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Reproduction of *Pratylenchus penetrans* on Potato and Crops Grown in Rotation with Potato[1]

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Abstract: The relative suitability of potato and crops frequently grown in rotation with potato as hosts for *Pratylenchus penetrans* was evaluated. Suitability of rye, wheat, corn, oat, sorgho-sudangrass, and potato were compared in pot studies based on ratios of final population : initial population density and densities of nematodes in roots at harvest. Population densities increased more on potato, oat, and corn than on rye, wheat, and sorgho-sudangrass. There were no differences among the four rye cultivars or between the two oat cultivars in host suitability. Population increases were not related to root weight or consistently to nematode densities in roots. Although rye and wheat were equally suitable hosts in pot studies, *P. penetrans* increased more on wheat than on rye in a field study, indicating that reproduction was reduced or mortality was increased on rye under field conditions.

Key words: *Avena sativa*, corn, oat, population density, potato, *Pratylenchus penetrans*, reproduction, root lesion nematode, rye, *Secale cereale*, *Solanum tuberosum*, sorgho-sudangrass, *Triticum aestivum*, wheat, *Zea mays*.

Rotation of potato (*Solanum tuberosum* L.) with cereals can increase potato yield (9) and help control the Colorado potato beetle, *Leptinotarsa decemlineata* Say (29). Rotation crops such as rye, however, can also increase *Pratylenchus* spp. population densities (7,17,24). *Pratylenchus penetrans* (Cobb, 1917) Filipjev & Schuurmans-Stekhoven, 1941 is an important pest of potato (5,12,16,21,27) and is widely distributed in North America (2,3,5,7,11,22). Rotation crops that limit *P. penetrans* population densities are desirable, especially in locations such as Suffolk County, New York (Long Island), where groundwater contamination restricts nematicide applications (13,15).

Rye (*Secale cereale* L.) is the crop most commonly rotated with potato in Suffolk County, but wheat (*Triticum aestivum* L.), oat (*Avena sativa* L.), corn (*Zea mays* L.), and sorgho-sudangrass hybrids (*Sorghum bicolor* (L.) Moench × *S. sudanense* (Piper) Stapf) are also used there and in other locations in North America. Although *P. penetrans* is known to have a wide host range (23,25), data on the relative host suitability of rotation crops for this nematode are inconsistent, and information about locally produced field cultivars is unavailable. In Canadian tests of 66 cultivars and breeding lines of rye, Sangaste/Dakold and Frontier rye were among 10 cultivars supporting the least reproduction of *P. penetrans* (19). In this study, we evaluated the relative host suitability of Sangaste/Dakold, Frontier, and locally reproduced rye, as well as other crops commonly grown in rotation with potato in Suffolk County.

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MATERIALS AND METHODS

Pot experiments: Changes in *P. penetrans* population densities on nine rotation crops and potato were compared in two pot experiments, designated experiment 1 and experiment 2. The same methods were used in both experiments except that crops were planted on 25 June 1984 and were grown for 6–8 weeks in experiment 1, whereas crops were planted on 26 June 1984 and were grown for 10–13 weeks in experiment 2. Inoculum consisted of a Riverhead sandy loam soil (a coarse loamy Typic Dystrochrept, 2.7% organic matter, pH 5.2) infested with *P. penetrans*. For each replication, 20 liters soil was passed through a 1-cm-pore screen, then mixed for 3 minutes in a cement mixer. Fertilizer and lime equivalent to 45 kg/ha (1:2:1) and 2,986 kg/ha, respectively, were added (assuming a 20-cm plow depth), and soil was mixed another 3 minutes before soil samples were taken to estimate initial nematode population densities (Pi). To ensure good drainage within pots, 2 liters nematode-infested soil was mixed with 2 liters methyl bromide-fumigated sand in a twin shell blender, and the mixture was emptied into each of 10 plastic pots (17.8 cm d, 17.8 cm deep).

Pots were partially submerged in beds of fumigated sand in a shadecloth-covered screenhouse (20% shade). Treatments were oat cultivars Garry and Astro, Redcoat wheat, Burpee's Sugarsweet corn, Agway 44 sorgho-sudangrass hybrid, Superior potato, and four rye cultivars: Aroostock, Sangaste/Dakold, Frontier, and a locally (Suffolk County) reproduced common rye. Treatments were arranged in a randomized block design with eight replications containing nematodes and two replications without nematodes. A single 4-cm-d potato tuber was planted per pot, and other crops were seeded into 15 holes in the center of each pot (30 seeds per pot). Seedlings were thinned to 15 seedlings per pot 3 weeks later.

Plants were harvested by block. The number and heights of plants, their foliage dry weights, root fresh weights, root volumes, and final nematode population densities (Pf) in roots and soil were determined. The soil from each pot was passed through a 6-mm-pore screen to catch the roots. Roots were washed and chopped, and nematodes were extracted from a 2-g subsample in 40 ml water on a wrist action shaker. After 3 days on the shaker, the root suspension was placed on a Baermann pan (10) for an additional 24 hours and nematodes were counted. The sieved soil was mixed, and samples (50 cm^3 per pot) were placed in plastic vials and stored at 4–5 C. Storage times varied from 2 to 5 weeks. Nematodes were extracted from the soil for 5 days with a Baermann pan at 20–25 C. After a nematode suspension was drawn off, fresh water was added to the pan and the extraction continued another 5 days. After each nematode suspension had settled overnight at 10 C, its volume was reduced to 50 ml, the 5-day and 10-day samples were combined, and the nematodes in a 5-ml aliquot were counted. When nematodes could not be counted immediately, the suspensions were stored at 10 C for up to 2 weeks.

Field experiment comparing wheat and rye: Frontier, Aroostock, and common rye and Redcoat and Tyler wheat were tested in a commercial potato field naturally infested with *P. penetrans*. The soil was a Riverhead sandy loam (as described for the pot experiments). Following potato harvest and disking of the field in early October 1984, 370 seeds/m^2 (94 kg/ha) were broadcast and covered with soil by raking in 9-m^2 plots in a randomized complete block design with 10 replications. This is the common seeding density for most rye cultivars. A fallow treatment was planted with Astro oat which died over the winter yet provided enough cover to suppress most weed growth during the summer. Initial population densities of *P. penetrans* were estimated at planting on 11 October 1984; final population densities were estimated on 20 June 1985 when grains were mature. Ten soil cores (2.5 cm d, 15 cm deep) taken from the central 1 m^2 of each plot were composited and passed through a 6-mm-pore screen. Roots caught on the screen were chopped and mixed with the soil. Representative 50-cm^3 soil samples were stored in plastic vials at 4–5 C for 22–24 weeks before they were assayed for nematodes and processed by block. Nematodes were extracted from one 50-cm^3 sample with a Baermann pan for a total of 10 days, as described for pot experiments.

Data were transformed with natural logarithms to stabilize the variance. Relative host suitabilities of different crops were determined by comparing the multiplication factor, Pf/Pi, between groups of treatments with linear orthogonal contrasts. The treatment sums of squares from two-way analyses of variance were partitioned into linear orthogonal contrasts using SAS (8).

Results

Pot experiments: Height, foliage dry weight, and root fresh weight of nematode-

TABLE 1. Change in *Pratylenchus penetrans* numbers per pot (Pf/Pi) on crops grown for 6–8 weeks (experiment 1) or for 10–13 weeks (experiment 2).

	Experiment 1	Experiment 2
Common rye	3.0 (1.6–5.5)	6.6 (4.1–10.7)
Aroostock rye	3.9 (1.9–7.7)	7.3 (5.4–9.9)
Sangaste/Dakold rye	4.1 (1.9–8.8)	6.1 (3.8–9.7)
Frontier rye	4.0 (2.2–7.3)	7.4 (5.2–10.6)
Garry oat	5.5 (3.0–10.1)	12.4 (9.9–15.6)
Astro oat	5.3 (2.9–9.8)	12.9 (9.5–17.7)
Redcoat wheat	3.4 (1.8–6.3)	2.9 (2.2–3.8)
Sugarsweet corn	8.4 (4.9–14.5)	11.7 (7.1–19.4)
Agway 44 sorgho-sudangrass	3.8 (2.7–5.4)	3.5 (2.8–4.4)
Superior potato	15.8 (11.2–22.3)	12.7 (7.7–20.9)
Error mean square†	1.2257	1.2658
Degrees of freedom	62	63

Geometric means of total population in roots and soil and 95% confidence intervals with eight replicates.
† Antilogarithm of error mean squares from two-way analyses of variance. Error mean square and degrees of freedom adjusted because one missing value was estimated.

infected plants were similar to those of uninoculated controls (data not presented) in all experiments. Among the eight replications, Pi ranged from 3,200 to 16,200/pot (geometric mean = 6,912) for experiment 1, and from 8,600 to 17,400/pot (geometric mean = 11,393) for experiment 2. *Pratylenchus penetrans* was detected in only 4 of the 40 uninoculated pots in the two experiments. A maximum of 83 *P. penetrans* per pot was detected in these uninoculated pots.

Pratylenchus penetrans populations increased on all crops in both experiments (Table 1). The relative suitability of the crops was similar in both experiments. Linear orthogonal contrasts showed that Pf/Pi was higher on potato than the mean of all grains in both experiment 1 ($P < 0.001$) and experiment 2 ($P < 0.01$). The population increase was greater on corn than on sorgho-sudangrass in experiments 1 ($P < 0.001$) and 2 ($P < 0.0001$). The increase in population density on oat was greater than that on wheat and rye in experiment 1 ($P < 0.01$) and experiment 2 ($P < 0.0001$). In experiment 1 but not experiment 2, Pf/Pi was higher on corn and sorgho-sudangrass than on small grains ($P < 0.05$). In experiment 2, the increase in population density was greater on rye than on wheat ($P < 0.0001$) even though these crops did not differ significantly in experiment 1.

Pratylenchus penetrans numbers per gram root were higher in experiment 2 than in experiment 1 on all crops except Sangaste/Dakold rye, wheat, and sorgho-sudangrass (Table 2). Root densities were higher on potato than on grains in both experiments 1 and 2 ($P < 0.0001$ for both). Higher population densities were found in roots of small grains than in roots of corn and sorgho-sudangrass in both experiment 1 ($P < 0.001$) and experiment 2 ($P < 0.0001$). Nematodes per gram root were higher on corn than on sorgho-sudangrass in experiment 1 ($P < 0.01$) and experiment 2 ($P < 0.0001$). Numbers of *P. penetrans* per gram root were higher on oat than on rye and wheat in experiments 1 and 2 ($P < 0.0001$ for both). Rye had a root population density higher than that of wheat in experiment 2 ($P < 0.01$); nematodes per gram root of rye and wheat did not differ significantly in experiment 1. In experiment 1 the density of *P. penetrans* was slightly higher in Sangaste/Dakold rye roots than in Frontier rye roots; however, in experiment 2 the root density was higher in Frontier rye ($P < 0.07$).

Root weights of all crops except potato were higher after 10–13 weeks (experiment 2) than after 6–8 weeks (experiment 1) (Table 3). Grains had more root weight than potato in experiments 1 and 2 ($P < 0.0001$). Corn and sorgho-sudangrass had

TABLE 2. *Pratylenchus penetrans* numbers per gram root on crops grown in pots 6–8 weeks (experiment 1) or 10–13 weeks (experiment 2).

	Experiment 1	Experiment 2
Common rye	220 (158–305)	318 (174–581)
Aroostock rye	232 (157–343)	298 (197–450)
Sangaste/Dakold rye	289 (202–415)	265 (157–449)
Frontier rye	243 (167–354)	415 (248–693)
Garry oat	736 (486–1,114)	1,154 (842–1,581)
Astro oat	706 (534–935)	1,018 (691–1,499)
Redcoat wheat	268 (193–372)	180 (138–233)
Sugarsweet corn	298 (190–467)	320 (233–440)
Agway 44 sorgho-sudangrass	159 (97–260)	83 (65–107)
Superior potato	1,945 (1,138–3,325)	2,010 (1,279–3,160)
Error mean square†	1.2155	1.2542
Degrees of freedom	63	63

Geometric means and 95% confidence intervals with eight replicates.
† Antilogarithm of error mean squares from two-way analyses of variance.

more root weight than small grains in experiments 1 and 2 ($P < 0.0001$). Root weight of corn was higher than root weight of sorgho-sudangrass in experiment 1, but the reverse was true in experiment 2 ($P < 0.05$). Rye and wheat had more root weight than oat in experiments 1 and 2 ($P < 0.0001$). Although root weights of wheat and rye did not differ in experiment 1, wheat had more root weight than rye in experiment 2 ($P < 0.01$). Root volume was positively and strongly correlated with fresh root weight. The statistical significance of linear contrasts comparing root volume among the treatments closely paralleled that of root weight (data not presented).

Field experiment comparing wheat and rye cultivars: Pratylenchus penetrans population densities in field plots planted to rye were higher ($P < 0.05$) at planting in October than at grain maturity the following June (Table 4). The reverse was true for wheat ($P < 0.05$). Final population densities in plots planted to Astro oats, which died during the winter, was not significantly higher than Pi. The Pf/Pi on wheat was higher than that on rye ($P < 0.0001$). Although the Pf was higher on Redcoat than on Tyler wheat ($P < 0.05$), Pf/Pi did not differ between these cultivars. Similarly, Pf/Pi did not differ between Frontier and the other rye cultivars even though Pf was

TABLE 3. Fresh root weight (g) of *Pratylenchus penetrans*-infected crops, grown in pots for 6–8 weeks (experiment 1) or 10–13 weeks (experiment 2).

	Experiment 1	Experiment 2
Common rye	36.3 (27.5–48.0)	53.9 (40.9–71.2)
Aroostock rye	33.9 (23.3–49.2)	56.1 (43.2–72.9)
Sangaste/Dakold rye	31.7 (23.3–43.3)	52.5 (38.9–70.8)
Frontier rye	39.6 (30.5–51.3)	54.5 (41.5–71.5)
Garry oat	21.5 (16.5–28.0)	28.5 (26.0–31.1)
Astro oat	21.1 (18.4–24.1)	26.9 (24.0–30.1)
Redcoat wheat	32.1 (26.0–39.5)	79.9 (61.6–103.7)
Sugarsweet corn	105.2 (86.1–128.4)	126.2 (115.2–138.3)
Agway 44 sorgho-sudangrass	80.7 (69.8–93.4)	187.9 (152.7–231.1)
Superior potato	8.2 (6.3–10.7)	2.2 (1.4–3.3)
Error mean square†	1.0821	1.1114
Degrees of freedom	63	63

Geometric means and 95% confidence intervals with eight replicates.
† Antilogarithm of error mean squares from two-way analyses of variance.

TABLE 4. *Pratylenchus penetrans* numbers per 100 cm^3 soil in field plots at planting (11 October 1984) and 8 months later (20 June 1985), and changes in population densities (Pf/Pi).

	Pi (Oct.)	Pf (June)	Pf/Pi
Common rye	2,008 (1,158–3,482)	1,353 (747–2,452)	0.67 (0.25–1.83)
Aroostock rye	2,142 (1,513–3,031)	1,272 (659–2,453)	0.59 (0.29–1.23)
Frontier rye	1,969 (1,195–3,246)	1,662 (1,064–2,594)	0.84 (0.4–1.77)
Redcoat wheat	1,786 (968–3,298)	2,871 (1,652–4,989)	1.61 (0.59–4.38)
Tyler wheat	1,339 (512–3,501)	1,993 (1,079–3,681)	1.49 (0.41–5.43)
Astro oat	1,455 (835–2,535)	1,577 (906–2,745)	1.08 (0.48–2.47)
Error mean square†	1.3502	1.1401	1.5045
Degrees of freedom	45	45	45

Geometric means and 95% confidence intervals with 10 replicates. Soil contained root fragments.
† Antilogarithm of error mean squares from two-way analyses of variance.

slightly higher on Frontier than on Aroostock and common rye ($P < 0.10$).

DISCUSSION

Pratylenchus penetrans reproduced better on Superior potato than on any of the grain crops tested except Astro oats in experiment 2. Potato had less root fresh weight than the grains in all the pot experiments, but the population densities in roots were extremely high. Superior is an early-maturing potato cultivar, and in our experiments this cultivar had much less root fresh weight after 10–13 weeks (experiment 2) than after 6–8 weeks (experiment 1) in both nematode-infested and uninfested soil. Although the number of *P. penetrans* per gram potato root was higher in experiment 2 than in experiment 1, the root mass was so small in experiment 2 that the ratio of Pf/Pi was smaller in the 10–13-week experiment than in the 6–8-week experiment. Pf/Pi was also low when Superior was grown in field microplots for 17 weeks; final *P. penetrans* population density was only 3.4 times higher than the initial population density of 2,050/kg soil (20). The decrease in potato root mass with time, especially in early-maturing cultivars, may explain why *P. penetrans* population densities in commercial potato fields were lower following potato than following rye or wheat (7).

Our experiments showing that sorghosudangrass was generally a poor host for *P. penetrans,* are in agreement with several other studies on *Sorghum* spp. (sorghum, sudangrass, and sorgho-sudangrass hybrids). In both field and pot experiments, *P. penetrans* reproduced less on the sorghosudangrass hybrid Zulu than on Black Winter rye (4). Others have found that oat is more suitable than some *Sorghum* spp. as a host of *P. penetrans.* In one 10-week greenhouse test, only 23% of the initial *P. penetrans* population was recovered from Piper sudangrass root systems, whereas the population density in oat root systems had increased 796% (14). Similarly, in a 13-week greenhouse experiment, oat was a more suitable host than sorghum for *P. penetrans* (18), but in these tests *P. penetrans* populations did not decrease on sorghum as they had on Piper sudangrass. Bird (1) and Dunn and Mai (6) both found that sorghum and its relatives are poor hosts for *P. penetrans* in pot experiments. However, *P. penetrans* reproduced more on a sorgho-sudangrass hybrid (cultivar Zulu) than on resistant oat (cultivar Saia) in both field and pot experiments (4).

Most researchers have found that corn cultivars are good hosts for *P. penetrans* (5,18). In our experiments, the number of *P. penetrans* per 100 cm^3 soil planted to Sugarsweet corn was never less than 278, and total population was always greater on corn than on the four rye cultivars we tested.

Like potato, oat had greater numbers of *P. penetrans* per gram root but less root mass than rye and wheat. The root mass of oat, however, did not decrease over time. Although oat had only half as many nematodes per gram root as potato in experiment 2, the total population per pot was as high on oat as on potato (Pf/Pi = 12.9). Olthof (18) also showed that *P. penetrans* reproduces well on dormoat (*Avena sativa* L. cv. 0A422), with Pf/Pi from 27.9 to 4.2, depending on Pi. Data from the field experiment confirmed that oat is a good host for *P. penetrans*. The relatively high initial populations were maintained on oat, even though they were winter killed after only 3 months of growth.

Relative host suitability of rye and wheat did not differ when grown for 6–8 weeks (Table 1). In an 8-week greenhouse experiment, Dunn and Mai (6) also found that wheat and rye were equally good hosts (Pf/Pi = 4.44 and 3.51, respectively) for *P. penetrans* when plants were grown from August until October. Rye was a better host than wheat in a similar experiment they conducted from November to January when light was quite different (6). However, the Pf/Pi ratio was much higher on wheat than on rye in our field experiment. Nematicidal substances occur in decomposing rye (26,28) and they may have suppressed *P. penetrans* in the field or during sample storage. Though previous observations (19) indicated Frontier and Sangaste/Dakold ryes were relatively unsuitable for *P. penetrans* reproduction, these ryes were similar to commonly grown ryes (common rye and Aroostock rye) in Pf/Pi ratios, *P. penetrans* densities in roots, and root mass.

As increases in *P. penetrans* populations were not directly related to population densities in roots or to total root populations, evaluation of the suitability of hosts for *P. penetrans* should be based on increase in total populations. Where *P. penetrans* causes losses in potato, our examination of relative host suitability suggests that rye, wheat, and sorgho-sudangrass would be better rotation crops than oat or corn.

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