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Reduction of Rhizoctonia Bare Patch in Wheat with Barley Rotations

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OVERVIEW

Rhizoctonia bare patch caused by *Rhizoctonia solani* AG-8 is a major fungal root disease in no-till cropping systems. In an 8-year experiment comparing various dryland no-till cropping systems near Ritzville, Washington, Rhizoctonia bare patch first appeared in year 3 and continued through year 8. Crop rotation had no effect on bare patch during the first 5 years, but from years 6 to 8, both soft white and hard white classes of spring wheat grown in a 2-year rotation with spring barley had an average of only 6.6% of total land area with bare patches compared to 15% in continuous annual soft white wheat or hard white wheat (i.e., monoculture wheat). Although average grain yields for both soft white wheat and hard white wheat were greater ($P < 0.001$) when grown in rotation with barley than in monoculture in years 6 to 8, monoculture hard white wheat was more severely affected by Rhizoctonia than soft white wheat. Soil water levels were higher in bare patches, indicating that the roots of healthy cereals did not grow into/underneath bare patch areas. This is the first documentation of suppression of Rhizoctonia bare patch disease in low-disturbance no-till systems with rotation of cereal crops.

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INTRODUCTION

Rhizoctonia bare patch and root rot is a major disease in no-till cereals in Australia (11) and the Pacific Northwest (PNW) (14). No-till is defined as planting directly into residue of the previous crop without tillage that mixes or stirs soil prior to planting. *Rhizoctonia solani* AG-8, the causal agent of bare patch, attacks seminal and crown roots, pruning away root tips and rotting the root cortex (Photo 1), resulting in patches of dead or stunted plants up to several yards in diameter in the field (Photo 2).

Farmers in the PNW are increasingly interested in no-till to reduce soil erosion, improve soil structure and organic matter, and reduce fuel inputs. The traditional crop rotation in the low-precipitation (less than 12 inches annually) zone of the inland PNW is winter wheat-summer fallow where only one crop is grown every two years. Intensive tillage during summer fallow buries excessive quantities of residue, reduces soil cloddiness and surface roughness, and causes recurrent wind erosion and air quality problems (12). Unfortunately, Rhizoctonia bare patch increases when tillage is eliminated (16, 19, 20), and the disease has become a major limiting factor to the adoption of no-till technology.

Other than tillage, there are few management options for control of Rhizoctonia. Reduction of the green bridge carryover of inoculum from volunteer and grassy weeds is achieved with application of glyphosate or other burndown herbicides at least 2 weeks before planting (22). Soil disturbance in the seed row by aggressive hoe-type no-till drill openers may also help (19). Fungicide seed treatments may provide limited protection for germinating seeds but do not protect roots or increase yield in patchy fields (4).

Crop rotation with broadleaf or a non-host crop is a management strategy that works well for some cereal soil-borne pathogens such as take-all (3) and sharp eyespot caused by *R. cerealis* (1, 26). However, in addition to cereals, *R. solani* AG-8 attacks (i.e., leaves bare patches) pulse and oilseed crops such as pea, canola, yellow mustard, safflower, sunflower, lentil, and chickpea (2, 20).

Photo 1. *Rhizoctonia solani* AG-8 attacks the seminal and crown roots of cereals, pruning away root tips and rotting the root cortex.

Photo 2. Rhizoctonia bare patch disease can result in several yards of dead or stunted plants in spring barley.

Few studies have quantified the benefits of crop rotation on control of Rhizoctonia. In Australia, King (8) found less *R. solani* infection on roots of wheat grown after grain legumes compared to grass or wheat. Rovira (20) reported no effect of rotation on root infection, but found less patch area in wheat after medic or peas compared to wheat after grass or wheat after wheat. Roget (18) also observed a long-term (7-year) trend of greater patch area in wheat after grass compared to wheat after peas or medic, although the statistical differences within a given year were often not significant. In the present study, during the first 5 years of conversion from conventional tillage to no-till in eastern Washington at the same experiment site as that reported by Cook et al. (2), crop rotation had no effect on the Rhizoctonia bare patch area of spring wheat.

The objective of our study was to determine the long-term feasibility of annual no-till cropping with diverse rotations in a 11.8-inch precipitation zone in eastern Washington. This paper reports new findings on reduction of Rhizoctonia bare patch area and increased grain yield for two classes of wheat grown in annual monoculture and a 2-year wheat-barley rotation.

MATERIALS AND METHODS

Field layout and treatments

An 8-year field study of no-till annual cropping systems was conducted from 1997 to 2004 at the Ron Jirava farm near Ritzville, Adams County, Washington. The soil at the experiment site is a Ritzville silt loam, greater than 6 ft deep with no rocks or restrictive layers and slopes less than 1%. Thirty-year average annual precipitation for the site is 11.8 inches (Table 1).

Although numerous crop rotations were evaluated for soil water dynamics, weed ecology, root disease (2), and economics (7) during phase I (1997–2000) and phase II (2001–2004) of the experiment, this paper reports findings from only four crop-rotation treatments: (i) continuous annual soft white spring wheat, (ii) a 2-year soft white spring wheat-spring barley rotation, (iii) continuous annual hard white spring wheat, and (iv) a 2-year hard white spring wheat-spring barley rotation. The continuous soft white wheat and soft white wheat-barley rotations were in existence for the entire 8 years and each crop of the rotation was grown each year. Experimental design was a randomized complete block with four replications and 60 by 500 ft plots. In 2001, the soft white wheat and soft white wheat-barley

Table 1. Plant-available soil water at time of sowing in the 6-ft soil profile and precipitation for the continuous annual soft white spring wheat treatment in Adams County, Washington.

Year	Available soil water†	Precipitation						
		Sept.–March	April	May	June	July	August	12 mo. total
	INCHES							
1997	10.1	15.3	1.4	1.3	0.8	0.2	0.1	19.1
1998	5.2	7.7	0.3	1.4	0.5	1.0	0.3	11.2
1999	4.8	6.7	0.2	0.2	0.4	0.1	0.3	7.9
2000	4.8	6.5	0.7	0.5	1.0	0.4	0.0	9.1
2001	3.2	5.7	0.7	0.9	0.2	0.1	0.5	8.1
2002	4.5	7.2	0.5	0.8	0.7	0.3	0.0	9.5
2003	5.7	8.7	1.2	0.5	0.1	0.0	0.1	10.6
2004	3.8	5.0	0.8	1.3	0.0	0.0	0.3	7.4
8-yr avg.	5.3	7.8	0.7	0.9	0.4	0.3	0.2	10.3
30-yr avg.‡	—	8.3	0.9	1.0	0.7	0.4	0.4	11.7

† Available soil water for cereals was calculated as average volumetric soil water (%) in the 6-ft profile minus 6.0% at the time of sowing (late March or early April).
‡ The 30-yr (1974–2004) average precipitation is for the city of Ritzville, located 5 miles east of the experiment site.

were split along the long axis to introduce hard white wheat (previously soft white wheat) and hard white wheat-barley (previously soft white wheat-barley). Thus, the plot size was 30 by 500 ft from 2001 to 2004. The varieties used were ‘Alpowa’ soft white wheat, ‘377S’ hard white wheat, and ‘Baronesse’ barley.

Glyphosate herbicide was applied 2 to 4 weeks before planting at 16 fluid ounces per acre to control weeds and green bridge (22). Planting was conducted during a 2-day period during the last week in March or first week of April in all years. In the first 3 years (1997–1999), all plots were planted and fertilized in one pass directly into the undisturbed soil and residue left by the previous crop using the cooperating farmer’s Flexi-Coil™ 6000 air-delivery no-till drill equipped with Barton II™ dual-disk openers on 7.5 inch row spacing. From 2000 to 2004, all plots were planted and fertilized in one pass using a custom-built no-till drill equipped with Cross-slot™ notched-coulter openers on 8-inch row spacing (Photo 3). Both drills cause little soil disturbance and provide simultaneous and precision placement of seed and fertilizer, with the fertilizer placed beneath and slightly to one side of the seed. The seeding rate over the years was held constant at 70 lb/A for soft white wheat, hard white wheat, and barley. Solution 32 provided the base for liquid fertilizer to supply an average of 35 lb N, 7 lb P, and 10 lb S per acre. The quantities of available soil water and residual N, P, and S were measured in all rotations in mid-March each year to determine fertilizer needs based on a yield goal. The fertilizer rate was the same for all treatments in all years.

Photo 3. A Cross-slot notched-coulter no-till drill with 8-inch row spacing was used to plant all crops.

Between the tillering and jointing phases of growth of soft white wheat, hard white wheat, and barley, in-crop broadleaf weeds were controlled with 10 fluid ounces of 2,4-D + 0.33 ounces Harmony Extra herbicide per acre from 1997 to 2000, and with 12 fluid ounces of 2,4-D + 4 fluid ounces dicamba herbicide per acre from 2001 to 2004. Russian thistle, a major broadleaf weed of spring-planted crops (21), was present at grain harvest in late July in 6 of 8 years. When present, Russian thistle was controlled with 24 fluid ounces of Surefire (paraquat + diuron) herbicide applied 7 days after grain harvest.

Soil water

Soil water content in a 6-ft soil profile was measured in continuous soft white wheat and both phases of soft white wheat-barley each spring before planting and again after grain harvest from 1997–2000. Soil volumetric water content in the 0- to 1-ft depth was determined from two 6-inch core samples using gravimetric procedures and in the 1- to 6-ft depth in 6-inch increments by neutron attenuation (5). Due to lack of soil water differences between treatments from 1997–2000 and constraints of labor and time, soil water content was measured only in continuous soft white wheat from 2001–2004. Precipitation was measured onsite during all years with a computerized weather station.

In 2003 and 2004, soil water content was measured within and outside of Rhizoctonia patches in continuous soft white wheat to determine whether soil water was stranded in the bare patches or if wheat roots extracted water from within patches.

Using the soil water measurement procedures described above (5), access tubes were placed in five locations: (i) 6 ft inside a patch, (ii) 4 ft inside a patch, (iii) 2 ft inside a patch, (iv) at the border of healthy wheat and a patch, and (v) 10 ft outside a patch in healthy wheat (Photo 4). Tubes were installed in one large (i.e., greater than 12-ft-diameter) bare patch in each of the four continuous soft white wheat replications. Soil water was measured in early June, as soon as bare patch areas could be clearly delineated, and again in mid-to-late July near the time of grain harvest.

Photo 4. Neutron probe access tubes were installed in Rhizoctonia bare patches and healthy wheat to measure soil water content. Soil water levels were higher in bare patches, indicating that wheat roots do not grow into/underneath bare patch areas.

Measurement of Rhizoctonia bare patch area

The location, size, and area of patches were determined with a backpack-mounted global positioning system (GPS) equipped with mapping software (Photo 5). Measurements were obtained by circling each clearly visible Rhizoctonia patch with the backpack-mounted GPS mapping unit every year from 1999 to 2004, except in 2001 when drought made it difficult to discern the border areas between Rhizoctonia bare patches and severely water-stressed wheat and barley.

Grain yield

Grain yield was determined in late July or early August by harvesting the grain from plants in a swath through each 500-ft-long plot with a commercial combine with 20-ft-wide cutting platform and auguring grain into a weigh wagon.

Statistical analysis

An analysis of variance was conducted for total water content in the 6-ft soil profile, Rhizoctonia bare patch area, and grain yield. Treatment means were considered significantly different at $P < 0.05$. The Bonferroni method was used to control the experimentwise error rate for multiple comparisons.

Photo 5. The surface areas of bare patches in the entire 20-acre experiment were measured each year using a backpack-mounted global positioning system.

RESULTS

Precipitation, available soil water, and soil water use by wheat and barley

Crop-year (1 Sept. to 31 August) precipitation ranged from 7.4 to 19.1 inches and averaged 10.3 inches over the 8-year period. Plant-available soil water for continuous soft white wheat at planting in late March or early April ranged from 3.2 to 10.1 inches and averaged 5.3 inches over the 8 years (Table 1). There were no differences in soil water between continuous soft white wheat and either phase of the soft white wheat-barley rotation from 1997–2000 (data not shown). Soft white wheat and barley extracted soil water to an average content of 6 to 7% by volume in the 6-ft soil profile by grain harvest in July. Over-winter precipitation storage efficiency (i.e., the percentage of precipitation from grain harvest until late March that was stored in the soil) averaged 67% for continuous soft white wheat during the 8 years.

Rhizoctonia bare patch area

Rhizoctonia bare patch first appeared in 1999 during year 3 of the experiment and continued through year 8, clearly apparent in safflower, yellow mustard, wheat, and barley regardless of crop rotation sequence (2). The percentage area of Rhizoctonia bare patch was not affected by crop or crop rotation in 1999 and 2000, but beginning in 2002 and continuing in 2003 and 2004, significantly less Rhizoctonia bare patch area was measured in soft white wheat and hard white wheat grown in rotation with barley compared to the continuous annual monoculture of soft white wheat and hard white wheat (Fig. 1). Averaged over the 3 years, bare patch comprised 15% of total plot area for continuous annual soft white wheat and hard white wheat, compared to less than 7% for soft white wheat and hard white wheat grown in rotation with barley (Fig. 1).

Rhizoctonia bare patch also occurred in barley every year. The three-year (2002–2004) average for total barley plot area with bare patch was 11.2% following soft white wheat and 8.7% following hard white wheat. Bare patches in barley were generally in the same location as found in the previous wheat crop, although some patches increased in size, other patches shrank, and some new patches formed. There were no significant differences in bare patch area in barley following soft white or hard white wheat in any year or when averaged over the 3 years.

Soil water stranded in bare patches

Healthy soft white wheat growing 10 ft from the nearest bare patch used significantly more soil water than wheat on the border of a patch on both early June and mid-to-late July measurement dates in 2003 and 2004 (Fig. 2). Soil water content at the border of patches was less than

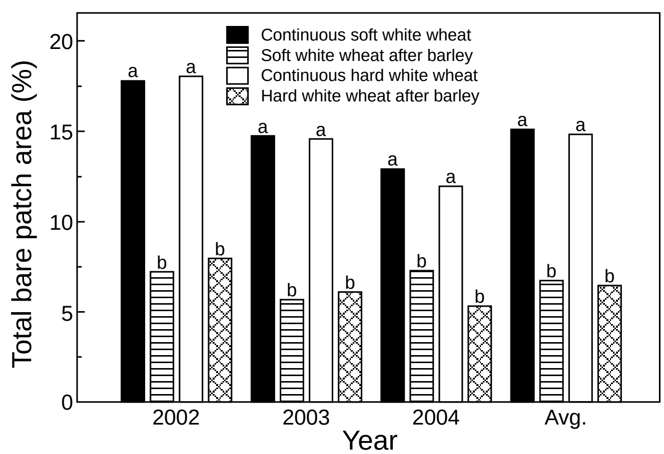

Figure 1. Rhizoctonia bare patch area as a percentage of total plot area in continuous annual soft white wheat and continuous annual hard white wheat compared to soft white wheat and hard white wheat grown in a 2-year rotation with spring barley. Within-year and 3-year average means followed by the same letter are not significantly different at $P < 0.05$.

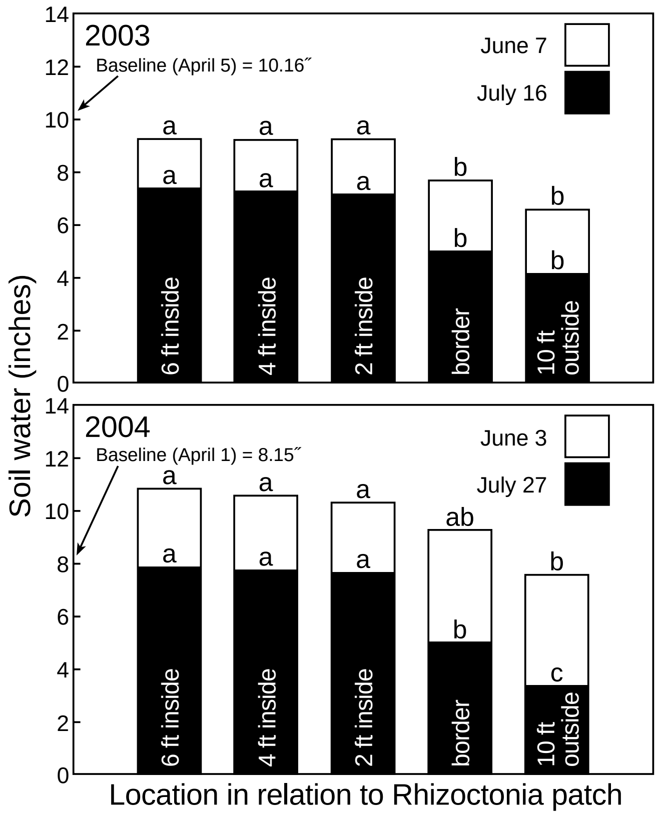

Figure 2. Total soil water content in the 6-ft soil profile in early June and mid-to-late July of 2003 and 2004 as affected by the location inside, at the border, and outside of Rhizoctonia bare patches. Means for each sampling date followed by the same letter are not significantly different at P < 0.05.

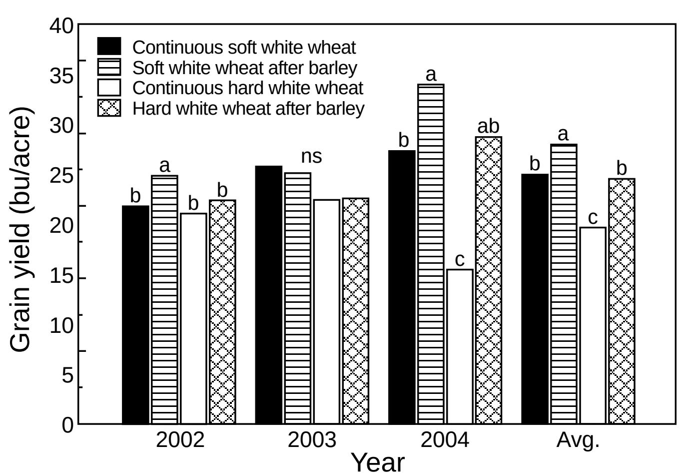

Figure 3. Grain yield of continuous annual soft white wheat and continuous annual hard white wheat compared to soft white wheat and hard white wheat grown in a 2-year rotation with spring barley. Within-year and 3-year average means followed by the same letter are not significantly different at P < 0.05.

from locations within the patch. Soil water content from access tubes located 2, 4, and 6 ft inside the bare patches was always the same on all dates during both years (Fig. 2).

Grain yield

From 2002 to 2004, the grain yield of soft white wheat after barley was greater than monoculture soft white wheat in 2 of 3 years as well as the 3-year average (Fig. 3). There were no significant differences in grain yield between hard white wheat after barley compared to monoculture hard white wheat in 2002 and 2003, but in 2004 (and in the 3-year average), monoculture hard white wheat had the lowest grain yield of all treatments (Fig. 3). Overall grain yields trended higher in 2004 (Fig. 3), even though only 7.4 inches of precipitation occurred during the crop year (Table 1). We attribute this phenomenon to timely and generous rain showers that totaled 1.3 inches during May 2004 (Table 1).

Barley grain yield following soft white wheat and hard white wheat averaged 0.87 and 0.88 tons/A, respectively, during the 3 years. There were no significant differences in barley grain yield between treatments in any year or when averaged over the 3 years.

DISCUSSION

This study is the first to document that barley provides a positive long-term rotation effect on wheat compared to monoculture wheat. Although there were no beneficial effects on soft white wheat grain yield when grown in rotation with safflower, yellow mustard, or barley during the first 5 years of the cropping systems experiment (2) due to the wide host range of *R. solani* AG-8, starting in year 6, a rotation effect was seen with barley in 2-year soft white wheat-barley and hard white wheat-barley rotations. This is surprising, since barley is very susceptible to *R. solani* AG-8. In fact, barley often shows greater stunting than wheat, a phenomenon also seen with *Rhizoctonia oryzae* (15). A rotation effect is usually seen with a non-host crop, such as when take-all caused by *Gaumannomyces graminis* var. *tritici* is controlled by rotation with a broadleaf crop-like pea (3). The rotation phenomenon observed in this study may be unique to long-term no-till cropping.

What are some possible explanations for this rotation effect? There was no difference in water use between barley and soft white wheat based on multiple-year measurements taken at the experimental site. Barley is a less favorable host for lesion nematodes than either soft white wheat or hard white wheat (6), but DNA testing in fall 2004 did not detect these nematodes (data not shown). One possible explanation is a suppressive microbial effect. Barley may select for microbes that are antagonistic to Rhizoctonia. Host genotype can affect beneficial bacteria such as Pseudomonas, which are involved in the biological control of fungal soil-borne pathogens (25). Different genotypes of phloroglucinol-producing *Pseudomonas fluorescens* have different preferences for colonizing the roots of pea and wheat (9, 17). In fact, a susceptible host is a prerequisite for the establishment of a monoculture decline such as take-all decline. The antagonistic *Pseudomonas* spp. multiply in the lesions on the root caused by pathogen infection, and produce antifungal compounds such as phloroglucinol and phenazine, which inhibit the spread of the pathogen in the root (27). Intact soil cores were taken from the centers and outside of these patches from our study site, and planted with five crops of barley over a 9-month period in a greenhouse. Initially, stunting was observed in most of the cores from the patch centers compared to cores from outside of the patches. However, by the end of the experiment, many cores from the center no longer showed stunting, suggesting that the patches had become suppressive (13). Other researchers have found evidence of Rhizoctonia suppression after long-term monoculture of wheat under direct seed conditions (10, 18), but no specific mechanism of suppression has been identified.

Another possibility for the rotation benefit is that barley leaves less inoculum in the soil for the subsequent crop. *R. solani* AG-8 survives in living roots, and does not readily form other survival structures such as sclerotia (14). Barley roots may decompose faster than wheat roots, leaving less inoculum for the following year.

Differences have also been observed between two wheat classes in the disease response to Rhizoctonia. Paulitz et al. (15) demonstrated that the hard red spring wheat variety ‘Scarlet’ was more damaged by isolates of *R. oryzae* than the soft white winter wheat variety ‘Madsen.’ Smith et al. (24) observed that the hard white variety ‘377S’ was more susceptible to *R. solani* AG-8 than the soft white wheat variety ‘Alpowa’ in greenhouse assays.

Inoculated field tests also showed differences in susceptibility among genotypes of spring wheat, but none were resistant. The hard white wheat variety '377S' was not tested, but the soft white wheat variety 'Alpowa' did not exhibit significant grain yield differences when grown in high vs. low inoculum (23). Although our study confirms differences in susceptibility between these two classes of spring wheat, generalizations to entire wheat classes cannot be made without further testing of a range of varieties.

In Mediterranean climate regions like the PNW, the quantity of water stored in the soil during the winter months is an important determinant of grain yield. If large patches are devoid of plants, can surrounding plant roots grow into these areas and utilize this water, thus compensating for yield loss from Rhizoctonia? Our results show that soft white wheat roots do not extract soil water from within Rhizoctonia bare patches. The uniform decline in soil water content within the patches between early June and mid-to-late July was probably due to evaporation, as wheat plants were severely stunted and/or dead by the June measurement. Since soft white wheat did not extract soil water even from just 2 ft inside the border, it appears that roots from healthy soft white wheat at the border do not extend into patches. Therefore, soil water within bare patches is truly stranded and grain yield reduction corresponding to the percentage of bare patch area can be expected.

Despite the fact that all rotation crops are susceptible to *R. solani* AG-8, a positive rotation effect of barley was measured on two classes of spring wheat in years 6, 7, and 8 of the study. Further research is needed to determine if other no-till management practices affect Rhizoctonia bare patch, including chemical fallow (to deny a host) and high disturbance hoe-type grain drill openers to provide a tillage zone around the developing seedling.

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