Wheat Research Progress Report

Project #: 3061-3564

Title: Relationship Between Populations of Pathogenic *Pythium* and *Rhizoctonia* and Yield in PNW Dryland Cereal Production Systems

Researchers: Patricia Okubara, Kurtis Schroeder, Timothy Paulitz

Cooperators: John Aeschliman, John Kuehner, David Harlow, Curtis Hennings, Ron Jirava, Hal Johnson, Steve Matsen, Patrick McGourin, Bruce Nelson, Roger Pennell, Robert Sievers, Randy Suess

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Accomplishments:

We collected soil samples from producers' parcels, WSU wheat variety testing sites and spring wheat grids at the Cook Agronomy Farm in 2008 (third year of study). Soils were analyzed for the six most pathogenic *Rhizoctonia* and *Pythium* species: *R. solani* AG-8, *R. solani* AG-2-1, *R. oryzae* group III, *P. ultimum*, *P. irregulare* group I and *P. irregulare* group IV. Three years (2006 to 2008) of pathogen quantification data from the former two venues and two years (2006 and 2007) of data from the Cook Agronomy Farm have been analyzed. Specific accomplishments for 2008 are:

- *Rhizoctonia solani* AG-8 and *P. irregulare* grp IV, normally ubiquitous, were relatively high throughout Washington in 2008, and found in both direct seeded and conventionally tilled parcels.

- *R. solani* AG-8 was prevalent at Bickleton, Central Ferry, Dayton, Pullman, Ralston, Ritzville, St. John, Walla Walla. *R. solani* AG-2-1 was highest in parcels with a history of legumes.

- *Pythium irregulare* grp IV was found at Colfax, Steptoe and Farmington.

- In contrast, *R. oryzae* grp III and *P. irregulare* grp I were less prevalent in 2008 than in past years.

- *P. ultimum* remained detectable in high to intermediate-high rainfall zones but was not more prevalent despite the extended cool, wet spring.

- The Cook Agronomy Farm spring wheat grids were found to harbor all three of the monitored *Rhizoctonia* pathogens and, additionally, *R. solani* AG-10 and AG-I-like binucleate species. Both of the latter occurred infrequently and at low levels, and were not quantified after 2006.

- Statistical correlations between rainfall zone, tillage, rotation, and *Rhizoctonia* and *Pythium* were analyzed for the cumulative three-year sampling period. *P. irregulare* grp I was found in high rainfall areas, whereas *R. solani* AG-8 was not. Both pathogens coincided with parcel histories of legumes, brassica and/or fallow. *P. irregulare* grp I was lower in conventionally tilled parcels. Both *P. irregulare* grp I and *P. ultimum* were positively correlated with legumes.

Results:

1) Soil sampling schemes for surveys of producers' parcels and wheat variety testing sites yielded consistent data for *Pythium* and *Rhizoctonia* during the three-year study (2006 through 2008). For growers' parcels, five soil cores were collected across each of three 300-foot transects and pooled. The transects captured terrain and aspect variations (where present) across the parcel, and each pool of soil cores represented a replicated sample. For variety testing sites, soils were collected using a "W" sampling scheme consisting of five 150-foot transects (replicated samples) spanning the entire site; five soil cores were collected and pooled per transect. *Pythium* spp. favored Pullman and Farmington and also were found in irrigated systems (Central Ferry). *R. solani* AG-8 was found in Ritzville, Lind, Connell, Walla Walla and Dayton, coincidental with occurrence of Rhizoctonia bare patch. The year-to-year consistency of our findings is a positive indicator that sampling schemes for risk predication models will be successful.

2) Pressure cycling technology using the Barocycler NEP 3229 (Pressure BioSciences, Inc., West Bridgewater, MA) was found to be essential for quantification of *Rhizoctonia* spp. from soil samples. Efficiency of DNA extraction was improved 10- to 16-fold using this technology. The technology was used for all soil samples (2006 through 2008) using refinements described in our 2006 Progress Report.

3) Real-time PCR analyses of soils collected in 2008 from 33 producers' parcels under different rotation, tillage and rainfall regimens have been completed (Table 1). Global Position System (GPS) coordinates were used to locate transects in each year. *R. solani* AG-8 remained ubiquitous throughout the dryland cereal production regions of Washington, but occurred at quantifiable levels in both direct-seeded and conventionally-tilled fields in intermediate to low rainfall zones. In contrast, *P. irregulare* grp I and *P. irregulare* grp IV were associated with both direct-seeded and conventionally-tilled parcels in high to intermediate-high rainfall zones. No parcels harbored high amounts of both *Rhizoctonia* and *Pythium* spp.

4) Over three years, *Rhizoctonia* and *Pythium* soil profiles have emerged at growers' parcels (Table 2). *R. solani* AG-8 was not particularly abundant in direct-seeded compared to conventionally-tilled parcels. However, *P. irregulare* grps I and IV were associated with direct-seeded parcels in high rainfall zones. *R. solani* AG-2-1 occurred at relatively high populations in parcels grown to pea.

5) Pathogen populations were quantified at 13 winter wheat and 10 spring wheat variety testing sites in 2008 (Table 3). *R. solani* AG-8 remained present at all sites, and highest at Bickleton,

Central Ferry, Connell, Dayton, St. John, Ritzville and Walla Walla. *R. oryzae* grp III was detected at Bickleton, Dayton, Farmington and Ritzville. To date *Pythium* has been quantified at 12 of the 23 sites. *P. irregulare* grp I was found at Farmington, and *P. irregulare* grp IV occurred at Farmington, Pullman, St. John and Walla Walla. *P. ultimum*, the most pathogenic *Pythium* species, was not observed in the sites tested to date. No site was free of pathogen in 2008.

6) Three years of pathogen data from WSU variety test sites are summarized in Table 4. Pathogen populations varied somewhat from year to year. However, *R. sola*ni AG-8 consistently occurred at relatively high levels at Connell, Dusty, Ritzville and Walla Walla. Low levels of *R. sola*ni AG-8 were detected at Central Ferry, Colton, Dayton, Farmington, Harrington, Lind, Pullman, and St. John. *P. irregulare* grp IV was widespread and consistently found at Colton, Farmington, Pullman, and St. John. Farmington harbored both *Rhizoctonia* and *Pythium* spp. No site was pathogen-free.

7) Spring wheat grids at the Cook Agronomy Farm (116 grids in 2006 and 114 grids 2007) harbored primarily *R. solani* AG-2-1 (Table 5). This finding was expected in view of the 3-year legume/brassica rotation applied to this portion of the farm. *R. solani* AG-8 and AG-10 were present in 3 to 15% of the grids but below the level required for accurate quantification. Processing of 2008 samples is in progress.

8) Relationships between rainfall zone, type of tillage, crop and rotation and populations of *Rhizoctonia* and/or *Pythium* spp. in growers' parcels were examined using combined data from 2006, 2007, and 2008. Significant correlations ($P<0.05$), determined using SAS (SAS Institute, Cary, NC), are highlighted in bold (Table 6). High populations of *P. irregulare* grp I were correlated to high rainfall, but conventional tillage reduced *P. irregulare* grp I. In contrast, *R. solani* AG-8 was not found in high rainfall areas. *P. irregulare* grp I and *R. solani* AG-8 were higher in parcels with histories of legumes, brassica and/or fallow. Both *P. irregulare* grp I and *P. ultimum* were positively correlated with legumes. In past years, *R. solani* AG-2-1 occurred primarily in legume and canola parcels or in parcels with a history of these crops. Its association with legume parcels was expected, and could account for the persistence of this AG in the PNW.

9) Presence of a specific pathogen was not significantly correlated to the crop grown at the time of soil sampling, but rather to parcel history, suggesting that pathogens accumulate over multiple growing seasons and cumulatively impact pathogen profiles in next growing year.

10) Relationships between pathogen populations and yield at variety testing sites and Cook Agronomy Farm spring wheat grids are being analyzed. Growers' parcels will be analyzed when yield data are available.

Table 1. 2008 *Rhizoctonia* and *Pythium* soil populations[1] (pg DNA per g soil) at producer parcels.

Rainfall[2]	Tillage[3]	AG-8	AG-2-1	*Ro* grp III	*P. irr*. I	*P. irr*. IV	*P. ult.*
H	DS	D	-	D	0.4	0.6	D
		D	-	D	0.2	0.4	-
		-	D	-	0.4	0.3	-
H	DS	0.8	-	D	-	D	D
		D	-	D	-	D	-
		-	D	D	-	D	-
		-	-	-	-	D	-
H	DS	D	-	D	-	-	-
		D	-	D	-	-	-
H	DS	1.0	-	-	-	D	-
		1.5	D	-	-	D	-
IH	DS	4.0	D	D	D	0.1	-
		0.7	-	-	D	0.8	-
		1.3	149.7	D	D	4.8	-
LI	DS	43.6	D	D	-	-	-
		3.0	D	D	D	-	-
		2.6	D	-	D	-	-
L	DS	2.9	D	-	-	-	-
		6.3	D	-	-	-	-
		D	-	-	-	-	-
H	C	D	D	-	-	D	-
		-	D	D	-	D	D
		-	228.9	-	-	D	-
IH	C	D	-	D	-	2.9	-
		2.1	118.5	-	-	2.7	-
		D	96.7	-	-	7.2	-
LI	IH,	1.5	-	-	-	D	-
		2.5	-	-	-	D	-
		1.7	-	D	-	D	-
		D	-	-	-	D	-
L	C	24.2	D	-	-	-	-
		D	D	-	-	-	-
		15.4	D	D	D	-	-

[1] Values are the average of three replicate samplings per parcel. D, detected below quantification threshold; - no pathogen detected.

[2] Average annual precipitation: L, low (7-14”); LI, low intermediate (11-15”); IH, intermediate high (16-18”); H, high (20-24”).
[3] DS, direct seed; C, conventional

Table 2. Three-year cumulative data of *Pythium* and *Rhizoctonia* populations[1] (pg DNA per g soil) at grower parcels.

Site[3]/Pathogen	Crop[1] 2005	2006	2007	2008	Pathogen level (pg/g)[2] 2006	2007	2008
H/DS Parcel 1	pea	SW	pea	WW			
R. solani AG-8					-	-	D
R. solani AG-2-1					-	192	-
R. oryzae III					-	-	D
P. irregulare I					1.6	1.6	0.4
P. irregulare IV					0.6	3.0	0.6
P. ultimum					-	-	D
H/DS Parcel 2	SW	pea	WW	SW			
R. solani AG-8					D	-	D
R. solani AG-2-1					D	-	-
R. oryzae III					-	D	D
P. irregulare I					0.1	0.2	0.2
P. irregulare IV					0.1	1.2	0.4
P. ultimum					-	-	-
H/DS Parcel 3	WW	WW	SW	SL			
R. solani AG-8					D	D	-
R. solani AG-2-1					-	-	D
R. oryzae III					-	-	-
P. irregulare I					0.2	0.5	0.4
P. irregulare IV					0.2	11.2	0.3
P. ultimum					-	-	-
H/DS Parcel 1	WW	WW	WW	WW			
R. solani AG-8					D	-	0.8
R. solani AG-2-1					-	-	-
R. oryzae III					D	D	D
P. irregulare I					D	-	-
P. irregulare IV					D	-	D
P. ultimum					-	-	D
H/DS Parcel 2	SW	WW	WW	WW			
R. solani AG-8					D	-	D
R. solani AG-2-1					-	-	-
R. oryzae III					-	D	D
P. irregulare I					-	-	-
P. irregulare IV					0.3	3.3	D

P. ultimum					-	-	-
H/DS Parcel 3	WW	SW	SW	WW			
R. solani AG-8					D	-	-
R. solani AG-2-1					-	D	D
R. oryzae III					7.9	D	D
P. irregulare I					-	-	-
P. irregulare IV					0.1	7.6	D
P. ultimum					-	-	-
H/DS Parcel 4	Len	WW	WW	SW			
R. solani AG-8					D	-	-
R. solani AG-2-1					24.6	-	-
R. oryzae III					-	-	-
P. irregulare I					D	D	-
P. irregulare IV					0.3	6.9	D
P. ultimum					-	-	-
H/DS Parcel 1	BG	BG	WW	Len			
R. solani AG-8					n.d.	-	D
R. solani AG-2-1					n.d.	D	-
R. oryzae III					n.d.	-	D
P. irregulare I					n.d.	-	-
P. irregulare IV					n.d.	0.1	-
P. ultimum					n.d.	-	-
H/DS Parcel 2	BG	WW	Len	WW			
R. solani AG-8					n.d.	-	D
R. solani AG-2-1					n.d.	D	-
R. oryzae III					n.d.	D	D
P. irregulare I					n.d.	-	-
P. irregulare IV					n.d.	0.5	-
P. ultimum					n.d.	-	-
H/DS Parcel 2	WW	SW	WL	WW			
R. solani AG-8					n.d.	D	1.0
R. solani AG-2-1					n.d.	-	-
R. oryzae III					n.d.	-	-
P. irregulare I					n.d.	-	-
P. irregulare IV					n.d.	5.2	D
P. ultimum					n.d.	-	-

H/DS Parcel 2	WW	SW	WL	WW			
R. solani AG-8					n.d.	2.6	1.5
R. solani AG-2-1					n.d.	-	D
R. oryzae III					n.d.	2.3	-
P. irregulare I					n.d.	-	-
P. irregulare IV					n.d.	5.5	D
P. ultimum					n.d.	-	-
IH/DS Parcel 1	WW	SW	SW	WW			
R. solani AG-8					D	-	4.0
R. solani AG-2-1					-	-	D
R. oryzae III					D	D	D
P. irregulare I					-	-	D
P. irregulare IV					-	0.2	0.1
P. ultimum					-	-	-
IH/DS Parcel 2	CF	WW	SW	WW			
R. solani AG-8					-	-	0.7
R. solani AG-2-1					-	D	-
R. oryzae III					D	-	-
P. irregulare I					-	-	D
P. irregulare IV					0.1	0.6	0.8
P. ultimum					-	-	-
IH/DS Parcel 3	WW	CP	WW	SW			
R. solani AG-8					-	-	1.3
R. solani AG-2-1					-	D	150
R. oryzae III					D	D	D
P. irregulare I					-	-	D
P. irregulare IV					2.0	157	4.8
P. ultimum					-	-	-
LI/DS Parcel 1	n.d.	SW	SW	SW			
R. solani AG-8					13.5	4.9	43.6
R. solani AG-2-1					-	-	D
R. oryzae III					8.7	-	D
P. irregulare I					-	-	-
P. irregulare IV					-	-	-
P. ultimum					-	-	-
LI/DS Parcel 2	n.d	SF	WW	SF			
R. solani AG-8					-	0.8	3.0
R. solani AG-2-1					-	-	D
R. oryzae III					-	D	D
P. irregulare I					-	0.1	D
P. irregulare IV					-	-	-
P. ultimum					-	-	-
LI/DS Parcel 3	n.d	WW	SF	WW			
R. solani AG-8					5.7	-	2.6
R. solani AG-2-1					-	D	D

R. oryzae III					3.3	D	-
P. irregulare I					-	-	D
P. irregulare IV					-	-	-
P. ultimum					-	-	-
L/DS Parcel 1	SW	SW	SW	SW			
R. solani AG-8					D	-	2.9
R. solani AG-2-1					-	D	D
R. oryzae III					D	D	-
P. irregulare I					-	-	-
P. irregulare IV					-	0.1	-
P. ultimum					-	-	-
L/DS Parcel 2	CF	WW	SW	SW			
R. solani AG-8					D	-	6.3
R. solani AG-2-1					D	-	D
R. oryzae III					-	-	-
P. irregulare I					-	-	-
P. irregulare IV					D	0.2	-
P. ultimum					-	-	-
L/DS Parcel 3,4,5	various[4]						
R. solani AG-8					-	-	D
R. solani AG-2-1					-	-	-
R. oryzae III					-	-	-
P. irregulare I					-	-	-
P. irregulare IV					-	-	-
P. ultimum					-	-	-
H,C Parcel 1	SB	CP	WW	SW			
R. solani AG-8					D	-	D
R. solani AG-2-1					D	-	D
R. oryzae III					D	-	-
P. irregulare I					-	-	-
P. irregulare IV					1.5	9.9	D
P. ultimum					-	-	-
H,C Parcel 2	WW	SW	SW	CP			
R. solani AG-8					D	D	-
R. solani AG-2-1					-	-	D
R. oryzae III					D	-	D
P. irregulare I					-	-	-
P. irregulare IV					0.1	8.7	D
P. ultimum					-	-	D
H,C Parcel 3	CP	WW	SW	CP			
R. solani AG-8					D	-	-
R. solani AG-2-1					D	339	229
R. oryzae III					-	-	-
P. irregulare I					-	-	-
P. irregulare IV					3.2	11.7	D

P. ultimum					-	-	-
IH,C Parcel 1	pea	WW	SW	pea			
R. solani AG-8					D	-	D
R. solani AG-2-1					-	29.6	-
R. oryzae III					2.9	-	D
P. irregulare I					-	-	-
P. irregulare IV					0.7	9.7	2.9
P. ultimum					-	-	-
IH,C Parcel 2	WW	SW	pea	WW			
R. solani AG-8					D	-	2.1
R. solani AG-2-1					-	D	118
R. oryzae III					D	D	-
P. irregulare I					D	0.7	-
P. irregulare IV					0.1	4.1	2.7
P. ultimum					-	-	-
IH,C Parcel 3	SW	pea	WW	SW			
R. solani AG-8					-	D	D
R. solani AG-2-1					104	D	96.7
R. oryzae III					D	26.2	-
P. irregulare I					-	-	-
P. irregulare IV					0.8	2.1	7.2
P. ultimum					-	-	-
LI/IH, C Parcel 1	SB	WW	SB	CF			
R. solani AG-8					-	-	1.5
R. solani AG-2-1					-	-	-
R. oryzae III					D	-	-
P. irregulare I					-	-	-
P. irregulare IV					0.2	0.5	D
P. ultimum					-	-	-
LI/IH, C Parcel 2	CF	SB	WW	SW			
R. solani AG-8					D	1.0	2.5
R. solani AG-2-1					-	-	-
R. oryzae III					D	-	-
P. irregulare I					-	-	-
P. irregulare IV					2.8	0.7	D
P. ultimum					-	-	-
LI/IH, C Parcel 3	SW	SW	SW	SW			
R. solani AG-8					D	D	1.7
R. solani AG-2-1					-	-	-
R. oryzae III					D	D	D
P. irregulare I					-	-	-
P. irregulare IV					2.2	4.0	D
P. ultimum					-	-	-
LI/IH, C Parcel 4	SB	mus	SW	WW			
R. solani AG-8					D	D	D

R. solani AG-2-1					D	-	-
R. oryzae III					D	D	-
P. irregulare I					-	-	-
P. irregulare IV					6.3	3.3	D
P. ultimum					-	-	-
L,C Parcel 1	can	WW	SF	WW			
R. solani AG-8					D	0.9	24.2
R. solani AG-2-1					-	D	D
R. oryzae III					D	3.2	-
P. irregulare I					-	-	-
P. irregulare IV					-	-	-
P. ultimum					-	-	-
L,C Parcel 2	SF	SW	SF	WW			
R. solani AG-8					D	1.5	D
R. solani AG-2-1					-	-	D
R. oryzae III					D	7.3	-
P. irregulare I					-	-	-
P. irregulare IV					-	-	-
P. ultimum					-	-	-
L,C Parcel 3	WW	can	SW	WW			
R. solani AG-8					D	0.9	15.4
R. solani AG-2-1					D	33.6	D
R. oryzae III					D	9.3	D
P. irregulare I					-	-	D
P. irregulare IV					-	-	-
P. ultimum					-	-	-

[1] B, barley; BG, bluegrass; can, canola; CF, chemical fallow; mus, mustard; SB, spring barley; SL, spring lentil; SW, spring wheat; WC, winter canola; WW, winter wheat

[2] Picograms DNA per gram of soil of detected pathogens; average of three replicates per parcel.
D, detected below quantification threshold; -, no pathogen detected; n.d., no data available.

[3] Average annual precipitation: L, low (7-14”), LI, low intermediate (11-15”); IH, intermediate high (16-18”); H, high (20-24”); Irrig., irrigated.
DS, direct seed; C, conventional

[4] SM3 - SW (2005), WW (2006)
SM4 - SW (2005), WW (2006), SW (2007)
SM5 - SW(2008)

Table 3. 2008 populations of *Rhizoctonia* and *Pythium* spp. in five replicated samplings (R1-R5) at 22 WSU winter (W) and spring wheat (S) variety test sites.

Location/Pathogen	I.D.	Type	Rainfall[2]	Pathogen Level (pg/g)[1] R1	R2	R3	R4	R5	av.
Bickleton	VT25	S	L						
R. solani AG-8				66.4	5.4	2.8	D	17.9	7.3
R. oryzae III				D	D	-	-	-	D
Bickleton	VT26	W	L						
R. solani AG-8				-	D	-	-	-	D
R. oryzae III				-	-	-	-	D	D
Central Ferry	VT7	W	Irrig.						
R. solani AG-8				1.6	3.7	D	D	D	1.1
P. ultimum				5.3	9.9	3.0	5.4	6.7	6.06
Colton	VT4	W	H						
R. solani AG-8				-	D	-	D	-	D
P. irregulare I				-	0.05	-	-	-	0.01
P. irregulare IV				-	2.4	0.5	1.6	-	0.9
Connell	VT18	S	L						
R. solani AG-8				-	D	-	D	-	D
Connell	VT16	W	L						
R. solani AG-8				D	3.1	-	3.1	D	1.2
P. irregulare I				-	0.05	-	-	-	0.01
Dayton	VT5	S	IH						
R. solani AG-8				D	D	D	D	D	D
R. oryzae III				D	-	-	-	-	D
Dayton	VT6	W	IH						
R. solani AG-8				D	D	-	D	nd	D
R. oryzae III				-	-	-	D	-	D
Dusty	VT15	W	LI						
R. solani AG-8				D	5.6	-	-	2.4	1.6
P. irregulare IV				2.1	1.2	1.9	2.8	-	1.6
Dusty	VT13	S	LI						
R. solani AG-8				D	D	1.7	-	-	0.3
Farmington	VT8	S	H						
R. solani AG-8				-	D	D	-	-	D
P. irregulare I				0.7	0.5	0.2	0.07	0.1	0.3
P. irregulare IV				1.4	2.0	0.6	0.03	1.8	1.2
Farmington	VT9	W	H						
R. solani AG-8				D	D	D	-	-	D

R. oryzae III				D	D	D	-	-	D
P. irregulare I				1.3	2.9	0.8	2.5	0.7	1.6
P. irregulare IV				0.1	0.3	0.3	2.1	5.3	1.6
Harrington	VT10	W	LI						
R. solani AG-8				D	-	D	D	D	D
Lind	VT20	S	LI						
R. solani AG-8				D	-	-	-	-	D
R. oryzae III				-	D	-	-	-	D
Lind	VT17	W	LI						
R. solani AG-8				-	D	D	D	4.1	1.4
Pullman	VT21	S	H						
R. solani AG-8				-	-	-	-	3.0	0.6
P. irregulare IV				-	0.1	-	-	-	0.02
P. ultimum				0.2	-	0.04	0.3	-	0.1
Pullman	VT1	W	H						
R. solani AG-8				D	-	D	-	D	D
R. oryzae III				-	-	-	-	D	D
P. irregulare IV				2.1	0.2	0.2	0.4	0.1	0.6
Ritzville	VT19	W	LI						
R. solani AG-8				-	D	2.2	-	D	0.4
St. John	VT11	S	H						
R. solani AG-8				D	-	-	6.9	1.1	1.6
P. irregulare IV				2.5	0.7	0.1	0.6	0.7	0.9
St. John	VT12	W	H						
R. solani AG-8				D	2.2	-	-	D	0.4
P. irregulare IV				0.3	-	0.4	0.2	2.4	0.7
Walla Walla	VT2	S	IH						
R. solani AG-8				-	D	-	-	-	D
P. irregulare IV				0.1	0.1	-	-	-	0.05
Walla Walla	VT3	W	IH						
R. solani AG-8				D	-	D	3.8	5.8	1.9
P. irregulare IV				0.3	-	-	0.1	0.5	0.2

[1] Picograms DNA per gram weight of soil. Only species that were detected are indicated. *R. solani* AG-2-1 was not monitored D, detected below level of quantification; -, not detected; nd, not determined.

[2] Average annual precipitation: L, low (7-14”), LI, low intermediate (11-15”); IH, intermediate high (16-18”); H, high (20-24”); Irrig., irrigated.

Table 4. Three-year cumulative data of *Pythium* and *Rhizoctonia* populations at 13 WSU winter (W) and 10 spring wheat (S) variety test sites.

Location/Pathogen	I.D.	Variety	Rainfall[2]	Pathogen level (pg/g)[1] 2006	2007	2008
Bickleton	VT25	S	L			
R. solani AG-8				-	-	7.3
R. oryzae				-	-	D
Bickleton	VT26	W	L			
R. solani AG-8				-	-	D
R. oryzae				-	-	D
Central Ferry	VT7	W	Irrig.			
R. solani AG-8				D	D	1.1
R. oryzae III				D	1.57	-
P. irregulare I				0.04	-	-
P. irregulare IV				-	-	-
P. ultimum				1.15	1.22	6.06
Colton	VT4	W	H			
R. solani AG-8				D	D	D
R. oryzae III				-	D	-
P. irregulare I				0.05	-	0.01
P. irregulare IV				0.79	-	0.90
Connell	VT18	S	L			
R. solani AG-8				D	1.25	-
P. irregulare I				-	0.03	-
Connell	VT16	W	L			
R. solani AG-8				0.08	14.87	1.2
R. oryzae III				D	0.59	-
P. irregulare I				-	0.02	-
P. ultimum				-	0.28	-
Dayton	VT5	S	IH			
R. solani AG-8				0.71	-	D
R. oryzae III				-	1.29	D
P. irregulare I				0.08	0.04	-
P. irregulare IV				0.79	-	-
Dayton	VT6	W	IH			
R. solani AG-8				D	D	D
R. oryzae III				D	1.05	D
P. irregulare I				0.08	0.03	-
P. irregulare IV				-	0.01	-

Dusty	VT13	S	LI			
R. solani AG-8				D	4.85	0.3
R. oryzae III				-	9.69	-
P. irregulare I				-	0.02	-
P. irregulare IV				-	0.09	-
Dusty	VT15	W	LI			
R. solani AG-8				D	2.16	1.6
R. oryzae III				-	D	-
P. irregulare I				D	0.01	-
P. irregulare IV				0.09	-	1.6
Farmington	VT8	S	H			
R. solani AG-8				D	0.08	D
R. oryzae III				-	D	-
P. irregulare I				1.31	0.18	0.3
P. irregulare IV				6.03	1.12	1.2
Farmington	VT9	W	H			
R. solani AG-8				D	-	D
R. oryzae III				7.60	D	D
P. irregulare I				1.78	0.51	1.6
P. irregulare IV				6.24	0.11	1.6
Harrington	VT10	W	LI			
R. solani AG-8				D	D	D
R. oryzae III				3.64	D	-
Lind	VT20	S	L			
R. solani AG-8				D	1.98	D
R. oryzae III				D	5.64	D
Lind	VT17	W	L			
R. solani AG-8				D	-	1.4
R. oryzae III				D	-	-
Pullman	VT21	S	H			
R. solani AG-8				D	D	0.6
R. oryzae III				D	D	-
P. irregulare IV				0.08	0.68	0.02
P. ultimum				4.44	0.12	0.1
Pullman	VT1	W	H			
R. solani AG-8				D	D	D
R. oryzae III				-	D	D
P. irregulare I				2.25	0.01	-
P. irregulare IV				-	0.02	0.6

Ritzville	VT14	S	IL			
R. solani AG-8				2.03	0.72	n.d.
R. oryzae III				9.31	-	n.d.
P. irregulare IV				-	0.11	n.d.
P. ultimum				-	0.12	n.d.
Ritzville	VT19	W	IL			
R. solani AG-8				2.44	7.30	0.4
R. oryzae III				D	2.71	-
P. irregulare I				-	0.02	-
St. John	VT11	S	H			
R. solani AG-8				D	-	1.6
R. oryzae III				-	4.90	-
P. irregulare I				D	0.01	-
P. irregulare IV				0.84	0.11	0.9
St. John	VT12	W	H			
R. solani AG-8				D	D	0.4
R. oryzae III				-	1.64	-
P. irregulare I				D	0.01	-
P. irregulare IV				0.16	0.14	0.2
Walla Walla	VT2	S	IH			
R. solani AG-8				2.33	8.90	D
R. oryzae III				-	2.53	-
P. irregulare IV				-	-	0.05
Walla Walla	VT3	W	IH			
R. solani AG-8				2.42	D	1.9
R. oryzae III				D	D	-
P. irregulare IV				D		0.2

[1] Picograms DNA per gram of soil of detected pathogens; average of five replicates per year. *R. solani* AG-2-1 was not monitored. D, detected below quantification threshold -, no pathogen detected; n.d., no data available.

[2] Average annual precipitation: L, low (7-14”), LI, low intermediate (11-15”); IH, intermediate high (16-18”); H, high (20-24”); Irrig., irrigated.

Table 5. Two-year cumulative data of *Rhizoctonia* populations at the Cook Agronomy Farm spring wheat grids.

Pathogen	2006		2007	
	Av. level (pg/g)[1]	% Detected[2]	Av. level (pg/g)[1]	% Detected[2]
R. solani AG-8	-	11.2	0.77	15.0
R. solani AG-2-1	15.4	11.2	154.5	28.0
R. solani AG-10	-	0.03	0.12	13.0
R. oryzae grp III	6.1	11.2	0.16	29.0

[1] Picograms DNA per gram of soil, average of all grids harboring quantifiable populations of pathogen. -, no pathogen occurred at high enough level to be quantifiable.

[2] Percentage of grids in which pathogen was detectable but below level of quantification.

Table 6. Correlation[1] between environmental variables and pathogen populations at 33 growers' parcels for 2006, 2007 and 2008.

	AG-8	AG-2-1	Ro III	P. irr I	P. irr IV	P. ult
Year	**0.15246**	0.072	0.07186	0.05863	-0.0085	0.03256
	0.0099	0.2256	0.2265	0.324	0.8864	0.5841
	285	285	285	285	285	285
Location	0.07753	0.05965	**0.15526**	0.07162	0.04847	0.07063
	0.1919	0.3156	**0.0087**	0.2281	0.415	0.2346
	285	285	**285**	285	285	285
Parcel	0.08241	0.07275	**0.16552**	0.07818	0.04433	-0.0694
	0.1653	0.2208	**0.0051**	0.1882	0.456	0.2429
	285	285	**285**	285	285	285
Rainfall	**-0.16188**	0.10963	0.06552	**0.18547**	0.05237	0.04468
	0.0062	0.0646	0.2702	**0.0017**	0.3784	0.4524
	285	285	285	**285**	285	285

	AG-8	AG-2-1	Ro III	P. irr. I	P. irr IV	P. ult
Tillage	- 0.07873 0.185 285	0.01512 0.7993 285	0.07536 0.2046 285	**-0.1625** **0.006** **285**	- 0.03567 0.5487 285	- 0.03957 0.5058 285
Rotation	**0.15634** **0.0082** **285**	0.07276 0.2208 285	0.08193 0.1678 285	**0.11919** **0.0444** **285**	- 0.06552 0.2703 285	- 0.07363 0.2153 285
Fallow	- 0.01174 0.8444 282	- 0.04523 0.4493 282	0.05609 0.348 282	-0.0487 0.4152 282	- 0.03474 0.5613 282	-0.0236 0.6931 282
Legume	- 0.07448 0.21 285	0.10942 0.0651 285	-0.0314 0.5976 285	**0.13424** **0.0234** **285**	- 0.00961 0.8716 285	**0.13973** **0.0183** **285**
Barley	- 0.02718 0.6478 285	- 0.02527 0.671 285	- 0.02316 0.6971 285	- 0.02775 0.6409 285	- 0.00652 0.9127 285	- 0.01319 0.8246 285
Crop	- 0.05217 0.3802 285	0.04373 0.4621 285	0.02385 0.6885 285	0.05067 0.3941 285	- 0.04567 0.4425 285	0.05194 0.3824 285

[1] Bold font indicates significant relationships First line, the Pearson correlation coefficient; second line, probability (Prob > |r| under H0: Rho=0); third line, number of observations.

Presentations and Reports

Okubara PA, "*Rhizoctonia* Tolerance in Scarlet-Rz1," WSU Extension Weed and Rhizoctonia Management Workshop, Spangle, WA. Feb. 19, 2008.

Okubara PA, "*Rhizoctonia* and *Rhizoctonia* Tolerance in Scarlet-Rz1," Columbia Country Extension Variety Research Field Day, Dayton, WA. June 30, 2008.

Okubara PA, "EMS-Generated *Rhizoctonia* Resistance in an Adapted Wheat." 9th International Congress of Plant Pathology, Turin, Italy. Aug. 28, 2008.

Okubara PA, "Improved Quantification of Pathogen DNA from Soil Using Pressure Cycling Technology." 9th International Congress of Plant Pathology, Turin, Italy, Aug. 25, 2008.

Okubara PA, "Rhizoctonia Tolerance in Adapted Spring Wheat." Plant Pathology departmental seminar, Pullman, WA, Oct. 29, 2008.

Paulitz TC, "Appeal and Pitfalls of Continuous Wheat Rotation." Spokane County Crop Improvement Association Annual Meeting, Airway Heights, WA. Nov. 20, 2007.

Paulitz TC, "The Appeals and Pitfalls of an All-Wheat Rotation." Kennewick Far West Associates Meeting. Dec. 11, 2007.

Paulitz TC, "The Appeals and Pitfalls of an All-Wheat Rotation." Clearwater Direct Association Meeting. Jan. 15, 2008.

Paulitz TC, "The Appeals and Pitfalls of an All-Wheat Rotation." Walla Walla Growers. Feb. 5, 2008.

Paulitz TC, "The Appeals and Pitfalls of an All-Wheat Rotation." Spokane Farm Forum. Feb. 6, 2008.

Paulitz TC, "Rhizoctonia Research: Fitting the Pieces of the Puzzle." Spokane County Growers, Spangle, WA. Feb. 19, 2008.

Paulitz TC, "Cultural Management of Rhizoctonia in Cereals." Soil Fungus Conference, Santa Paula, CA. Mar. 27, 2008.

Paulitz TC, "Canola Disease Control Methods." Bio-Energy Workshop, Nespelam, WA. Apr. 10, 2008.

Paulitz TC, "Plant Pathology 101: Cereal Diseases." Presented to the Seed Academy, a 3-day workshop for seed workers, Pullman, WA. June 4, 2008.

Paulitz TC, "Fusarium Diseases of Cereals." Lind Field Day. June 19, 2008.

Paulitz TC, "Greenbridge Management of Rhizoctonia." ARS Palouse Conservation Farm Field Day, June 26, 2008.

Paulitz TC, "Diversity of *Rhizoctonia* in Direct-Seed Cropping Systems of the Pacific Northwest USA: Management and Solutions." Rhizoctonia Workshop, Berlin, Germany. Aug. 19, 2008.

Paulitz TC, "Integrated Control of Soilborne Wheat Pathogens." 9th International Congress of Plant Pathology, Torino, Italy. Aug. 28, 2008.

Scientific Publications

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Okubara PA, Steber CM, DeMacon VL, Walter, NL, Paulitz TC, Kidwell, KK. EMS-treated hexaploid wheat genotype Scarlet has enhanced tolerance to the soilborne necrotrophic pathogens *Rhizoctonia solani* AG-8 and *R. oryzae*. Theor Appl Genet, in revision.

Okubara PA and Jones SS (2008) Seedling tolerance to *Rhizoctonia* and *Pythium* in wheat chromosome grp 4 addition lines from *Thinopyrum* spp. Can J Plant Pathol., in revision.

Yan G, Smiley RW, Okubara PA, Skantar A, Easley SA, Sheedy JG, Thompson AL (2008) Detection and discrimination of *Pratylenchus neglectus* and *P. thornei* in DNA extracts from soil. Plant Dis 92(11): 1480-1487.

Okubara PA, Li C, Schroeder KL, Schumacher RT, Lawrence NP (2007). Improved extraction of *Rhizoctonia* and *Pythium* DNA from wheat roots and soil samples using pressure cycling technology. Can J Plant Pathol 29(3): 304-310.

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Schroeder KL, Flanagan RC and Paulitz TC (2008) Diversity of *Rhizoctonia* species in eastern Washington as determined by AFLP analysis. Phytopathology 98:S141-S142.

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Technical Reports/Extension

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Hulbert S, Babiker E, Paulitz T and Schroeder K (2008) Management of Rhizoctonia damping-off of *Brassica* oilseed crops in the PNW. pp. 26. In: *2008 Dryland Field Day Abstracts: Highlights of Research Progress*. Dept. of Crop and Soil Sciences Technical Report 08-1, Washington State University, Pullman. p. 26.

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Technology Transfer

CRADA No. 58-3K95-8-1268-M with Western Laboratories, Inc. for transfer of *Rhizoctonia* and *Pythium* real-time PCR technology

CSREES SBIR grant proposal "Enhanced-Throughput Quantification of *Rhizoctonia* and *Pythium* DNA in Soil Samples", submitted by Western Laboratories, Inc.