Cover Crops Resistant to Root-lesion Nematodes in Raspberry

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Abstract. Cover crops used in red raspberry plantings (*Rubus idaeus* L.) are often good hosts of the root-lesion nematode (*Pratylenchus penetrans* Filipjev & Sch. Stekoven), a major soilborne pathogen of raspberry. The effects of two susceptible cover crops, white clover (*Trifolium repens* L.) and barley (*Hordeum vulgare* L.), planted in between rows, on nematode density and growth of raspberry plants were compared to those of three cover crops resistant to the nematode: redtop (*Agrostis alba* L.), creeping red fescue (*Festuca rubra* L.), and 'Saia' oat (*Avena sativa* L.). Nematode multiplication in raspberry roots and in cover crop roots was assessed over 4 years. Growth and vigor of plants were estimated at the end of the experiment by counting primocanes and determining height and biomass. Nematode multiplication was suppressed in roots of 'Saia' oat, fescue, and redtop compared to barley or white clover. Nematode density in roots and rhizosphere soil of raspberry was not affected by the choice of cover crops. Nematode suppression in the three resistant cover crops did not translate into increased vigor of raspberry plants.

Cover crops are used in red raspberry plantings to minimize soil erosion, reduce competition from weeds and the need for weed control, increase soil organic matter, and provide a habitat for beneficial arthropods. However, permanent covers can also compete with the raspberry plants for soil water and nutrients and subsequently reduce yields (Allott, 1970; Catzefflis et al., 1987). Chamberlain and Crandall (1979) observed that a cover of red fescue or ryegrass (*Lolium perenne* L. cv. Manhattan) between raspberry rows caused a decrease in cane growth and fruit yield one year but not the next, after irrigation and fertilization regimes were adjusted to compensate for competition from the cover crop. Sanderson and Cutcliffe (1988) found that a continuous grass sod lowered raspberry yields by 25% when compared to soil cultivation, whereas cultivation until harvest and then planting oats did not lower yields.

The root-lesion nematode is a soilborne pest of raspberry plantings in the Pacific Northwest and most other producing regions (McElroy, 1972; Vrain et al., 1994, 1996). Raspberry transplants are so susceptible to this nematode that infested fields must be fumigated before planting (McElroy, 1977). The host status of cover crops for the root-lesion nematode has been assessed in greenhouse (Dunn and Mai, 1973; Ingham and Kaufman, 1992; Townshend, 1989; Townshend and Potter, 1976) and field experi-

ments involving apple (*Malus domestica* Borkh.) (MacDonald and Mai, 1963; Marks and Townshend, 1973; Merwin and Stiles, 1989) and raspberry (Edwards et al. 1994; Townshend et al., 1984). These earlier studies did not always specify the cultivar of cover crop tested, but it has recently been shown that grain crops like oat or rye (*Secale cereale* L.), which are normally excellent hosts for this nematode, have some resistant cultivars that restrict multiplication of the nematode (Kaufman, 1995; Townshend, 1989). Most of these studies determined whether particular cover crops could be used to reduce nematode density in soil before planting a susceptible crop. These earlier studies also did not consider the effects of cover crops planted between rows of an established perennial crop. Furthermore, it was not determined whether changes in crop growth were the indirect result of changes in nematode parasitism or the direct result of competition with the cover crop for water and nutrients.

Barley is traditionally used as a temporary cover crop in raspberry plantings in British Columbia, mostly to prevent soil erosion and increase soil organic matter content. It is planted between raspberry rows in August, immediately after fruit harvest, and grows in late summer and fall. The barley plants are killed during the winter and the remains are left as mulch or are disked under in the spring. Unfortunately, barley is a very good host of the root-lesion nematode, which multiplies to high densities in the roots. Since barley promotes nematode multiplication in the proximity of raspberry roots, its use as a cover crop could increase parasitic pressure by the nematode on the raspberry plants, thereby decreasing vigor and lowering fruit yield.

The objective of this study was to determine whether cover crops other than barley could be used advantageously between rows of raspberries. The cover crops chosen showed a distinct advantage in previous studies. Redtop, creeping red fescue, and 'Saia' oat all had suppressed nematode multiplication (Edwards et al., 1994; Townshend, 1989), while white clover, although a good host of the nematode, had increased raspberry yields (Bowen and Freyman, 1995; Freyman, 1989). The direct effects of the cover crops on raspberry growth and vigor, and indirect effects through nematode suppression, were compared to those of barley.

Materials and Methods

A 4-year experiment was set up at the Abbotsford (British Columbia) experimental farm of the Pacific Agriculture Research Centre of Agriculture and Agri-Food Canada. The design was a randomized complete block with six treatments (five cover crops plus a control) in each of five blocks. Each cover crop plot (9 × 6 m) had a row of 'Willamette' raspberry in the middle, bordered by a guard row of 'Willamette' raspberry on each side, for a total of 13 rows per block. Each row consisted of 18 plants 50 cm apart planted in a 40-cm-wide strip left clear of any cover when the experiment was established (28 Mar. 1990).

Cover crops were seeded (28 Mar. 1990) as a solid planting (9 × 2.60 m) on each side of the center row of raspberry. The cover crops were: 'Canada #1' redtop; 'Roland 21' creeping red fescue; 'Saia' oats; 'Galt' barley; and 'New Zealand Dwarf' white clover. The control plots had no ground cover, and were rototated as necessary to prevent excessive weed growth. The soil was a well-drained sandy loam with 7.5% organic matter, pH 5.3 to 5.7, infested with root-lesion nematodes. Cultivation, thinning, pruning and training of raspberry canes, fertilization, and disease and insect control measures were uniformly applied, when required, according to local recommendations (British Columbia Ministry of Agriculture, 1992). Weeds were controlled as necessary by hand and hoe weeding.

Nematode density (number/50 mL soil) in each plot was determined 3 weeks before planting to ensure that there were no significant differences in initial nematode densities between plots. Densities in rhizosphere soil and root samples of each cover crop and of the raspberry plants were determined by sampling the central eight plants of each plot and adjacent covers during the next 3 years: 28 Nov. 1990; 10 Apr., 6 Aug., and 26 Nov. 1991; 17 Mar. and 3 Nov. 1992; and lastly on 12 May 1993. Ten cores of soil (2 cm in diameter) were taken to 25 cm deep in each raspberry row,

Table 1. Analysis of variance of log₁₀ transformed root-lesion nematode densities in soil before treatment (Mar. 1990).

Source of variation	df	Mean square
Future cover crop	5	0.0079
Block	4	0.0200
Error	20	0.0169

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within 20 cm of the center of rows, and in each adjacent cover crop. Pieces of roots in each soil sample were washed of soil and weighed. Nematodes were extracted from each root fraction for 7 days in a misting chamber at 25 °C (Seinhorst, 1956), and extracted from 50 mL of soil of each sample in Baermann pans for 7 days (Townshend, 1963).

Nematode counts were transformed to $\log_{10}(x + 100)$ before analysis of variance (ANOVA) to correct for heterogeneity of variance (Proctor and Marks, 1974). Nematode counts measured in the soil in Mar. 1990, before treatment, were tested by ANOVA to ensure that there were no pretreatment differences. The effect of the cover crops on nematode densities in soil and roots were tested by ANOVA with the eight dates of sampling as repeated measures. The F tests for the sources of variation involving dates were corrected using the Greenhouse–Geisser adjustment (Littell, 1989). Biomass of raspberry primocanes was measured 7–8 Mar. 1994. The number of primocanes per plant, height of each cane, diameter at 50 cm height, and weight of each cane were recorded. The effects of the cover crops on the raspberry cane variables were tested by ANOVA. Correlations were calculated among the log-transformed nematode densities separately for the three spring (Mar. 1991, Mar. 1992, May 1993) and the three fall samples (Nov. 1990 through 1992) because relationships may differ at the two seasons of

the year. Correlations also were calculated between the log-transformed nematode densities in May 1993 and the raspberry fruiting cane variables measured in Mar. 1994.

Results and Discussion

There were no significant differences in nematode density in soil among plots before seeding in Mar. 1990 (Table 1). The use of resistant cover crops had no significant impact on the nematode density in roots and rhizosphere of adjacent raspberry plants (Tables 2 and 3). The nematode densities in cover crop soil and roots varied among cover crop species (Table 2). ‘Saia’ oats, creeping red fescue, and redtop usually supported a fraction of the nematode densities found in barley roots and rhizosphere soil. These differences changed detectably with time, i.e., there were cover crop $\times$ time interactions (Table 3). Weeds were not completely controlled in the control plots and the root-lesion nematode multiplied to extremely high counts on certain weed species. Correlations among nematode densities in soil or roots of cover crops and of raspberries in the spring or the fall sampling were calculated. Many such correlations were significant, more so in the fall than in the spring, during the 4 years of the study (Table 4).

Our finding confirms previous observations (Powlowski, 1991), where a nematode

population having reached equilibrium in roots and rhizosphere soil of a perennial crop was not necessarily influenced by a nematode suppressive cover crop. Marigolds (*Tagetes patula* L.) nearly eradicated root-lesion nematodes from infested apple orchard soil, but they had no significant effects on nematode density in roots of established young trees (unpublished data).

Yield of raspberries is determined by the vigor and health status of the plants in the previous year. Growth measurements taken in Mar. 1994 on primocanes likely reflect parasitic pressure on the raspberry plants in 1993. Measurement of height and diameter of canes gives a good estimate of yield, since cane height is correlated with cane diameter and both are correlated with yield (Crandall et al., 1974). There were detectable differences among cover crops in total mass but not in total number of fruiting raspberry canes (Table 5). Fruiting canes tended to be largest with the control cover and smallest with the fescue cover as measured by average cane mass, height, and diameter. Given the design of the experiment, it was not possible to determine whether the cover crops affected the raspberry plants directly through allelopathy or competition for soil water and nutrients, or indirectly through increasing or decreasing parasitic pressure from nematodes. Correlations between densities of root-lesion nematodes in May 1993 and raspberry plant variables did not

Table 2. Density of root-lesion nematodes in rhizosphere soil and roots of raspberry and adjacent cover crops at various times during 3 years.

Cover crop and location	Density of root-lesion nematodes (counts) at time indicated								
	Mar. 1990	Nov. 1990	Apr. 1991	Aug. 1991	Nov. 1991	Mar. 1992	Nov. 1992	May 1993	Mean
<i>Raspberry soil²</i>									
None	143	1061	495	1244	822	861	503	372	765
Barley	106	754	491	1214	824	756	229	287	651
White clover	108	616	497	1471	969	1013	301	312	740
Oats	124	716	847	1216	919	728	173	290	699
Red fescue	99	755	483	1099	778	737	227	246	618
Redtop	73	705	364	1136	790	937	211	347	642
RSE ³	0.13	0.13	0.11	0.14	0.14	0.12	0.18	0.22	0.07
<i>Raspberry roots²</i>									
None		3618	2820	3597	4009	1680	1654	1434	2687
Barley		2957	3461	4515	4366	1910	4164	2443	3402
White clover		4896	1737	8578	4839	1934	1718	1029	3533
Oats		5253	3131	3211	3248	1889	1643	1557	2847
Red fescue		15193	3344	3285	1024	1609	1040	1075	3796
Redtop		3714	3657	2944	5080	1612	976	980	2709
RSE ³		0.34	0.26	0.39	0.41	0.45	0.34	0.20	0.20
<i>Cover crop soil²</i>									
None (weeds)		344	238	119	171	131	177	153	190
Barley		333	398	465	228	364	203	437	347
White clover		1149	469	1707	1349	564	590	456	897
Oats		57	107	291	104	100	58	135	122
Red fescue		261	163	94	101	93	96	52	123
Redtop		149	117	142	201	134	84	66	128
RSE ³		0.09	0.11	0.17	0.14	0.22	0.36	0.20	0.07
<i>Cover crop roots²</i>									
None (weeds)		4608	59300	1492	1988	2080	5537	1974	15461
Barley		4570	6886	6936	4365	6799	5039	8067	5988
White clover		6432	8486	2702	6282	3858	3346	3913	5002
Oats		1156	1725	2465	837	275	762	2904	1462
Red fescue		2391	1101	164	343	342	358	316	716
Redtop		996	460	268	1038	478	169	157	508
RSE ³		0.30	0.53	0.40	0.43	0.36	0.36	0.35	0.27

²Nematode count (all juvenile and adult stages) per 50 mL of rhizosphere soil.

³Relative standard error (the standard error of a mean is: mean $\times$ RSE).

⁴Nematode count (all juvenile and adult stages) per gram of fine roots.

point to an effect of the nematodes in cover crop roots or soil on the growth of the raspberry plants (Table 6). Moreover, the correlations that are significant, when positive, suggest an indirect effect of the cover crops confounded with a nonsignificant nematode effect (Table 6).

Barley, a good host for the nematode, was used as the standard for comparing the effects of potential alternative cover crops. Creeping red fescue and redtop depressed raspberry cane growth, compared to barley and oat. The two grasses were chosen for this experiment because they suppressed the nematode in earlier research in apple orchards (Edwards et al., 1994). In that study and others, marigolds suppressed root-lesion nematode better than other covers, but grew too slowly and required too much handweeding to establish effectively. Freyman (1989) found that a continuous cover of white clover stimulated raspberry growth compared to barley, although these results were not confirmed in our experiment. Other studies with cover crops in raspberry have demonstrated competition and lower yields from perennial ryegrass (Chamberlain and Crandall, 1979), timothy (*Phleum pratense* L.) (Sanderson and Cutcliffe, 1988), and other grasses (Catzefflis et al., 1987). Since most plantings of raspberry are infested with the root-lesion nematode, it is possible that a nematode effect was not accounted for in some of the earlier studies.

Many weeds are good hosts of the root-lesion nematode (Townshend and Davidson, 1960). In this experiment, the root systems of various weeds growing in the control plots supported many nematodes, but without any apparent effect on the nematode density in the roots or vigor of adjacent raspberry plants. The mass, diameter and number of canes was higher in the control plots than in the creeping red fescue and redtop plots, where nematode multiplication was suppressed. There may have been a combination of effects of competition for water and nutrients from the resistant cover crops, and of nematode suppression. If so, the latter effect was weaker than the former and the net effect was that raspberry growth was not affected positively by the resistant cover crops.

This study has shown that the use of resistant cover crops had no significant effect on nematode density in roots and in the rhizosphere of adjacent raspberry plants. While it is well established that resistance to root-lesion nematode is an important factor in the choice of a cover crop to reduce the nematode population before planting, it should not necessarily be the primary factor driving the choice of cover crops planted in between rows of established raspberry.

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British Columbia Ministry of Agriculture, Fisheries

Table 3. Mean squares for repeated measures analyses of variance of log₁₀ transformed root-lesion nematode densities, Nov. 1990 to May 1993.

Source of variation	df	Raspberries		Cover crops	
		Soil	Roots	Soil	Roots
Cover crop	5	0.050	0.161	1.996**	5.964**
Block	4	0.038	0.044	0.155	0.208
Error A	20	0.021	0.164	0.027	0.116
Date	6	1.374**	1.267**	0.175**	0.656**
Date × cover crop	30	0.022	0.134	0.077**	0.315*
Date × block	24	0.019	0.159	0.026	0.134
Error B	120	0.022	0.015	0.024	0.149
Epsilon ²		0.553	0.631	0.629	0.464

²Greenhouse-Geisser epsilon.

*,**Significant at $P \leq 0.05$ or 0.01, respectively.

Table 4. Correlations among densities² of root-lesion nematodes in spring (Apr. 1991, Mar. 1992, May 1993), and fall (Nov. 1990 through 1992).

	Raspberry roots	Cover crop soil	Cover crop roots
Spring			
Raspberry soil	0.10	0.15	0.03
Raspberry roots		0.09	0.24*
Cover crop soil			0.60**
Fall			
Raspberry soil	0.35**	0.33**	0.27*
Raspberry roots		0.19	0.38**
Cover crop soil			0.60**

²Transformed to log₁₀ (x + 100).

*,**Significant at $P \leq 0.05$ or 0.01, respectively (df = 88).

Table 5. Effect of cover crops on raspberry fruiting cane count, biomass, and mean height and diameter, Mar. 1994.

Raspberry canes					
Cover crop	Total mass ^z (g)	Count ^y	Mass (g)	Ht (cm)	Diam (mm)
None	1670	43.6	38.5	234	7.2
Barley	1630	51.8	32.0	223	6.7
White clover	1100	40.4	27.2	205	6.2
Oats	1770	48.8	37.0	223	6.4
Red fescue	750	26.4	28.3	182	5.3
Redtop	820	30.8	27.9	199	5.9
SE	235	6.93	1.86	5.65	0.23
<i>Analysis of variance</i>					
Source of variation	df				
Cover crop	5	104*	499	120**	1837**
Block	4	32	382	41	161
Error	20	28	240	17	160

²Total mass of canes per plot.

³Number of canes per plot.

*Values in this column are to be multiplied by 10⁴ to give correct total weight mean squares.

*,**Significant at $P \leq 0.05$ or 0.01, respectively.

Table 6. Correlations between densities of root-lesion nematodes in May 1993, and raspberry fruiting cane biomass and count, and mean mass, height and diameter in Mar. 1994.

Location	Nematode density ²				
	Total mass ² (g)	Count ³	Mass (g)	Ht (cm)	Diam (mm)
Raspberry soil	-0.12	0.22	0.24	-0.01	-0.16
roots	0.25	0.26	0.12	0.42*	0.47**
Cover crop soil	0.17	0.21	0.03	0.24	0.20
roots	0.51**	0.49**	0.25	0.48**	0.38*

²Transformed to log₁₀ (x + 100).

*,**Significant at $P \leq 0.05$ or 0.01, respectively (df = 28).

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