'R' is for Resistance

RESISTANT WHEAT VARIETIES OFFER SUSTAINABLE CONTROL OF STRIPE RUST

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Compared to the epidemic of stripe rust that occurred between 2002 and 2005, wheat growers in the Pacific Northwest (PNW) have enjoyed relatively low levels of stripe rust the last 3 years. Even under those low levels, however, research has shown susceptible winter wheat varieties would have had losses of 18 percent in 2009 if the disease hadn't been controlled, as shown in Table 1.

Club wheat *PS 279,* which is not a commercial variety but is used in our research experiments as a susceptible check, had an 18.3 percent yield loss in comparison with the same variety sprayed with a fungicide. Similarly, *Declo,* a hard red winter wheat variety grown on 17,600 acres in Washington in 2009, had a 15.5 percent yield loss.

Most other varieties in the table did not have significant yield losses thanks to resistance bred into them. That resistance is money in the bank to farmers. It's estimated that without resistant wheat lines, grain losses of more than 15 million bushels (worth $80 million) would have occurred—and that's just winter wheat. Losses are potentially higher for spring wheat.

The 15 to 18 percent potential yield loss for susceptible varieties in 2009 was the lowest in the past 8 years. Consider the fact that from 2002 to 2004, the yield loss of *PS 279* was estimated at 31 to 36 percent, jumping to 57 percent in 2005 and then declining to 22 to 28 percent yield loss in the period from 2006 to 2008. The amount of fungicides

Above: typical susceptible reaction of wheat varieties without any effective resistance to stripe rust. Below: typical reaction of wheat varieties with durable high-temperature adult-plant resistance to stripe rust. WSU photos

used to control the disease also correlates to the reduced pressure: in 2009, such applications were at their lowest level in 8 years.

The recent low levels of stripe rust can be attributed to three changes: first, the weather was less favorable for rust; second, timely application of fungicides helped slow down the spread of the disease; and third, a greater proportion of farmers are growing resistant varieties on more acreage.

Looking at each of those reasons individually, the temperatures in December and January of 2001-2002, 2002-2003, and especially 2004-2005 winters, were much warmer than normal, which allowed high survival rates of the pathogen and early rust development. In contrast, the weather during January 2007 and 2008, and December 2006 and 2009 were colder than normal. That reduced rust survival during the winter and delayed rust development in the spring. We recently developed improved models for forecasting stripe rust, which allows us to accurately predict the low rust level for the 2009 season as early as January.

The hard red winter wheat region in the Horse Heaven Hills is a stripe rust "hot spot" where (except for the western part of the state) the disease always shows up first. Because the winter wheat crop is planted earlier in this region than in other regions, stripe rust begins to infect the crop in the fall. The lack of resistance in the major hard red varieties has also made the region an important incubator of rust. From 2006 to 2009,

TABLE 1: Yield losses by stripe rust and increases by fungicide application on winter wheat varieties in experimental plots under natural infection near Pullman, WA, in 2009

	Acreage	Stripe rust AUDPC[b,c]		Yield (BU/A)[b,c]			Yield loss (%)	Yield Inc. (%)	Test Weight (LB/BU)[b,c]	
Cultivar	in 2009	Check	Fungicide	Check	Fungicide	Difference	by stripe rust	by fungicide	Check	Fungicide
AP700CL	13,000	12.50	0.00	119.40	125.67	6.27 *	4.99	5.25	59.10	59.00
Bauermeister	50,400	239.50	3.50 *	116.83	122.87	6.04	4.92	5.17	58.75	59.28
Boundary	10,400	783.50	7.50 **	106.17	111.44	5.28	4.74	4.97	60.48	61.04
Bruehl	96,400	8.50	0.00	125.76	117.68	-8.08	-6.87	-6.42	56.92	57.52
Brundage 96	32,100	178.00	0.00 ***	118.24	123.88	5.64	4.55	4.77	57.97	59.49 *
Cashup	16,500	244.00	0.00	108.71	115.35	6.64 **	5.76	6.11	60.12	60.44
Chuckar	15,600	17.50	0.00	123.87	129.09	5.23	4.05	4.22	59.63	59.31
Declo	17,600	1,134.00	1.50 **	92.89	109.98	17.09 *	15.54	18.40	59.59	61.64 *
Eddy	31,900	335.50	0.00	106.37	105.74	-0.63	-0.59	-0.59	63.12	63.12
Eltan	488,000[d]	322.00	0.00	116.19	119.07	2.88	2.42	2.48	58.71	59.10
Farnum	0	158.50	0.00 *	94.27	90.99	-3.28	-3.61	-3.48	59.35	59.56
Finley	25,400	660.50	54.00 *	93.06	92.62	-0.44	-0.48	-0.48	62.48	63.44 *
Lambert	35,600[d]	542.00	0.00 *	118.23	124.45	6.22 *	5.00	5.26	58.01	59.35 *
Madsen	199,500[d]	0.00	0.00	110.70	112.15	1.46	1.30	1.31	59.49	60.19
Masami	40,000[d]	201.50	10.00 *	121.16	124.02	2.86	2.31	2.36	58.36	59.03
ORCF-101	33,000[d]	62.50	0.00	109.05	111.66	2.61	2.33	2.39	59.07	59.35
ORCF-102	175,500[d]	72.50	2.00 *	119.68	120.86	1.18	0.98	0.99	59.95	60.41 *
Paladin	12,000	205.50	22.50 *	108.30	114.93	6.62 *	5.76	6.12	61.89	62.45
PS 279	0	1,655.00	23.00 ***	83.12	101.74	18.62 **	18.30	22.40	57.87	60.90 **
Rod	128,800[d]	178.00	0.00 *	125.28	131.10	5.83 *	4.44	4.65	58.29	58.68
Stephens	55,900[d]	82.00	0.00	115.16	118.63	3.46	2.92	3.01	57.76	58.36
Tubbs 06	10,200	288.00	0.00	123.19	129.91	6.72	5.18	5.46	57.97	59.35 *
Westbred 528	133,300[d]	45.50	0.00	123.55	122.74	-0.81	-0.66	-0.66	60.90	60.79
Xerpha	0	262.50	6.00	129.66	133.03	3.37	2.53	2.60	59.56	60.09

[b] AUDPC (area under the disease progress curve) is a measure of disease severity over time.
[c] Significant levels: * at $P = 0.05$; ** at $P = 0.01$; and *** at $P = 0.001$.
[d] Including acreage of mixture.

LEFT: XIANMING CHEN AT SPILLMAN AGRONOMY FARM, PULLMAN, WA/SCOTT YATES PHOTO fungicides were applied on time to wheat crops as the disease was observed. These early applications not only controlled rust in this region, but also reduced spores that might spread to other locations.

Growing resistant varieties is the most important factor for keeping stripe rust levels low. We can proudly say that wheat varieties grown in the PNW generally have the best stripe rust resistance in the world. This is the result of the long-term research and development by scientists of several generations. Since the early 1960s, high-temperature, adult-plant (HTAP) resistance that is durable has gradually become the key type of resistance used in breeding programs. Almost all soft white winter wheat varieties currently grown in the PNW have HTAP resistance.

Significant changes in varieties have occurred since 2002. Susceptible varieties disappeared gradually or quickly from production. For example, in Washington the acreage of *Westbred 470,* one of only a few soft white winter wheat varieties susceptible to stripe rust, decreased from 30,600 acres in 2002, to 26,900 in 2005, to 22,800 in 2007, to not-listed in 2008 and 2009. Susceptible hard red winter wheat *Hatton* decreased from 33,900 acres in 2002, to 5,900 in 2005, to not-listed since 2006. Susceptible soft white spring wheat *Zak* decreased from 85,500 acres in 2002, to 8,400 acres in 2005, to not-listed since 2006.

New varieties released in Washington since 2002 generally have very good resistance to stripe rust. Many new releases have quickly become major varieties. For example, the soft white spring wheat variety *Louise,* which has excellent HTAP resistance and was released in 2004, was grown on 14,200 acres in 2006. *Louise* became the No 1 soft white spring variety (70,100 acres) in 2007, and was grown on 128,500 acres in 2008 and 178,900 acres in 2009.

The release of *Bauermeister* with HTAP resistance in 2005 changed the previous hard red situation of general susceptibility. *Bauermeister* was the No 1 hard red winter wheat variety for the last 3 years, growing on 90,500 acres in 2007, 72,300 acres in 2008, and 50,400 acres in 2009.

The stripe rust fungus is able to change its ability to attack varieties with race-specific resistance. Every year, we identify new races and determine distributions, frequencies of races, and the impact of new races on currently grown varieties, breeding lines and resistant germ plasms. We have detected three major waves of race changes during the past ten years. Races able to attack more resistance genes have become predominant. The new races in recent years have broken down the high level of race-specific resistance in many of the hard red

XIANMING CHEN AT SPILLMAN AGRONOMY FARM, PULLMAN, WA/SCOTT YATES PHOTO

Table 2: Stripe rust reaction ratings of winter and spring varieties of wheat and barley

Winter Wheat and Barley

Variety	Stripe rust rating
Soft White Winter	
AP700 CL (CLEARFIELD®)	R
Brundage 96	MR
WB 456	MR
WB 523	R
WB 1020M (CLEARFIELD®)	R
Cashup	R
Clearfirst	R
Concept	R
Eltan	R
Finch	R
Hill 81	R
Idaho 587 (CLEARFIELD®)	R
Lambert	R
Lewjain	MR
Madsen	R
Masami	MR
Mohler	MR
ORCF-101 (CLEARFIELD®)	MR
ORCF-102 (CLEARFIELD®)	MR
ORCF-103 (CLEARFIELD®)	MR
Rjames	R
Rod	MR
Salute	R
Simon	R
Stephens	R
Tubbs	MR
Tubbs 06	MR
WB-528	R
Xerpha	MR
Hard Red	
AgriPro Paladin	MS
Bauermeister	MR
Boundary	MS
Buchanan	S
Declo	S
Eddy	MS
Farnum	MR
Finley	S
Juniper	MS
Norwest 553	R
Whetstone	MR
Hard White	
MDM	MR
Palomino	MS
UI Darwin	R
Club	
Bruehl	R
Cara	R
Chukar	R
Coda	MS
Edwin	MR
Moro	S
Rely	MR
Winter Barley	
Boyer	MS
Charles	- -
Hesk	S
Hundred	S
Kamiak	S
Kold	R
Strider	MR
Sunstar Pride	S
Westbred Sprinter	S
Hoody	S

Spring Wheat and Barley

Variety	Stripe rust rating
Soft White Common	
Alpowa	MR
Alturas	MR
Babe	MR
Louise	R
Nick	S
UI Cataldo	MR
Wakanz	MR
Whit	MR
Zak	S
Soft White Club	
Eden	MS
JD	MR
Hard Red	
Buck Pronto	MR
Cabernet	MR
Express	MR
Expresso	R
Hank	S
Hollis	MS
Jedd (Clearfield®)	S
Jefferson	MS
Jerome	MS
Kelse	MR
Scarlet	S
Solano	MR
Tara 2002	S
Volt (ASC52610)	R
Westbred 926	MS
Hard White	
Blanca Grande	R
Lolo	S
Macon	S
Otis	MR
Waikea	MR
Spring Malting Barley	
AC Metcalfe	S
Harrington	S
Legacy	S
Morex	S
Spring Non-Malting Barley	
Baronesse	MS
Bob	MR
Boulder	S
Burton	S
Camas	S
Champion	S
Farmington	MS
Kent	S
Radiant	S
Spaulding	S
Spring Hooded Barley	
Belford	S

R— Resistant
MR— Moderately Resistant
S— Susceptible
MS— Moderately Susceptible

Severe stripe rust in a winter wheat field in 2004. WSU photo

and hard white spring wheat varieties, such as *Hank, Hollis, ID377s, Jefferson, Tara 2002, Westbred 926,* and the soft white spring wheat *Nick.* For better stripe rust management, such varieties should be withdrawn from production.

A good aspect of the race changes is that they do not have much effect on HTAP resistance in the majority of the currently grown varieties. This is the reason that breeders make every effort to ensure new varieties have HTAP resistance. In recent years, our program, working jointly with other programs, has identified numerous resistance genes and developed markers for incorporating these genes into new cultivars, as well as combined different genes to achieve a high-level of durable resistance.

To assist growers in choosing which resistant varieties to plant, stripe rust reaction ratings of currently grown and newly released varieties are listed in Table 2. Varieties with "R" for resistant and "MR" for moderately resistant ratings should be chosen before those with "S" for susceptible and "MS" for moderately susceptible, which should be avoided. Farmers must confront the challenge of choosing varieties with excellent quality and also adequate stripe rust resistance. ARS scientists, along with breeders at WSU, are working together to bring both traits into new varieties. ■