Decline of Rhizoctonia Root Rot on Wheat in Soils Infested with *Rhizoctonia solani* AG-8

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ABSTRACT

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Soils collected from two sites were used for up to six successive plantings of wheat in the greenhouse. Soils were infested before each of the first four plantings with *Rhizoctonia solani* AG-8 or *R. oryzae*, or left non-infested. *R. solani* stunted seedlings during the first planting. After a second or third crop, depending upon the soil origin, shoot weights were significantly higher in infested soils than in controls. Shoot growth was never suppressed when soils were infested with *R. oryzae*. Disease suppressiveness tests performed during a fifth crop demonstrated that successive plantings of wheat into soils infested with *R. solani* AG-8 caused a decline of the disease. Both a susceptible host (wheat) and virulent pathogen (*R. solani* AG-8) were necessary to achieve disease suppressiveness. In contrast, *R. oryzae* did not induce soil suppressive to *R. solani*. Induction of Rhizoctonia root rot decline occurred earlier in tilled than nontilled soil, and rates of applied nitrogen had little effect on decline.

Additional keyword: *Triticum aestivum*.

Rhizoctonia root rot is an important disease of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) in Australia (7), South Africa (3), and the United States (19) and has been reported in England (4) and Scotland (11) as well. When most severe, this disease appears in the field as patches of stunted plants resulting from root rot caused by *Rhizoctonia solani* Kühn. Rhizoctonia root rot causes significant constraints to yield of wheat and barley in the Pacific Northwest region of the United

States (13,18,19). Although a complex of two *Rhizoctonia* species and several intraspecific groups is associated with the disease in the Pacific Northwest (12), the dominant and most virulent species appear to be *R. solani* AG-8 and *R. oryzae* Ryker & Gooch.

Severity of Rhizoctonia root rot is greater when the crop is sown by direct drilling ("no-till") than when sown after cultivation (10,13,19). In greenhouse experiments, disease is more severe on soils collected from the field as intact cores than soil mixed during collection (9). Whether this response to soil disturbance results from a decline in pathogen survival and/or pathogenicity remains unclear.

Soil suppressiveness to *R. solani* has been documented. Five successive weekly plantings of radish (*Raphanus sativus*)(6) and cucumber (*Cucumis sativus*) (8) led to suppression of damping-off caused by *R. solani*. Suppressiveness to *R. solani* did not occur in similar experiments with sugarbeet (*Beta vulgaris* L.), alfalfa (*Medicago sativa* L.), or wheat (8). Each of these experiments was performed with the same isolate of *R. solani* AG-4 (6,8). Disease incidence for radish, cucumber, sugarbeet, and alfalfa was assessed as the percentage of seedling damping-off. Wheat sustained only superficial brown discoloration of cortical tissue and was not killed (8), which presumably indicated a lack of virulence of this isolate on wheat.

Experiments presented in this paper were designed to determine whether suppressiveness to Rhizoctonia root rot of wheat could be induced by either the highly virulent *R. solani* AG-8 or the weakly virulent *R. oryzae*. We also examined the importance of soil cultivation, nitrogen fertilizer, and the presence of the host for induction of soil suppressiveness to Rhizoctonia root rot.

MATERIALS AND METHODS

Soils. A Walla Walla silt loam (coarse-silty mesic Typic Haploxeroll) was collected from two sites. This soil is deep (>100 cm to basalt or hardpan) and well drained. One soil was collected at the Thompson farm 24 km north of Pendleton, OR, where mean annual precipitation is 350 mm. The pH of the surface 10 cm of soil was 6.3 (in 0.01 M $CaCl_2$). Samples were collected after harvest from a field in which spring barley was produced annually from 1986 to 1990. Segments of the field were managed either with annual tillage by moldboard plow and disk or without tillage (no-till). Herbicide use on each tillage sequence had been uniform. Samples were taken from adjacent (not replicated) locations that represented each tillage system.

The second soil was collected from a tillage × nitrogen fertilizer experiment at the Columbia Basin Agricultural Research Center (CBARC) 13 km northeast of Pendleton, where mean annual precipitation is 430 mm. The CBARC soil had a pH of 5.3–5.6. This experiment has been conducted continuously in a wheat-fallow rotation since 1940 (14); wheat was harvested every odd-numbered year. Samples were collected from soil with standing stubble during autumn, 1989, before the plots were tilled in preparation for summer fallow to be followed by a wheat crop. Soils were collected from plots tilled with a moldboard plow and disk (23-cm depth) and from plots tilled with a subsurface sweep (15-cm depth, considered here as no-till). Soil samples that represented each tillage variable were collected from plots treated with one of three rates of fertilizer (0, 90, or 180 kg N/ha) during the summer prior to seeding wheat. Although the plots had been treated with 0, 90, and 180 kg N/ha since 1989 (one crop year), earlier application rates were 0, 11, and 11 kg N/ha from 1941 to 1952 (six crop years); 0, 34, and 34 kg N/ha from 1953 to 1962 (five crop years); and 45, 90, and 180 kg N/ha from 1963 to 1988 (13 crop years). Herbicide use on each tillage × nitrogen combination had been uniform.

Intact soil cores (8-cm diameter × 13-cm high) were removed from each field or plot. Cores were collected with a sampler (17) in which cylinders made from plastic drain tile were inserted into the sampling tube prior to insertion into the soil. A plastic plate was placed under each soil core to retard evaporative water loss from the bottom of the soil column.

Experiments with Thompson soil. Forty-eight cores of soil (24 from tilled and 24 from nontilled areas) were collected at the Thompson farm. Cores from each tillage system were divided into three subtreatments (eight cores each for six subtreatments) by infesting them with *R. solani* AG-8, *R. oryzae*, or neither pathogen. The pathogens were grown on millet seeds that had been autoclaved twice for 30 min at 120 C at a 24-h interval, infested, incubated for 4 wk at 22 C, and air-dried. Four millet seeds were inserted to 6-cm depth by dropping them into 2-mm-diameter holes bored vertically into each soil core. Millet seed was not applied in cores in noninfested treatments. Five grains of winter wheat cv. Stephens were then seeded at 2-cm depth and spaced equidistantly from the millet seeds in each core. A similar arrangement was used in the noninfested controls. Plants were grown in the greenhouse under conditions favorable to virulence of both pathogens (12): 20–28 C, 12-h photoperiods, photon flux densities of 120–180 $\mu mol \cdot \cdot s^{-1} m^{-2}$ at plant height during the light period, and watered every 2 days to approximately −100 J/kg matric potential, based upon the initial weight of each core and moisture retention relationships for the soil. After 33 days, plants were cut at soil level and assessed individually for Haun growth stage (2,5) and height and collectively for shoot dry weight for each core. Immediately after harvest, soil with roots in each tilled-soil core was mixed thoroughly and placed back into the same core. Nontilled soil remained in the cores, without mixing. Tilled and nontilled soils were then reinfested and recropped three more times, with plant growth periods ranging from 34 to 39 days. No fertilizer was applied during the experiment, as deficiency symptoms were not observed.

Four of the eight cores (four replicates) in each of six tillage × pathogen subtreatments examined in crops 1–4 were infested with *R. solani* AG-8 and planted to a fifth crop of wheat. Thirty-nine days after plant emergence, soil was washed from roots, and percentages of coronal roots with cortical necrosis and/or severance (characteristic "spear tip" symptom) from Rhizoctonia rot were determined. Plants and soils were discarded, terminating this phase of the experiment.

The remaining 24 cores (four replicates of six tillage × pathogen treatments) examined in crops 1–4 were also cropped a fifth time but were reinfested or not infested with the same pathogen treatments used during the first four crops. Thirty-nine days after plant emergence, the foliage was removed, and the soil, wheat crowns, and roots from four pots in each treatment were composited and mixed for further testing.

A disease suppressiveness test (crop 6) was performed with mixtures of soil, wheat crowns, and roots remaining from crop 5. Mixtures from each of six previous tillage × pathogen treatments was placed into 12 plastic tapered tubes (21 × 4 cm; Ray Leach Cone-Tainer, Canby, OR). Six tubes (six replicates) served as controls, and the remaining six tubes for each mixture treatment were infested with three millet seeds colonized by *R. solani* AG-8. Each infested mixture had a millet seed placed 3, 6, and 9 cm below the wheat seed. Disease was assessed after 30 days by measuring the lengths of coronal roots that exhibited or did not exhibit symptoms of Rhizoctonia root rot and calculating the percentage of coronal root length affected by the pathogen.

Experiments with CBARC soil. The field experiment from which soil was collected for this experiment contained three replicates for each of six tillage × nitrogen combinations: 0, 90, and 180 kg N/ha in tilled or nontilled soil. Thirty cores were taken from each replicate of each field treatment (90 cores/treatment × six treatments = 540 cores total). Ten cores from each replicate of each field treatment were grouped (180 cores total) as three subtreatments for the greenhouse experiment. Subtreatments used cores infested with *R. solani* AG-8, *R. oryzae,* or neither pathogen, as described previously. Each tillage × nitrogen × pathogen combination contained 30 cores. Four crops of wheat were grown in the CBARC soil, as described previously for the Thompson soil. However, the experimental technique for this experiment differed from that for the Thompson soil in that 1) half of the cores (15 pots) in each tillage × nitrogen × pathogen combination were planted with wheat, and the other half were not planted

TABLE 1. Analysis of variance for shoot weights (mg/plant) in four successive wheat crops planted in cores of soil from the Columbia Basin Agricultural Research Center (CBARC) and Thompson sites

Source of variation	df	Mean squares			
		Crop 1	Crop 2	Crop 3	Crop 4
Thompson soil					
Pathogen	2	398.65**[z]	424.39*	1,602.61**	1,661.22**
Replication	7	568.08**	301.81	191.82	203.16
Main plot error	14	36.95	84.43	91.65	49.64
Tillage	1	3,495.25**	220.16	1,166.24	2,030.60**
Pathogen × tillage	2	92.92	615.78	1,451.65*	31.32
Residual error	21	124.42	197.39	294.26	180.89
CBARC soil					
Pathogen	2	5,398.86**	42,629.76**	14,125.48**	9,436.53**
Replication	14	305.60	602.30	855.41	630.52
Main plot error	28	467.22	503.04	368.84	551.90
Tillage	1	738.11	3,996.67**	4,312.05**	12,446.73**
Nitrogen	2	13,653.36**	6,074.98**	8,054.60**	4,319.90**
Pathogen × tillage	2	494.46	3,423.72**	5,582.17**	760.93
Pathogen × nitrogen	2	541.33	346.73	2,136.25**	1,373.09**
Tillage × nitrogen	2	688.22	1,370.83**	3,109.66**	982.21
Pathogen × tillage × nitrogen	4	134.32	293.27	1,613.35**	433.21
Residual error	210	303.61	276.37	270.06	365.98

[z] Numbers followed by ** denote significant F test at $P = 0.01$ and by * at $P = 0.05$.

but were watered and reinfested at the same time as the planted series, and 2) soil from tilled cores was not removed or mixed between successive croppings.

During the fifth crop, 12 of the 15 cores in each tillage × nitrogen × pathogen combination, including cores from the previously unplanted series, were planted. Six of the 12 cores in each treatment were infested with *R. solani* AG-8 and six cores were not infested. Soil was washed from roots at the end of the test, and percentages of coronal roots with cortical necrosis and/or severance were determined.

Data analysis. Cores were arranged as a split-plot design for the experiment with Thompson soil (main plot = pathogen, subplot = tillage), as a split-plot factorial design for CBARC soil (main plot = pathogen, subplot = tillage × nitrogen) during crops 1–4 and as a randomized factorial design for CBARC soil during crop 5. Data were tested for homogeneity of variances, transformed when necessary, and analyzed by ANOVA. Main-effect means were compared by the Student-Newman-Keuls test. Contrasts were used as a test to identify significant differences between means of significant first-order interactions between treatments.

RESULTS

Influence of *R. solani* and *R. oryzae* on biomass of four successive wheat crops in Thompson soil. Infesting soil with *Rhizoctonia* species caused significant effects on final biomass of wheat shoots during all four crop sequences (Table 1). A significant pathogen × tillage interaction also occurred during crop 3 (Table 1). *R. solani* resulted in an initial suppression of shoot weight compared with the noninfested controls (−11% for crop 1, −17% for crop 2) (Table 2). During the third crop, shoot weight was significantly greater in tilled soil infested with *R. solani* than in tilled soil that had not been infested (Table 3). Shoot weights were not affected by *R. solani* in nontilled soil (Table 3). No interaction between tillage and pathogen was observed during crop 4 (Table 1), and shoot weight was significantly greater in *R. solani*-infested soil than in the control (Table 2). Ratios of shoot weights for plants growing in *R. solani*-infested versus noninfested soils were nearly always greater in tilled than nontilled soils (Fig. 1), and the ratios generally became larger with successive plantings. Similar relationships were observed for shoot height and developmental stage (Fig. 1).

Plant biomass in soils infested with *R. oryzae* was always similar to biomass in the controls (Tables 2 and 3).

Disease suppressiveness of Thompson soil (crops 5 and 6). Analysis of variance of percentages of coronal roots affected by Rhizoctonia root rot for the fifth crop in Thompson soil showed a significant interaction ($P = 0.05$) between infesting soil during crops 1 to 4 and tillage (*variance table not shown*). Symptoms of Rhizoctonia root rot were present on 63 and 37% of the coronal roots in the tilled and nontilled treatments, respectively, in cores

TABLE 2. Shoot weights of four successive wheat crops[y] planted in cores of soil from the Columbia Basin Agricultural Research Center (CBARC) and Thompson sites and infested with supplemental *Rhizoctonia solani* AG-8, *R. oryzae*, or neither

Site / Pathogen	Shoot weight (mg/plant)			
	Crop 1	Crop 2	Crop 3	Crop 4
Thompson soil				
R. solani	69.4 a[z]	49.2 a	106.7	99.9 b
R. oryzae	78.4 b	52.3 ab	91.0	83.9 a
Control	77.7 b	59.2 b	88.1	80.9 a
R. solani/control	0.89	0.83	1.21	1.23
CBARC soil				
R. solani	70.1 a	59.4	82.1	124.2
R. oryzae	82.9 b	94.7	105.2	106.4
Control	84.0 b	99.2	102.0	106.5
R. solani/control	0.85	0.60	0.80	1.17

[y] Combined means for tillage (tilled and nontilled) treatments in Thompson soil and tillage × nitrogen treatments in CBARC soil.

[z] Numbers followed by the same letter within each column, for each soil, are not significantly different ($P = 0.05$) according to the Student-Newman-Keuls test. Absence of letters, except in *R. solani*/control ratios, denotes the presence of significant pathogen × tillage interactions (detailed in Table 3), tillage × nitrogen interactions (Table 6), or nitrogen alone (Table 6).

TABLE 3. Significant pathogen × tillage interactions ($P < 0.05$) for shoot weights (mg/plant) of wheat grown in selected treatments designated in Table 2

Tillage	Pathogen		
	Rhizoctonia solani	*R. oryzae*	Control
Thompson soil[y] (crop 3)			
Tilled soil	112.7	79.8	78.5
Nontilled soil	100.7	102.3	97.6
CBARC soil[z] (crop 2)			
Tilled soil	62.6	88.0	91.0
Nontilled soil	56.2	101.3	107.3

[y] Contrast for *R. solani* vs. others in tilled soil, $P = 0.0002$; nontilled soil, $P = 0.9215$.

[z] Contrast for tilled vs. nontilled soil treated with *R. solani*, $P = 0.0638$; *R. oryzae* or no pathogen, $P = 0.0001$.

that were infested with *R. solani* for the first time during the fifth crop (Table 4). A similar range (61 and 39%) of symptoms occurred on roots from cores infested with *R. oryzae* during the first four crops. In crops infested with *R. solani* during the first four crops, the disease was greatly suppressed (7%) in tilled soil but not in nontilled soil (47%) (Table 4).

Induction of soil suppressive to *R. solani* was confirmed in the subsequent test, during which plants were grown in soil incubated in Cone-Tainers during the sixth successive wheat crop. As with the fifth crop, there was a significant ($P = 0.05$) interaction between the three factors analyzed (infesting soil during crop 6, infesting soil during crops 1 to 5, and tillage; *variance table not shown*). The least root rot, expressed as a percentage of coronal root length with necrosis, occurred in soils that were either not infested with *R. solani* (10% for tilled soil and 1% for no-till) or infested five or six times with *R. solani* (1% for tilled soils and 5% for no-till) (Table 5). Suppressiveness did not occur in the nontilled soil (33%) or in soil previously infested with *R. oryzae* (34% for tilled soil and 32% for no-till)(Table 5).

Influence of *R. solani*, tillage, and nitrogen fertilizer on biomass of four successive wheat crops in CBARC soil. *R. solani* had significant effects on shoot weight during each of the four successive crops, but also interacted significantly with other treatments during crops 2, 3, and 4 (Table 1). Infesting soil with *R. solani*-stunted plants for crops 1 and crop 2 (−15% and −40%, respectively) relative to plants grown in noninfested soil, independent of tillage or nitrogen treatment (Tables 2 and 3). The significant pathogen × tillage interaction for crop 2 (Table 1) represented differences in response to tillage for plants grown in soil infested or not infested with *R. oryzae* (Table 3) but had no bearing on growth effects caused by *R. solani*. A significant second-order interaction between pathogen, tillage, and nitrogen occurred for shoot weight during crop 3. This interaction indicated the presence of a negative effect of *R. solani* in the nontilled soil either treated with a high rate of nitrogen (180 kg of N) or not fertilized (Table 6). For all other experimental conditions, the shoot weight in soil infested with *R. solani* did not differ from that in the noninfested soils (Table 6). The pathogen treatments during crop 4 did not interact with tillage but interacted significantly with the level of nitrogen fertilizer (Table 1). *R. solani* did not affect shoot weight in nonfertilized soil but caused shoot weights to increase in soil treated with 90 or 180 kg N/ha (Table 6).

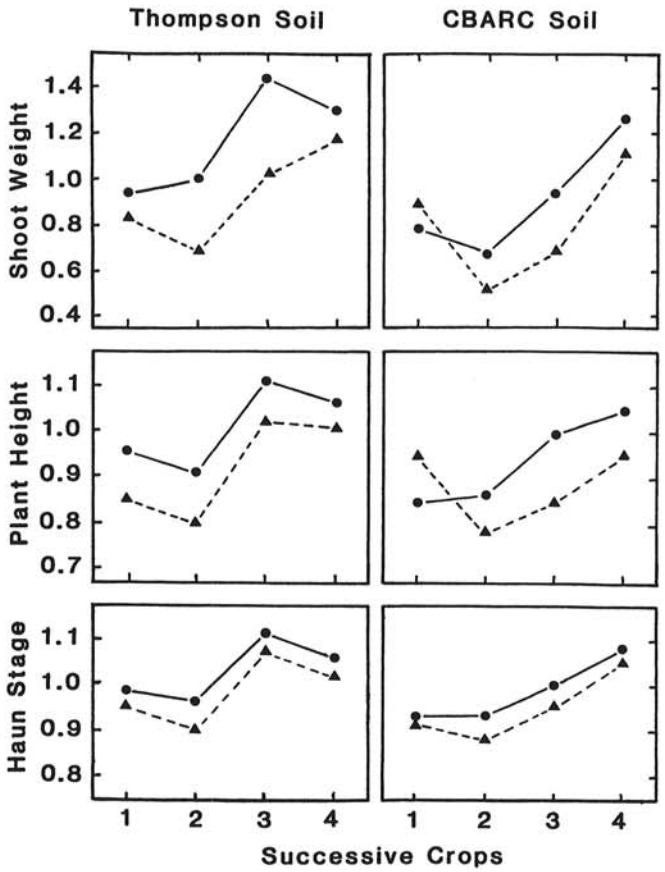

Fig. 1. Influence of *Rhizoctonia solani* AG-8 on shoot weight, height, and development of four successive crops of wheat grown in Columbia Basin Agricultural Research Center (CBARC) and Thompson soils that were either tilled (●) or not tilled (▲) expressed as the ratio of values for plants grown in soils infested or not infested with the pathogen.

TABLE 4. Percentage of coronal roots with Rhizoctonia root rot when Thompson soil was infested with *Rhizoctonia solani* before planting the fifth successive wheat crop

	Pathogen treatments in crops 1–4		
Tillage	*R. solani*[z]	*R. oryzae*	Control
Tilled soil	6.7	60.8	62.6
Nontilled soil	46.9	38.5	37.1

[z] Contrast for *R. solani* × tilled soil vs. others, $P = 0.0028$.

Disease suppressiveness of CBARC soil (crop 5). In this experiment, half of the cores from the fourth crop were infested with *R. solani*, and the other half were not infested. Wheat was planted in all cores, including those that had not been planted previously. Significant interactions for seminal and coronal root rots occurred among the following treatments: infesting soil during crop 5, infesting soil during crops 1 to 4, and planting or not planting wheat during "crops" 1 to 4 (*variance table not shown*). In soils planted throughout the experiment, disease incidence on seminal

TABLE 5. Coronal root length (%) exhibiting symptoms of Rhizoctonia root rot in Thompson soil infested or not infested with *Rhizoctonia solani* before planting the sixth successive wheat crop

	Pathogen treatments in crops 1–5[y]		
Tillage	*R. solani*	*R. oryzae*	Control
Tilled soil			
Infested[z]	0.9 (0.42)	34.1 (5.78)	10.1 (3.14)
Not infested	1.1 (0.87)	10.6 (3.04)	9.9 (2.80)
Nontilled soil			
Infested[z]	32.6 (5.35)	32.2 (4.80)	13.5 (3.67)
Not infested	5.3 (1.76)	35.2 (6.03)	0.5 (0.30)

[y] Data required square-root transformation before analysis (in parentheses); second-order interaction significant at $P = 0.0031$ (error mean square = 3.19, 24 df).
[z] Pathogen treatments for crop 6.

TABLE 6. Significant pathogen × tillage × nitrogen, or pathogen × nitrogen, interactions ($P < 0.05$) for shoot weights (mg/plant) of wheat grown in selected treatments designated in Table 2

Tillage and nitrogen rate (kg N/ha)	*Rhizoctonia solani*	*R. oryzae*	Control
CBARC soil[y] (crop 3)			
Tilled soil			
0 N	89.2	99.1	85.3
90 N	84.2	89.6	93.5
180 N	85.8	112.1	93.2
Nontilled soil			
0 N	72.4	89.2	101.6
90 N	83.2	107.4	97.8
180 N	77.7	133.7	140.7
CBARC soil[z] (crop 4)			
Nitrogen rate			
0 N	112.7	97.1	107.3
90 N	126.7	103.4	105.4
180 N	133.1	118.8	106.6

[y] Contrast for *R. solani* vs. control in nontilled soil fertilized with 0 or 180 N, $P = 0.0001$.
[z] Contrast for *R. solani* vs. control in 0 N, $P = 0.2801$; 90 and 180N, $P = 0.0001$.

roots was similar in soils that had never been infested (8%) or in those that had been infested with *R. solani* four or five times (9 and 10%, respectively) (Table 7). When *R. solani* was added to soil during the fifth crop, the incidence of root rot on coronal roots increased from 2 to 44% in previously noninfested soils, and from 8 to 61% in soils previously infested with *R. oryzae*. In contrast, disease incidence was not altered (31 and 33%) in soils infested with *R. solani* during each of four previous crops. When cores were planted for the first time (infested repeatedly but not planted during "crops" 1 to 4), disease incidence was always high on seminal (50 and 52%) and coronal (60 and 61%) roots whenever *R. solani* was introduced.

DISCUSSION

R. solani AG-8 was highly virulent to winter wheat and caused initial suppression of shoot growth and development. In contrast, *R. oryzae* did not significantly affect final dry weight and development of wheat plants. After several crops of wheat were produced in *R. solani*-infested soil, growth and development of subsequent crops were not suppressed by additional inoculum. In fact, these responses in plant growth and development were characterized over successive plantings by increasing ratios of values for plants grown in infested relative to noninfested soil. The increasing ratios with successive crops resulted from a progressive increase in growth and development of plants in infested soil and a relatively uniform growth and development of each crop in noninfested soil. A comparable sequence has been detected in wheat produced on tilled and nontilled soils in several wheat-fallow rotations in eastern Oregon (R. W. Smiley, *unpublished*). When soils were first converted from low-residue (moldboard plow) to high-residue (chisel plow or no-till) management systems, wheat yields were lower in the conservation systems than in the low-residue systems. Rhizoctonia root rot became a principal constraint to wheat growth and yield in the conservation systems. However, after several successive crops, the impact of disease diminished, and the yield of wheat in conservation systems became equal to that in the low-residue system.

When *R. solani* was introduced into soils that had produced four or five successive crops of wheat, the incidence of root rot was less in soils previously infested with *R. solani* than in soils previously infested with *R. oryzae* or with neither pathogen. A progressive decline in disease incidence and severity occurred in *R. solani*-infested soils.

The Rhizoctonia root rot decline phenomenon was distinctly affected by soil mixing. Induction of disease decline occurred earlier in mixed soil than in nonmixed soil. In disease suppressiveness tests, the tillage effect was immediately demonstrated with the Thompson soil that had been tilled annually and then also removed and mixed thoroughly between each crop in the greenhouse. In contrast, appearance of the tillage effect was delayed in CBARC soil, which differed in treatment by tillage only during alternate years in the field and by not being mixed between crops in the greenhouse.

TABLE 7. Seminal and coronal roots (%) with Rhizoctonia root rot in Columbia Basin Agricultural Research Center soil infested or not infested with *Rhizoctonia solani* before planting the fifth successive wheat crop

Root type and cropping history	Pathogen treatments in crops 1–4		
	R. solani	*R. oryzae*	Control
Seminal roots[x]			
Planted during crops 1–4			
Infested[y]	10.0	32.7	14.4
Not infested	8.9	17.3	8.3
Not planted previously			
Infested[y]	51.5	23.5	23.5
Not infested	50.4	15.8	8.7
Coronal roots[z]			
Planted during crops 1–4			
Infested[y]	32.8	60.9	44.0
Not infested	30.9	7.8	2.3
Not planted previously			
Infested[y]	60.5	48.7	55.5
Not infested	59.9	13.9	1.9

[x]Second-order interaction significant at $P = 0.0010$ (error mean square = 82.9; 360 df).
[y]Pathogen treatments for crop 5.
[z]Second-order interaction significant at $P = 0.0001$ (error mean square = 186.7; 360 df).

Disease suppressiveness tests provided information on factors leading to Rhizoctonia root rot decline. Soil infested with *R. oryzae* did not produce soil suppressiveness to *R. solani*. Suppressiveness also did not occur in the absence of a host, indicating that both host and pathogen are necessary. Furthermore, the millet seed used as a carrier for the *R. oryzae* inoculum apparently did not serve as an important nutrient source for other microorganisms, which are presumed to be involved in disease decline (1). This was expected in view of the extremely low amount of inoculum used and the wide spatial separation of individual millet seeds planted in these soils.

R. solani AG-8 was indigenous to the soils collected from infested field sites, which were not disinfested before greenhouse experiments were performed. The incidence of coronal roots infected (8–9%) on plants grown in soils without supplemental inoculum was low. Disease severity in soils infested with supplemental inoculum during the fifth crop sequence (but not previously) was intermediate between that in soils continuously reinfested with *R. solani* and either planted (low disease severity) or not planted (high disease severity) during the first four cropping sequences. This supports the hypothesis that wheat crops with a low incidence of Rhizoctonia root rot can induce a low to intermediate level of soil suppressiveness that may be beneficial to successive crops.

Induced suppression of *R. solani* AG-8, achieved only when both host and pathogen are present, is not unique. Similar conditions are required for induced suppression of radish damping-off caused by *R. solani* AG-4 (6) and for induction of take-all decline (15) caused by *Gaeumannomyces graminis* var. *tritici*. In both cases, the mechanisms of disease suppression have mostly been attributed to microbial interactions (8,15,16). Additional studies are needed to identify the mechanism(s) of Rhizoctonia root rot decline in wheat monocultures.

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