving potato yields (Jagdale et al., 2000; Bélair et al., 2002; Ball-Coelho et al., 2003; Bélair et al., 2005). In eastern Canada, forage pearl millet hyb. CFPM 101 has been adapted by some potato growers, with an estimated 400-ha area grown as a one-year crop rotation in the province of Québec alone (G. Michaud, Semico Inc., personal communication). Because millet is a warm climate crop, it competes poorly with cool-adapted and faster growing weedy plants during the spring. Currently, there are no herbicides registered for controlling grassy weeds in pearl millet in Canada, thus weeds could maintain high *P. penetrans* densities under a poor-host crop such as pearl millet. The effective control of weeds will be essential for the successful management of nematodes with crop rotation (Manuel et al., 1980; Whitehead, 1998). The host status of *P. penetrans* for many common weeds is unknown. The objective of this study was to determine the host suitability of 24 common weed species in sandy soils to *Pratylenchus penetrans* from Québec and to compare them with forage pearl millet hyb. CFPM 101.

Materials and Methods

In 2003 to 2004, two greenhouse trials were carried out in the research facilities of Agriculture and Agri-Food Canada's Horticultural R&D Centre in St-Jean-sur-Richelieu, Québec. The following weeds were included in our trials: *Amaranthus powellii* (green pigweed), *Amaranthus retroflexus* (redroot pigweed), *Ambrosia artemisiifolia* (common ragweed), *Cerastium fontanum* (*Cerastium vulgatum*) (mouse-eared chickweed), *Cirsium arvense* (Canada thistle), *Chenopodium album* (lamb's quarters), *Cyperus esculentus* (yellow nut sedge), *Digitaria ischaemum* (smooth crab grass), *Echinochloa crusgalli* (barnyard grass), *Elytrigia repens* (*Agropyron repens*) (quack grass), *Leucanthemum vulgare* (*Chrysanthemum leucanthemum*) (ox-eye daisy), *Matricaria discoida* (*Matricaria matricarioides)* (pineappleweed), *Panicum capillare* (witch grass), *Polygonum convolvulus* (wild buckwheat), *Polygonum persicaria* (lady's-thumb), *Polygonum scabrum* (green smartweed), *Raphanus raphanistrum* (wild radish), *Rorippa palustris* (*Rorippa islandica*) (marsh yellow cress), *Setaria faberii* (giant foxtail), *Setaria pumila* (*Setaria glauca*) (yellow foxtail), *Setaria viridis* (green foxtail), *Spergula arvensis* (corn spurry), *Stellaria media* (chickweed) and *Vicia cracca* (tufted vetch). Brown mustard (*Brassica juncea*) and rye (*Secale cereale* cv.

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Horticulture Research and Development Centre, Agriculture and Agri-Food Canada, St-Jean-sur-Richelieu, Québec, J3B 3E6, Canada.
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E-mail: belairg@agr.gc.ca
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Musketeer) were included as positive controls (good hosts) and forage pearl millet hyb. CFPM 101 as a poor host.

The experimental design was a randomized complete block design with 26 and 21 treatments in 2003 and 2004, respectively, and each treatment was replicated six times. Plastic containers (15.24-cm diam., 1.5-liter volume) filled with pasteurized sand from the Lanaudière region, Québec (87% sand, 7% silt, 6% clay; 3.3% organic matter; pH 6.3–7.3), were used to grow all plants. Twenty-five seeds of each weed species were sown per container to obtain a final population of 3 to 7 plants/container. All containers were watered daily using a saucer underneath each container to avoid leaching of nematodes. Fertigation was done weekly for 5 consecutive d with a mix of one part of 20-8-20 at the rate of 0.5 g/liter and one part of 14-0-14 at the rate of 0.4 g/liter. The temperature in the greenhouse was maintained between 25°C ± 3°C with a photoperiod of 16 hr light and 8 hr dark at 70% humidity.

Nematodes used in both years were obtained from a pure culture of *P. penetrans* reared on tobacco cv. Delgold at 25°C in the greenhouse. Nematode adults and larvae were recovered from roots following a mist chamber extraction for 2 wk at 22°C (Seinhorst, 1950). Twelve days after sowing, all plants were inoculated at the rate of 5,000 *P. penetrans*/kg soil (7,500 nematodes/container) in 2003 and at 2,500 *P. penetrans*/kg soil (3,750 nematodes/container) in 2004. Plants were harvested after 77 d of growth in 2003 and 63 d in 2004.

Soil and root samples from each container were collected to determine the number of *P. penetrans*. Soil nematode density was estimated by processing two 100-cm^3 subsamples for each container by the Baermann pan method (Townshend, 1963). The entire root system in each container was washed under running tap water and weighed, and one subsample per container (approx. 15 g) was placed in a misting chamber for a 2-wk extraction period at 22°C (Seinhorst, 1950). After the extraction period, roots were oven-dried (65°C) for 2 d and weighed. Nematodes were quantified and expressed as numbers per kg soil, numbers per g dry root weight and numbers per container. For each plant, a reproduction factor (Pf/Pi) was calculated, where Pf = total number of nematodes from soil and roots for each container and Pi = initial number of nematodes inoculated in soil per container. At harvest, the growth stage of plants was recorded according to the BBCH scale, which is a standardized plant growth-stage scale (Lancashire et al., 1991). The fresh and dry biomasses of aerial parts of the plants were also noted for each container.

Parameters that were used in the statistical analyses were the number of *P. penetrans* per kg soil, number of *P. penetrans* per g dry root, and reproduction factor (Pf/Pi). Nematode counts were transformed using (log10[x+1]) before statistical analysis. Data were subjected to analysis of variance and general linear model (GLM) procedures (SAS Institute). Waller's test was used to compare treatments when the analysis of variance showed significant differences among the means ($P \leq 0.05$).

The host suitability of weeds for *P. penetrans* was determined by comparing the nematode multiplication rate (Pf/Pi) of each weed species to forage pearl millet hyb. CFPM 101, a poor host, and to rye and brown mustard, good hosts. Because pearl millet hyb. CFPM 101 as a one-year rotation crop was demonstrated to reduce *P. penetrans* densities below the economic threshold of 1,000 nematodes/kg soil under field conditions (Bélair et al., 2005), we have established the following classification: 1) poor host: Pf/Pi ≤ pearl millet; 2) intermediate hosts: pearl millet < Pf/Pi < rye and/or brown mustard; and 3) good host: Pf/Pi ≥ rye or brown mustard.

In order to identify groups based on information provided by the different variables measured, a cluster analysis (Proc Cluster) using the complete linkage method was carried out on the complete data (SAS Institute). This analysis showed that data were distributed between five clusters where the reproduction factor was the best indicator of the cluster. On the other hand, there was no cluster grouped by species. Following cluster analysis, a factor analysis (Proc Factor) was performed on data from both years excluding data points identified as outliers by the cluster analysis. Factor analysis is used to explain correlations among a set of variables, and it condenses the information contained in the original variables into a smaller set of dimensions (factors). It assumes that the relationships between variables are linear. The guidelines to determine the number of factors to retain were based on the Kaiser rules. If the Kaiser value is less than 1, the factor is retained. Subsequently, the Varimax method (orthogonal rotation) was used to determine which variables were associated with each factor. An analysis of variance using a mixed model procedure (Proc Mixed) was used to verify for each factor retained, possible interaction between year of evaluation and species, life cycle, or botanical family attribution.

Results

The 24 species of weeds evaluated in this study belonged to 19 genera and nine families. Weeds differed significantly for *P. penetrans* reproduction (Table 1). Brown mustard was included as a positive control and showed the highest number of *P. penetrans* in soil and the highest Pf/Pi value for both years. Rye, also included as a positive control, showed high levels of nematodes in the soil and a high reproduction level (Table 1).

Average *P. penetrans* numbers per kg soil varied from five to 27 nematodes in *Ambrosia artemisiifolia* from 9,720 to 10,123 in brown mustard *B. juncea* in 2003 and

TABLE 1. Reproduction of *Pratylenchus penetrans* on 24 common weed species in the greenhouse.

Host	2003 Number of *P. penetrans* per kg soil	2003 Number of *P. penetrans* per g dry root	2003 Pf/Pi	2004 Number of *P. penetrans* per kg soil	2004 Number of *P. penetrans* per g dry root	2004 Pf/Pi
Amaranthaceae						
Amaranthus powellii	2,480 b–f[a]	996 e–g	0.94 d–g	2,083 cd	347 c	0.96 fg
A. retroflexus	1,292 f–h	441 g–j	0.52 h–k	1,450 d	273 cd	0.71 hi
Asteraceae						
Ambrosia artemisiifolia	5 l	502 ij	0.04 n	27 g	1 g	0.01 k
Cirsium arvense	5,264 ab	8,891 c	2.29 ab	2,770 bc	407 c	1.60 b–d
Leucanthemum vulgare	1,983 c–f	26,852 b	2.54 ab	—	—	—
Matricaria discoida	1,709 d–f	98,156 a	1.80 bc	2,804 bc	8,003 a	2.05 bc
Brassicaceae						
Brassica juncea brown mustard	9.720 a	5,152 cd	3.24 a	10,123 a	1,857 b	4.37 a
Raphanus raphanistrum	4,776 a–c	2,029 ef	1.15 c–f	4,762 b	574 c	2.01 bc
Rorippa palustris	3,505 b–e	30,718 b	1.50 b–e	—	—	—
Caryophyllaceae						
Cerastium fontanum	2,576 b–f	1,655 f–i	0.99 e–h	2,360 cd	1,108 c	1.23 d–g
Spergula arvensis	838 g–i	1,645 d–f	0.33 kl	1,463 cd	500 c	0.79 g–i
Stellaria media	588 g–i	822 h–j	0.62 i–l	2,096 cd	144 de	1.00 e–g
Chenopodiaceae						
Chenopodium album	5,849 a–d	465 h–j	1.55 c–f	2,722 bc	507 c	1.50 c–f
Cyperaceae						
Cyperus esculentus	265 jk	49 l	0.15 m	174 f	21 f	0.09 j
Fabaceae						
Vicia cracca	122 k	1,647 e–h	0.39 kl	329 e	2,287 b	0.94 gh
Poaceae						
Digitaria ischaemum	200 k	143 jk	1.46 b–e	—	—	—
Echinochloa crusgalli	1,190 gh	665 jk	0.73 f–i	2,047 cd	2,433 b	1.51 c–e
Elytrigia repens	608 h–j	1,007 e–g	0.71 f–i	1,658 cd	597 c	1.47 c–f
Panicum capillare	253 jk	873 e–g	0.46 h–k	—	—	—
Pennisetum glaucum pearl millet	738 h–j	43 l	0.25 lm	260 ef	5 g	0.11 j
Secale cereale rye	4,270 b–e	289 h–j	1.74 b–d	5,189 b	53 f	2.54 b
Setaria faberii	—	—	—	1,707 cd	145 e	0.88 g–i
Setaria pumila	347 ij	124 kl	0.43 j–l	1,302 d	44 f	0.62 i
Setaria viridis	1,380 e–g	527 g–j	0.64 g–j	—	—	—
Polygonaceae						
Polygonum convolvulus	1,426 ef	7,064 c–e	0.71 f–i	—	—	—
Polygonum persicaria	608 g–i	950 f–i	0.65 f–i	3,265 bc	280 c	1.71 b–e
Polygonum scabrum	1,713 d–f	2,690 ef	0.62 g–j	2,723 bc	257 cd	1.63 b

[a] Values in the same column followed by the same letter are not significantly different ($P < 0.05$) from another, as determined by Waller's test.

2004, respectively (Table 1). In both years, *A. artemisiifolia* and *C. esculentus* were considered to be poor hosts and sustained the lowest number of *P. penetrans* per kg soil and the lowest Pf/Pi when compared to pearl millet ($P \leq 0.0001$). The Pf/Pi ratio of the poor hosts ranged from 0.04 to 0.15 for 2003 and from 0.01 to 0.09 for 2004 (Table 1).

In 2003, *C. arvense*, *R. raphanistrum* and *C. album* had higher numbers of *P. penetrans* in soil than rye (Table 1). Also, in 2003, *C. arvense*, *L. vulgare* and *M. discoida* showed higher Pf/Pi values than rye. In 2004, no weeds supported higher nematode densities than rye and brown mustard. *Cirsium arvense*, *L. vulgare* and *M. discoida* were considered to be good hosts of *P. penetrans* and harbored higher densities than rye ($P \leq 0.0001$). The nematode multiplication rate on these three weeds ranged from 1.80 to 2.54 in 2003 and from 1.60 to 2.05 in 2004 (Table 1).

Amaranthus powellii, *A. retroflexus*, *R. raphanistrum*, *R. palustris*, *C. fontanum*, *S. arvensis*, *S. media*, *C. album*, *V. cracca*, *E. repens*, *D. ischaemum*, *E. crusgalli*, *P. capillare*, *S. faberii*, *S. pumila*, *S. viridis*, *P. convolvulus*, *P. scabrum* and *P. persicaria* were classified as intermediate hosts. The multiplication rate on intermediate hosts ranged from 0.33 to 1.55 for 2003 and from 0.62 to 2.01 for 2004.

The number of *P. penetrans* per g dry root differed between weeds for both years ($P \leq 0.0001$). The majority of weeds, previously classified as good hosts, showed a higher numbers of nematodes per g dry root than brown mustard and rye (Table 1).

The factor analysis isolated four factors (Kaiser criteria = 0.9268). The variance for each factor (1 to 4) accounts for: 28.1%, 19.6%, 18.3% and 18.1%, for a total of 84.1%. The Varimax method (orthogonal rotation) showed that factor 1 was positively associated with nematode data: *P. penetrans* per kg soil, *P. penetrans* per container and Pf/Pi (Table 2). Factor 2 was positively associated with year and negatively associated with length of growth period (days). Factor 3 was positively

TABLE 2. Factor pattern of standardized scoring coefficients for observed variables with the first four common factors following rotation by orthogonal transformation.

	Factor 1	Factor 2	Factor 3	Factor 4
Year[a]	–0.015	0.949	–0.013	–0.084
BBCH[b]	0.101	0.074	–0.261	–0.010
P. penetrans per kg soil	0.884	0.102	–0.068	0.010
P. penetrans per container	0.957	–0.156	–0.040	–0.028
P. penetrans per g dry root	0.457	–0.299	–0.211	–0.076
Pf/Pi	0.939	0.220	–0.086	–0.071
Fresh biomass (g)	–0.026	–0.199	0.159	0.911
Dry biomass (g)	–0.073	–0.019	0.227	0.919
Fresh root weight (g)	–0.075	0.135	0.892	0.268
Dry root weight (g)	0.019	0.047	0.912	0.178
Day[c]	–0.048	–0.908	0.017	0.132

[a] Year represents differences in the growing conditions between the two trials.
[b] BBCH represents a standardized plant growth-stage scale.
[c] Day represents the length of the growing period prior to evaluation of nematode counts.

associated with fresh and dry root weights. Factor 4 was positively associated with fresh and dry biomass. Factor 1 corresponded to nematode-related variables, factor 2 corresponded to time variables, factor 3 to plant root weight variables and factor 4 to plant biomass variables. The BBCH was not associated with any of the factors.

According to the first variance analysis (Proc mixed), species and species-by-year interaction had a significant influence on all factors (Table 3). The year only influenced factor 2. On the other hand, life cycle had a significant influence on all factors except factor 1, and botanical family had a significant impact on all factors. In all statistical models, year influenced factor 2 only (Table 3).

The reproduction factor was different between botanical families (Table 4). The Brassicaceae family was the best family for the reproduction of *P. penetrans*, and all others were similar. The Cyperaceae, Chenopodiaceae and Fabaceae were represented by only one species and were excluded from the comparison.

TABLE 3. Summary of analysis of variance performed with three statistical models on scoring coefficients for each factor.

Model	Factor 1	Factor 2	Factor 3	Factor 4
Species	---------- *P* value ----------			
Species	0.0001	0.0001	0.0001	0.0001
Year	0.8699	0.0001	0.7404	0.1446
Species * year	0.0072	0.0001	0.0001	0.0018
Life cycle				
Life cycle	0.4813	0.0001	0.0032	0.0001
Year	0.9707	0.0001	0.7193	0.1340
Life cycle * year	0.7592	0.4440	0.9172	0.1356
Botanical family[a]				
Botanical family	0.0001	0.0001	0.0001	0.0001
Year	0.6330	0.0001	0.3062	0.0170
Botanical * year	0.1694	0.0001	0.0005	0.0985

[a] Minimum 2 species per family.

TABLE 4. Reproduction factor of different botanical families of weedy species to *Pratylenchus penetrans* (years confounded).

Botanical family	Number of species tested (n)	Pf/Pi[a]
Brassicaceae	3	2.76 ± 0.28 a
Chenopodiaceae[b]	—	1.52 ± 0.33
Asteraceae	4	1.37 ± 0.18 b
Polygoniaceae	3	1.17 ± 0.18 bc
Poaceae	9	1.01 ± 0.12 bc
Caryophyllaceae	3	0.83 ± 0.10 c
Amaranthaceae	2	0.78 ± 0.09 c
Fabaceae[2]	—	0.67 ± 0.15
Cyperaceae[2]	—	0.12 ± 0.02

[a] Values in the same column followed by the same letter are not significantly different ($P < 0.05$) from one another, as determined by Waller's test.
[b] Families represented by a single species were not included in the comparison.

DISCUSSION

Twenty-two weeds were hosts of *P. penetrans* which maintained or increased populations to densities greater than those recorded on pearl millet. Our results confirm earlier work done by Townshend and Davidson (1960), which had recovered *P. penetrans* from roots of 55 weed species. Now, *A. retroflexus*, *A. artemisiifolia*, *C. fontanum*, *C. album*, *C. arvense*, *L. vulgare*, *M. discoida*, *P. convolvulus*, *P. persicaria* and *S. media* were reported as hosts but their host suitability was not assessed. The numbers of *P. penetrans* recorded per gram dry root in this study were similar to those found by Townshend and Davidson (1960) even though theirs were based on field data only. Manuel et al. (1980) stated that a host suitability test performed in the greenhouse with individual potted plants was not always indicative of what actually occurred in the field. But pot experiments are useful to observe the maximum potential of reproduction and to calculate a Pf/Pi, which is not feasible in the field. Vanstone and Russ (2001) demonstrated that the classification of weeds could be different based on the number of nematodes per gram dry root when compared to Pf/Pi, because differences exist among the root biomass of each weed species tested. Based on our greenhouse study, the classification of weeds according to host suitability has been proven dependable, as the cluster and factor analyses have demonstrated the reliability of the nematode data as a better predictor of host suitability than time or biomass data.

When looking at the interaction between year and species, life cycle or botanical family, we observed that all factors except factor 2 (time-related variables) were highly influenced by biological data. Individual species and botanical family had a significant impact on nematode data (factor 1), but the species life cycle had no significant impact on nematode data (factor 1). Since our experiment was performed on the first 63 to 77 days of growth, life cycles of species tested were limited and grouped into three categories: 1) annuals and facultative biennials, 2) winter annuals and 3) perennials

and facultative perennials. Further testing would be needed to assess more plant species covering a greater diversity of life cycles as well as assessing the nematode reproduction capacity over a longer period to include perennial species with longer life cycles.

In our experiment, species from the Asteraceae and Brassicaceae proven to be good hosts. This confirms previous findings where 63% of the weeds in which *P. penetrans* was found belonged to the families of Asteraceae (Compositae) and Brassicaceae (Cruciferae) (Townshend and Davidson, 1960). Thus, the results emphasize the need of adequate weed control (with the exception of *A. artemisiifolia* and *C. esculentus*) for the management of *P. penetrans* in sandy soils where rotation with pearl millet is commonly practiced. Currently, there is also a great interest for green manures by growers with cruciferae crops, like mustards, which are part of a good management practice in both field crops and vegetable crops in eastern Canada (Jean Coulombe, agronomist, personal communication). The total glucosinolate content of the crop is one of the primary criteria in the decision making for its activity as a biofumigation agent in the soil (Sang et al., 1994; Brown and Morra, 1997). Because many cruciferae crops are good hosts for *P. penetrans*, this information should be considered in the farm decision making and the implementation of an intergraded management of this nematode pest (Johnson et al. 1992; Bélair et al., 2002).

In a weed survey performed in potato fields in a major production area near Montreal, it was found that: 1) *C. album*, *E. crusgalli* and *E. repens* occurred in 75 to 100% of the field surveyed; 2) *A. retroflexus* and *A. artemisiifolia* in 50 to 75%; 3) *C. esculentus*, *D. ischaemum*, *P. capillare*, *P. convolvulus*, *P. scabrum*, *R. palustris*, *S. pumila*, *S. viridis*, *S. arvensis*, *S. media* and *V. cracca* in 25 to 50%; and 4) *C. fontanum*, *C. arvense*, *L. vulgare*, and *P. persicaria* in 0 to 25% (Doyon et al., 1986). Although broadleaf weeds may be controlled by herbicide applications, there are currently no herbicides that can be used to control grass weeds in pearl millet. In order to reduce weed pressure, growers often make a false seedbed preparation in early to mid-May to stimulate the germination of grass species, followed by an application of glyphosate (Roundup, Monsanto Co., St. Louis, MO). Pearl millet is seeded shortly afterward with minimal soil disturbance. A narrow row spacing and high seeding rate of forage pearl millet may prove beneficial to the crop. If the soil is warm, the crop will emerge within a week, grow rapidly and out-compete the weeds. Nematodes are able to multiply or persist in weeds, providing a ready source of inoculum (Bélair and Benoit, 1996) for later planted susceptible crop plants. The importance of weed control is thus crucial to the establishment of any nematode control program.

In Québec's potato production system, pearl millet as a crop rotation has been introduced to suppress *P. penetrans* population in all major production areas. Normally sown in the first week of June (frost-free period), pearl millet will rapidly become well-established at a seeding rate of 10 ton/ha. But if a cool and damp period occurs after sowing, the crop will start very slowly, and many weeds which are usually more invasive under these cooler conditions will take over rapidly and compete with the pearl millet and increase the nematode population during the rotation year. Weed control is also an important part of an IPM program to reduce competition with the main crop for water, light and nutrients. Furthermore, subsequent crops will also benefit from more effective control of *P. penetrans* and other root diseases that can decrease crop production.

Literature Cited

Ball-Coelho, B., Bruin, A. J., Roy, R. C., and Riga, E. 2003. Forage pearl millet and marigold as rotation crops for biological control of root-lesion nematodes in potato. Agronomy Journal 95:282–292.

Bélair, G., and Benoit, D. L. 1996. Host suitability of 32 common weeds to *Meloidogyne hapla* in organic soils of Southwestern Quebec. Journal of Nematology 28:643–647.

Bélair, G., Dauphinais, N., Fournier, Y., Dangi, O. P., and Clément, M. F. 2005. Effect of forage and grain pearl millet on *Pratylenchus penetrans* and potato yields in Quebec. Journal of Nematology 37: 78–82.

Bélair, G., Fournier, Y., Dauphinais, N., and Dangi, O. P. 2002. Reproduction of *Pratylenchus penetrans* on various crops in Quebec. Phytoprotection 83:111–114.

Bernard, E. C., and Laughlin, C. W. 1976. Relative susceptibility of selected cultivars of potato to *Pratylenchus penetrans*. Journal of Nematology 8:239–242.

Brown, P. D., and Morra, M. J. 1997. Control of soilborne plant pests using glucosinolate-containing plants. Advances in Agronomy 61:167–231.

Doyon, D., Bouchard, C. J., and Néron, R. 1986. Inventaire des mauvaises herbes dans les cultures du Québec (1980–1984). Principales données des relevés floristiques et agronomiques des régions agricoles. Ministère de l'Agriculture, des Pêcheries et l'Alimentation du Québec. Service de recherche en phytotechnie de Québec. Mémoire no.4: Vol. 5, Région agricole de L'Assomption (10): ix + 131 pp.

Dunn, R. A., and Mai, W. F. 1973. Reproduction of *Pratylenchus penetrans* in roots of seven cover crop species in greenhouse experiments. Plant Disease Reporter 57:728–730.

Jagdale, G. B., Ball-Coelho, B., Potter, J., Brandle, J., and Roy, R. C. 2000. Rotation crop effects on *Pratylenchus penetrans* and subsequent crop yields. Canadian Journal of Plant Science 80:543–549.

Jensen, H. J. 1953. Experimental greenhouse host range studies of two root-lesion nematodes, *Pratylenchus vulnus* and *Pratylenchus penetrans*. Plant Disease Reporter 37:384–387.

Johnson, A. W., Golden, A. M., Auld, D. L., and Summer, D. R. 1992. Effects of rapeseed and vetch as green manure crops and fallow on nematodes and soilborne pathogens. Journal of Nematology 24: 117–126.

Lancashire, P. D., Bleiholder, H., Van Den Boom, T., Langelüddeke, P., Stauss, R., Weber, E., and Witzenberger, A. 1991. A uniform decimal code for growth stages of crops and weeds. Annals Applied Biology 119:561–601.

Manuel, J. S., Reynolds, D. A., Bendixen, L. E., and Riedel, R. M. 1980. Weeds as hosts of *Pratylenchus*. Research Bulletin No. 1123, Ohio Agricultural Research and Development Center, No. 1123, Wooster, Ohio.

Olthof, T. H. A. 1980. Screening rye cultivars and breeding lines for resistance to the root-lesion nematode *Pratylenchus penetrans*. Canadian Journal of Plant Science 60:281–282.

Olthof, T. H. A. 1986. Reaction of six *Solanum tuberosum* cultivars to *Pratylenchus penetrans*. Journal of Nematology 18:54–58.

Olthof, T. H. A. 1987. Effects of fumigants and systemic pesticides on *Pratylenchus penetrans* potato yield. Journal of Nematology 19:424–430.

Olthof, T. H. A. 1989. Effects of fumigant and nonfumigant nematicides on *Pratylenchus penetrans* and yield of potato. Journal of Nematology 21:645–649.

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

Sang, J. P., Minchinton, I. R., Johnstone, P. K., and Truscott, R. J. W. 1994. Glucosinolate profiles in the seed, root, and leaf tissue of cabbage, mustard, rapeseed, radish and swede. Canadian Journal of Plant Science 64:77–93.

Seinhorst, J. W. 1950. De betekenis van de toestand van de grond voor het optreden van aanstasting door het stengelaaltje [*Ditylenchus dipsasae*) (Kühn) Filipjev)]. Tijdschrift over Plantenziekten 56:291–349.

Thies, J. L., Peterson, A. D., and Barnes, D. K. 1995. Host suitability of grasses and legumes for root lesion nematode *Pratylenchus penetrans*. Crop Science 35:1647–1651.

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

Townshend, J. L., and Davidson, T. R. 1960. Some weed hosts of *Pratylenchus penetrans* in premier strawberry plantations. Canadian Journal of Botany 38:267–273.

Vanstone, V. A., and Russ, M. H. 2001. Ability of weeds to host the root lesion nematodes *Pratylenchus neglectus* and *P. thornei*. I. Grass weeds. Australian Plant Pathology 30:245–250.

Vrain, T. C., and Dupré, M. 1982. Distribution des nématodes phytoparasites dans les sols maraîchers du sud-ouest du Québec. Phytoprotection 63:79–85.

Whitehead, A. G. 1998. Plant nematode control. CAB International: Wallingford, UK, 384 pp.