STRIPE RUST ON FORAGE WHEAT AND OTHER DISEASES OF CEREAL FORAGES

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ABSTRACT

Wheat stripe rust was devastating to the California wheat crop in general, and to the forage wheat crop in particular, in 2003. Many other states across the country also experienced severe stripe rust. The disease developed early and was more severe than normal throughout much of the U.S. A combination of very mild winter temperatures (particularly December through January) and early sowing resulted in very early infections, about 6 weeks earlier than normal for California's Central Valley. Cool conditions persisted much longer in spring than usual and stripe rust reached very high levels throughout the Central Valley and surrounding areas. Where stripe rust was most severe, highly susceptible cultivars suffered 75% or more yield loss; susceptible cultivars, 50-70% yield loss; moderately susceptible cultivars, 20-40% yield loss; and moderately resistant cultivars, 5-15% yield loss. Very few cultivars maintained resistance through the season. The causal fungus, *Puccinia striiformis tritici*, is tremendously diverse; new races/strains able to cause disease on previously resistant cultivars are quick to develop. At the end of the 2002 season 12 races of wheat stripe rust had been identified in California. Additional new races became established in 2003. Although stripe rust was the most important disease of cereal forages in 2003, the common practice of early sowing wheat and oat forages makes them vulnerable to other diseases such as BYD (wheat and oat) and Septoria tritici blotch (wheat). Other important diseases include leaf rust (wheat), crown rust (oat) and stem rust (oat). Use of resistant cultivars is the most important disease control practice.

Key Words: wheat, oat, cereal forages, diseases, stripe rust, Puccinia striiformis

INTRODUCTION

Wheat stripe rust, caused by the fungus *Puccinia striiformis tritici*, was widespread in California in 2003. I even detected a small focus of infection in the Imperial Valley; this probably is the first report of stripe rust in that region. Many other states across the country also experienced severe stripe rust. The disease developed early and was more severe than normal throughout much of the U.S. It hit Washington and Oregon in the Pacific Northwest, Texas and Oklahoma in the Southern Plains, Kansas and Nebraska in the Central Plains, South Dakota, North Dakota, and Minnesota in the Northern Plains, Louisiana, Georgia, Arkansas, and Missouri in the South, Illinois and Ohio in the Mid East, and Virginia in the East. In California wheat fields where stripe rust was most severe (fields receiving no fungicide application), highly susceptible cultivars suffered 75% or more yield loss; susceptible cultivars, 50-70% yield loss; moderately susceptible cultivars; 20-40% yield loss, and moderately resistant cultivars, 5-15% loss. Very few cultivars maintained resistance through the season. The popular forage cultivar Dirkwin is

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highly susceptible, as are Yecora Rojo and Brooks, cultivars preferred for green-chop forage in the San Joaquin Valley. Although stripe rust was most prevalent and damaging in 2003, other diseases also threaten cereal forages. Among the more important diseases are barley yellow dwarf (BYD), Septoria tritici blotch, and several rust diseases (leaf rust of wheat, crown rust of oat, and stem rust of oat).

WHEAT STRIPE RUST

Early Disease Development in 2003. A combination of very mild winter temperatures (particularly December through January) and early sowing (particularly of wheat for forage for dairies) resulted in very early infections, about 6 weeks earlier than normal for California's fall-sown spring wheat crop. Cool conditions persisted much longer in spring than usual and stripe rust reached very high levels throughout the Central Valley and surrounding areas. The spores that cause infection can be carried very long distances in the air; the Central Valley can be considered one large mixing basin. It doesn't take many initial infections to start an epidemic since the fungus is very prolific; it has the potential for a 10,000-fold increase per spore generation. Under cool, damp conditions it only takes 7-10 days from infection to the production of new sporulating pustules.

Disease Cycle – Initial Infection and Over-Season Survival. Urediospores, the reddish-yellow repeating spore stage of the fungus, are spread by wind to initiate infections. Multiple disease cycles occur over the course of the season as disease increases in severity. Near the end of the season black-colored pustules containing teliospores develop as the plant reaches maturity; teliospores are not infective; the fungus, an obligate parasite, requires a living host for it to survive. Although some grasses are hosts, volunteer wheat that develops between growing seasons in orchards, roadsides, ditchbanks, and in other crops and becomes infected by air-borne spores is the most important source of initial inoculum for the later sown wheat crop.

Disease Cycle – Spread During the Growing Season. The literature on wheat stripe rust says that disease development is most rapid at temperatures of 10-15°C with intermittent rain and dew and that secondary cycles can occur at 7-10 day intervals as long as conducive weather conditions occur. The disease can continue to develop where daytime temperatures are quite high (San Joaquin Valley in late spring) as long as nighttime temperatures are not higher than about 15°C. This low temperature optimum (compared to that of leaf rust) makes stripe rust a potentially more damaging disease than leaf rust since it can start earlier in the season and go through more disease cycles. The other side of the coin is that high temperatures have been thought to be unfavorable and to halt disease progress later in the season when temperatures rise and rain and dew are less likely to occur. I'm not sure that that's the case any more. The pathogen may have adapted to warmer, dryer conditions. During the 2003 season, stripe rust continued to thrive on wheat throughout the Central Valley very late in the season; I observed active sporulation on spikes and green leaves through the 4^{th} week of May.

Changes in Cultivar Susceptibility. The fungus is tremendously diverse. New races able to cause disease on previously resistant cultivars are quick to develop. The changes in susceptibility of cultivars that occurred during 2003 can be attributed to the very favorable conditions for disease that occurred, producing an abundant inoculum load and the opportunity for mutations to higher virulence to occur (generating new races). At the end of the 2002 season, 12 races of wheat stripe rust had been identified in California (Table 1). Additional new races became established in 2003 (Table 2).

Table 1. Races of Wheat Stripe Rust in California, 2002

Race	Virulence	# Collections by Region
PST-12	1,5,6,12	SAC (1)
PST-49	1,3,11,14	SAC (1)
PST-67	1,2,3,11,12,16	SJV (1)
PST-77	1,11,12,16,17,18,19,20	SAC (2), SJV (1)
PST-78	1,3,11,12,16,17,18,19,20	SAC (3), SJV (1)
PST-80	1,3,8,11,12,16,17,18,19,20	SAC (3)
PST-90	1,3,11,12,14,16,17,18,19,20	SAC (1)
PST-94	1,9,10,12	SJV (1)
PST-96	1,4,6,8,10,12,14	SAC (3)
PST-97	1,3,10,11,12,16,17,18,19,20	SAC (3), SJV (4)
PST-98	1,3,8,10,11,12,16,17,18,19,20	SAC (2), SJV (1)
PST-99	1,3,9,10,11,12,16,17,18,19,20	SAC (1)

Table 2. Races of Wheat Stripe Rust in California, 2003 (Preliminary)

Race	Virulence	# Collections by Region
PST-21	2	COAST (1)
PST-77	1,11,12,16,17,18,19,20	SJV (3)
PST-78	1,3,11,12,16,17,18,19,20	SAC (1), COAST (1)
PST-79	1,8,11,12,16,17,18,19,20	SAC (1), SJV (1)
PST-80	1,3,8,11,12,16,17,18,19,20	SAC (2), SJV (3)
PST-97	1,3,10,11,12,16,17,18,19,20	SAC (5), SJV (3)
PST-98	1,3,8,10,11,12,16,17,18,19,20	SAC (8), SJV (7)
PST-99	1,3,9,10,11,12,16,17,18,19,20	SJV (3)
NEW (GP1)	1,3,8,9,10,11,12,16,17,18,19,20	SAC (1), SJV (2)
NEW (GP2)	1,8,10,11,12,16,17,18,19,20	SJV (2)

Susceptibility of the main wheat cultivars in California, based on disease levels in the 2003 University of California Regional Wheat evaluation tests, are shown in Table 3.

Table 3. Reaction of California Wheat Cultivars to Stripe Rust

Reaction Class	Cultivar(s)
Highly Susceptible	Dirkwin, Bonus, Brooks, Cavalier
Susceptible	Yecora Rojo, Anza, Klasic, Eldon, Yolo, Kern, Serra, Dariel, Kama
Moderately Susceptible	Express
Moderately Resistant	Stander, Beth Hashita
Resistant	Summit, Blanca Grande, Plata

Effectiveness of Genes for Resistance – 2003 Season. A wheat stripe rust screening nursery was grown and evaluated at UC Davis in 2003. The nursery included the stripe rust differentials (lines containing known genes for resistance to stripe rust) (Table 4). Based on the disease reactions of the differentials in the 2003 nursery, the genes Yr1, Yr2, Yr3a, Yr4a, Yr7, Yr9, Yr13, Yr18, Yr20, Yr21,Yr22, Yr23 were not effective against California's 2003 population of *Puccinia striiformis tritici*. Additional sources of resistance are needed.

Table 4. Wheat Stripe Rust Differentials

Diff.	Name	Genes for Resistance
1	LEMHI	Yr21
2	CHINESE 166	Yr1
3	HEINESE VII	Yr2, YrHVII
4	MORO	Yr10, YrMor
5	PAHA	YrPa1, YrPa2, YrPa3
6	DRUCHAMP	Yr3a, YrDru1, YrDru2
7	RIEBESEL 47/51	Yr9 + ?
8	PRODURA	YrPr1,YrPr2
9	YAMHILL	Yr2,Yr4a,YrYam
10	STEPHENS	Yr3a,YrSte1,YrSte2
11	LEE	Yr7,Yr22,Yr23
12	FIELDER	Yr6,Yr20
13	TYEE	YrTye
14	TRES	YrTr1,YrTr2
15	HYAK	Yr17,YrTye
16	EXPRESS	Yr?
17	Yr8/6*AVS	Yr8
18	Yr9/6*AVS	Yr9
19	CLEMENT	Yr9,YrCle
20	COMPARE	Yr8,Yr19

Underlined: Not effective against California's *Puccinia striiformis tritici* population, 2003

Disease Severity and Yield Loss of California Wheat Cultivars, 2003. Statewide yield losses to wheat stripe rust in 2002 were 6%. Losses in 2003 were much higher since the disease was both more severe and more widespread than it was in 2002. Where disease was most severe (and fields were not treated with either Tilt or Quadris fungicides), highly susceptible cultivars sustained 75% or more yield loss; susceptible cultivars, 50-70% yield loss; moderately susceptible cultivars, 20-40% yield loss; moderately resistant cultivars, 5-15% yield loss; and resistant cultivars, 0-5% yield loss. Statewide, yield losses averaged 25% or more. Data from the UC Regional test sites in the Sacramento Valley where disease levels were very high confirm these loss estimates (Table 5). The most severely diseased cultivars had the lowest yields. For example, the highly susceptible cultivar Bonus, which has a high yield potential in the absence of stripe rust, had extremely low yields where stripe rust was severe. In contrast, Summit, which is resistant to stripe rust, had very high yields at sites where stripe rust was severe. Stripe rust also was severe at the UC Regional test sites in the San Joaquin Valley, although it was later to develop and had a less dramatic affect on yield (Table 6). At the Kings Regional Test site, the only site where the grower applied fungicide (Quadris), yields of susceptible cultivars such as Brooks and Yecora Rojo were about 1000-2000 lbs/acre higher than at the other sites, with the difference attributed to the fungicide application. Losses still were substantial, however, since disease control was not maintained for the entire season. New resistant cultivars are needed. All wheat breeding programs in California are working towards that goal.

Table 5. Grain Yield vs Stripe Rust Severity, Sacramento Valley, 2003

	Grain Yield (lb/acre)				Stripe Rust (1-8)			
Cultivar	Butte	Colusa	UC Davis	Sac-SJ Delta	Butte	Colusa	UC Davis	Sac-SJ Delta
ANZA	2750	2710	2420	3510	5.0	4.5	5.3	3.0
YECORA ROJO	1920	660	980	360	7.5	7.3	8.0	7.8
YOLO	2290	850	1630	2120	4.8	8.0	8.0	6.5
KLASIC	2430	1760	1670	2450	7.0	8.0	8.0	6.3
SERRA	3770	2700	2730	2530	4.0	4.5	5.5	3.8
EXPRESS	4040	3870	3350	3200	3.0	5.0	2.8	3.0
CAVALIER	1090	260	740	320	7.3	8.0	8.0	8.0
BROOKS	1150	270	440	270	7.8	8.0	8.0	8.0
BONUS	2030	170	670	610	8.0	8.0	8.0	5.8
KERN	2880	2400	2290	2900	5.3	8.0	8.0	5.3
ELDON	2410	650	840	600	6.3	8.0	7.5	7.3
STANDER	4980	6110	5540	5980	1.0	1.3	1.3	1.0
SUMMIT	6000	7570	6260	7310	1.3	1.5	1.8	1.3
BLANCA GRANDE	4460	6050	6040	6540	1.5	1.3	1.5	1.0
PLATA	5880	7240	6260	6890	1.0	1.0	1.0	1.0
BETH HASHITA	3880	4810	4700	5720	1.0	2.3	2.0	1.0
DARIEL	2330	230	1320	300	5.3	8.0	7.8	7.5
KAMA	3080	1850	1730	790	4.5	4.5	4.8	4.3
MEAN	3210	3130	2960	3300	4.2	5.2	5.1	4.3
CV	14.6	12.7	10.8	6.8	19.4	8.9	12.3	11.5
LSD (.05)	660	560	450	310	1.1	0.6	0.9	0.7

Stripe rust scale (area of flag-1 leaf affected): 1 = 0-3%, 2 = 4-14%, 3 = 15-29%, 4 = 30-49%, 5 = 50-69%, 6 = 70-84%, 7 = 85-95%, 8 = 96-100%.

Table 6. Grain Yield vs Stripe Rust Severity, San Joaquin Valley, 2003

Cultivar	Grain Yield (lb/acre)			Stripe Rust (1-8)		
	Madera	Kings*	Kern	Madera	Kings	Kern
ANZA	3800	5280	4040	4.0	3.5	4.8
YECORA ROJO	1400	3800	2880	8.0	5.8	6.8
YOLO	2610	5000	4010	8.0	5.8	6.0
KLASIC	2750	5410	3920	8.0	5.0	7.3
SERRA	2670	5290	4730	4.8	3.8	4.0
EXPRESS	4600	5120	5590	4.5	4.0	4.0
CAVALIER	580	3640	2400	8.0	6.0	7.3
BROOKS	250	2490	1260	8.0	5.8	8.0
BONUS	1630	3070	1760	8.0	5.3	7.5
KERN	2990	5200	4840	8.0	5.0	5.5
ELDON	1790	2880	3610	8.0	6.3	6.8
STANDER	6210	6760	6450	3.0	1.3	1.5
SUMMIT	6440	7240	8170	1.0	1.0	1.3
BLANCA GRANDE	4850	7750	6900	1.0	1.3	1.0
PLATA	6540	7230	7960	1.0	1.0	1.0
BETH HASHITA	5270	6220	6640	1.0	1.0	1.0
DARIEL	1830	3720	3690	7.8	4.8	6.5
KAMA	2420	4530	3670	4.0	4.0	4.3
MEAN	3460	5070	4810	5.0	3.7	4.3
CV	10	10.7	9.5	12.7	14.4	15.9
LSD (.05)	480	760	640	0.9	0.8	1.0

Stripe rust scale (area of flag-1 leaf affected): 1 = 0-3%, 2 = 4-14%, 3 = 15-29%, 4 = 30-49%, 5 = 50-69%, 6 = 70-84%, 7 = 85-95%, 8 = 96-100%.

* Quadris fungicide applied on March 29 (late boot to early heading stage).

OTHER DISEASES OF CEREAL FORAGES

Septoria tritici leaf blotch. Septoria tritici leaf blotch of wheat, caused by the fungus *Mycosphaerella graminicola* (anamorph = *Septoria tritici*), is most important on wheat in the Sacramento and northern San Joaquin valleys and can be severe during years of higher than average rainfall and when late spring rains persist after emergence of the flag leaf. Chlorotic flecks become visible on lowermost leaves and expand to irregularly shaped lesions. The lesions first appear water-soaked, then become dry, yellow and, finally, red-brown with gray-brown ashen centers. The fungus survives between cropping seasons on wheat residue. The spores (ascospores) of *M. graminicola* are discharged into the air from perithecia (sexual fruiting bodies) produced in wheat residue from the previous crop. The spores are capable of long distance spread; they are carried by wind to infect the developing wheat crop. Lesions containing *Septoria tritici* pycnidia appear 3 to 4 weeks later. Spores (conidia) formed within pycnidia are dispersed by rain-splash and wind-driven rain and spread the disease within fields. Spore germination and disease development are optimal at 16° to 25°C when free moisture is present on the foliage. Under conducive moisture and temperature conditions, secondary cycles of infection occur every 21 to 28 days. Dry periods and warm weather prevent infection and disease spread. The disease is most severe on early-sown (October) wheat because the plants are exposed over a longer period of time when weather conditions are favorable for disease development. Later sowings (November to December) are less likely to be severely affected. Use of resistant cultivars and disease-free seed and elimination of wheat residue and volunteer wheat plants also help control disease. Rotations in which wheat appears every third year eliminate most carryover inoculum, but do not provide protection from infection by ascospores from distant fields.

Barley yellow dwarf (BYD). BYD is an aphid-transmitted virus disease of wheat, barley, oat, and other grasses. Early sowing dates, preferred for production of forage for dairies in the Central Valley, increases crop vulnerability to BYD. Symptoms include uneven, blotchy leaf discoloration in various shades of yellow, red, or purple, progressing from leaf tip to base and margin to midrib. Wheat leaves usually become yellow while oat leaves usually become red. Plants can be stunted and those infected as seedlings may be killed. Infected plants have less developed root systems than healthy plants. Oat panicles can be blasted (florets become sterile). The virus survives in most common grain aphids (including bird cherry-oat aphid, English grain aphid, rose grass aphid, corn leaf aphid, and greenbug) and on numerous cereal and grass hosts. The Russian wheat aphid is not a vector. Aphids can acquire the virus in a feeding period of as short as 30 minutes, although 12 to 30 hours is more typical. Transmission can occur one to four days after acquisition following a feeding period of four hours or more. Epidemics are most likely to occur in cool, moist seasons that favor grass and cereal growth and aphid multiplication and migration. Plants can be infected throughout the growing season. Disease control is through the use of resistant cultivars and avoidance of very early (September to October) or very late (February to March) sowing dates for fall-sown small grain crops. Sowing the crops during such times exposes plants to active aphid populations when plants are in early growth stages and most vulnerable to damage from infection.

Wheat Leaf rust. Leaf rust, caused by the fungus *Puccinia recondita*, is a late season disease that is most severe in years with lower than normal late spring temperatures and high humidity. Pustules on wheat are reddish orange and scattered or clustered on upper leaf surfaces. As the plants mature, the pustules turn dark and shiny, indicating the formation of teliospores. Teliospores do not play a role in disease development or survival in California. Volunteer wheat plants and distant wheat fields are the sources of primary inoculum. Spores (urediospores) produced in pustules on leaves are dispersed over long distances by wind and cause initial infections. Similar to stripe rust, secondary cycles can occur at 7-10 day intervals as long as conducive weather conditions occur. Leaf rust is most severe when temperatures are about 15° to 25°C and humidity is high or rainfall is intermittent. It will cause the greatest reductions in yield if infections occur prior to spike emergence and continue for 30 to 40 days during the grain fill period. Use of resistant cultivars is the most important disease control practice.

Crown Rust of Oat and Stem Rust of Oat. Crown rust of oat, caused by the fungus *Puccinia coronata*, has a similar epidemiology to leaf rust of wheat. Pustules of crown rust are oblong and orange colored. The shape of the spore and its ornamentation are the reasons for the name "crown rust". Pustules of stem rust, caused by the fungus *Puccinia graminis*, develop on stems as well as on leaves and leaf sheaths. The pustules are elongated, have conspicuously tattered edges in contrast to the smooth edges of pustules of crown rust, and contain brick-red spores. As plants mature, pustules of both stem rust and crown rust turn dark as teliospores form. Common cultivars of oat Curt, Swan, Kanota, Sierra, Montezuma, and California Red are susceptible to crown rust; Swan, Kanota, Sierra, Montezuma, California Red are susceptible to stem rust. Use of resistant cultivars is the most important disease control measure.