

Epidemiology of Stripe Rust, Virulence of *Puccinia striiformis* f. sp. *hordei*, and Yield Loss in Barley

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ABSTRACT

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Barley stripe rust (caused by *Puccinia striiformis* f. sp. *hordei*) was found for the first time in the United States in 1991. This study was conducted from 1991 to 1994 to determine the occurrence and spread of the disease, the identity and relative frequency of races present, and the amount of yield loss attributable to the disease on cultivars having different levels of resistance. Surveys and urediniospore collections were made in commercial barley fields, barley breeding nurseries, and wild *Hordeum* spp. throughout Texas, southwest Oklahoma, and northeast New Mexico. Commercial fields of the cultivars Post and Tambar 500 in Winters and Era, Texas, were systematically assessed for stripe rust severity. Race determinations were made by inoculating the urediniospore collections onto a set of 18 differential cultivars. To determine yield loss, four fungicide treatments (triadimefon + mancozeb, propiconazole, tebuconazole, and flusilazole) were compared with untreated checks of seven barley cultivars. In 1991, *P. s. f. sp. hordei* was found only in the breeding nursery at Uvalde, and on *H. jubatum* and *H. leporinum* in the Uvalde area. Stripe rust occurred in commercial barley throughout the state in 1992 and 1993, yet was found only on highly susceptible cultivars in nurseries in 1994. The highest severity found in commercial barley was 8% at the soft dough development stage on cv. Post at Winters in 1993. From a total of 273 isolates, 255 were race 24, 14 were race 23, and 4 were of a different race, labeled TXG. The most grain yield loss was about 72% on cv. Perkins at Uvalde in 1992. We found that cv. Tambar 401 was resistant and cvs. Tambar 500 and Kold were moderately resistant to *P. s. f. sp. hordei*, and none of these three cultivars sustained significant yield loss to barley stripe rust. Over cultivars, locations, and years, all of the fungicide-treated plots had significantly less yield loss than untreated checks. Even though barley stripe rust has the potential to become a severe disease in the U.S., host resistance in winter barley and fungicides can effectively minimize yield loss.

On 18 April 1991, stripe rust was found on barley (*Hordeum vulgare* L.) plots in a Texas A&M University small grain breeding nursery located at Uvalde, Tex. Stripe rust was severe on the barley, but absent from adjacent plots of wheat (*Triticum aestivum* L.). Leaves with rust uredinia were placed in glassine envelopes and sent to the USDA Cereal Rust Laboratory in Minnesota. Subsequent virulence analysis indicated the spores were those of *Puccinia striiformis* Westend. f. sp. *hordei* Eriksson, the stripe rust pathogen of barley (17). This was the first confirmed occurrence of barley stripe rust in the United States.

Historically, barley stripe rust has occurred in parts of western Europe, the Middle East, south Asia, and east Africa (21). In the Western Hemisphere, the disease was found first in 1975 near Bogota, Colombia, where it was probably introduced from Europe (4). The rust spread predominantly southward from Colombia, and by 1982 was responsible for yield loss

in much of the cultivated barley in South America. The northward movement of stripe rust from Colombia was slower, probably due to a scarcity of compatible hosts. However, by 1990, the disease was found on barley cultivars in mountainous areas of north central Mexico. *Puccinia s. f. sp. hordei* race 24 was the principal virulence combination found in the Americas, although variants were detected (4).

The limited hectareage of barley in Texas and the way the crop is used will affect the epidemiology of barley stripe rust in the southern Great Plains. During the course of this study (1991 to 1994), barley was sown annually on about 28,000 hectares in Texas. This hectareage was a 20% decrease from the 35,000 ha planted annually from 1985 to 1990. This decrease in barley hectareage was due mainly to a parallel increase in wheat plantings. Forecasters estimate that barley hectareage in Texas will increase somewhat during the years 1995 to 2000, to an annual level of about 40,000 ha (Texas Department of Agriculture, unpublished data). In the twentieth century, the most acreage sown to barley in Texas was about 110,000 ha; this occurred from the mid-1960s to early 1970s. Barley, like other cool season cereal crops in the state, typically is sown in the late summer or

early fall, and subsequently used as fall and winter grazing pasture for beef and dairy cattle. In late winter, the cattle may be removed from the pasture to allow the crop to produce grain, or the cattle may be allowed to graze-out the pasture (1). On average, 40% of the planted barley area is harvested for grain in Texas. The grain that is harvested is typically used for animal feed. The three main barley cultivars grown in Texas are Post (CI 15695), Post 90 (PI 549081), and Tambar 500 (PI 561204). Although exact figures are not available, it is not uncommon for Texas producers to mix barley cultivars, or even mix barley with wheat and/or triticale (*x Triticosecale*) prior to sowing, particularly in graze-out fields.

This research was conducted from April 1991 to June 1994 with the objective of determining the occurrence, severity, and physiologic races of *P. s. f. sp. hordei* present in Texas, southwestern Oklahoma, and northeastern New Mexico. We also determined the amount of grain yield lost to barley stripe rust in 1992 and 1993 by means of fungicide-treated and untreated plots.

MATERIALS AND METHODS

Disease survey. Occurrence and severity of stripe rust in commercial barley fields, barley breeding nurseries, and wild *Hordeum* spp. were monitored about every 6 to 8 weeks from June through January, and about every 2 to 3 weeks from February through the end of May in each year, beginning in April 1991. The surveys were conducted as previously described (10), noting field location, crop growth stage (8) and condition, and rust severity.

Near Winters and Era, Texas (Fig. 1), we identified stripe rust in two production fields each of Post and Tambar 500 winter barley, and monitored the disease progress in 1992, 1993, and 1994 (eight fields per year; 24 fields total). For stripe rust assessment in each field, we walked a meandering course of about 300 m, and arbitrarily picked a flag leaf (uppermost leaf) approximately every 6 m, to obtain 50 leaves per field. Stripe rust severity (visual percentage of leaf surface covered) was estimated on each leaf with the aid of diagrams (18,24), and the average severity for the field was determined from the 50 leaves. Each field was assessed four times in 1992 and 1993, and three times in 1994. The first assessment was made just after Feekes stage 9 (boot stage), and the time

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between assessments of any one field ranged from 12 to 20 days. The area under the disease progress curve (AUDPC) was calculated for each field according to Campbell and Madden (3) and expressed in units of percent-days. AUDPC values were analyzed by analysis of variance, with mean separation based on Fisher's least significant difference (LSD) at a 5% probability level (12).

Virulence analysis. During the field surveys, leaves containing sporulating uredinia were placed in glassine envelopes, stored in a cooler, and transported to the laboratory at Dallas, where the urediniospores were inoculated immediately onto seedlings (five 3-week-old plants clumped in the center of a 100-cm² pot) of the winter barley cultivar Sussex (PI 471914). Inoculated plants were placed in a dew chamber at 10°C for 48 h (each 24 h cycle was 16 h light and 8 h dark) to promote infection (22), then placed and kept in a growth chamber with 16 h light at 15°C and 8 h dark at 12°C. A clear plastic cage was placed over each pot to minimize urediniospore movement in the chambers. Fourteen to 16 days after inoculation, a solitary uredinium of *P. s. f. sp. hordei* was excised from a leaf and used to inoculate a second pot of Sussex plants, under the conditions described above. This was done to purify each isolate and to produce urediniospores of each isolate for further testing. After 14 to 16 days, the urediniospores of each isolate were inoculated onto a set of differentials (Table 1), placed in the dew chamber, and then moved to the growth chamber as described above. Two seedlings of each differential were inoculated per isolate. The average stripe rust reaction of the seedlings was noted about 14 days following inoculation on primary and secondary leaves, using a 0 to 9 scale (11). On this scale, values of 0 to 3 represent resistant reactions, 4 to 6 are intermediate, and 7 to 9 are considered susceptible. The experiment was repeated three times for each isolate.

Yield loss experiments. Field experiments were conducted at Dallas and Uvalde in the 1992 season and at Prosper and Uvalde in 1993. The barley cultivar Perkins (PI 536646) was used in 1992, while the cultivars Hundred (PI 536543), Kold (PI 584507), Steptoe (CI 15229), Sussex, Tambar 401 (CI 13778), and Tambar 500 were used in 1993. The sowing rate was 84 kg per ha and each plot measured 4.6 m², with 7 rows at 18 cm row spacing. The experimental design was a randomized complete block with four replications. Five treatments were used: (1) unsprayed check; (2) triadimefon (Bayleton 50DF) at 70 g a.i. per ha plus mancozeb (Manzate 200) at 1.79 kg a.i. per ha; (3) propiconazole (Tilt 3.6E) at 117 g a.i. per ha; (4) tebuconazole (Folicur) at 219 g a.i. per ha; and (5) flusilazole (Punch 2E) at 270 g a.i. per ha. A compressed air,

backpack sprayer was used to apply all fungicides, with propiconazole application at about Feekes stage 8 (flag leaf visible) and the remaining treatments at about Feekes stage 10.1 (first spikelet visible).

RESULTS

Disease occurrence and severity. In 1991, barley stripe rust was not found on cultivated barley outside the barley breeding nursery at Uvalde. However, some

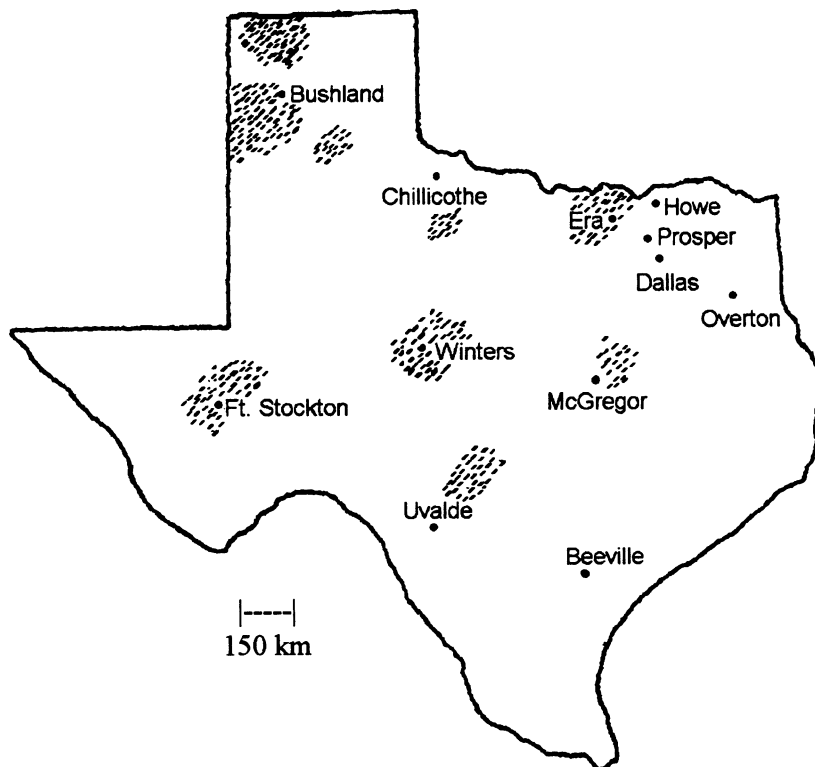


Fig. 1. Twelve locations in Texas where barley nurseries were grown from 1991 to 1994. Stippled areas represent areas with commercial barley production.

Table 1. Race determination of *Puccinia striiformis* f. sp. *hordei* isolates on differential cultivars of barley^a

Differential cultivar	Accession number ^b	Race 23 ^c	Race 24 ^c	TXG race
Abed Binder 12	PI 327961	3 (1 to 3)	3 (2 to 3)	1 (0 to 1)
Abyssinian 14	PI 151789	0 (0 to 1)	0 (0 to 1)	2 (0 to 2)
Astrix	PI 494107	1 (0 to 2)	7 (6 to 9)	9 (8 to 9)
BBA 806	PI 548743	1 (0 to 1)	0 (0 to 1)	1 (0 to 2)
Bigo	PI 328754	0 (0 to 1)	0 (0 to 1)	7 (5 to 9)
Cambrinus	PI 321779	1 (1 to 3)	7 (6 to 8)	8 (8 to 9)
Emir	PI 321787	2 (1 to 2)	2 (0 to 2)	8 (8 to 9)
Fong Tien	NIC	9 (8 to 9)	9 (8 to 9)	9 (7 to 9)
Heils Franken	PI 290183	2 (0 to 2)	7 (6 to 8)	9 (8 to 9)
I5	PI 268187	1 (0 to 1)	1 (1 to 3)	8 (7 to 8)
Mazurka	PI 399501	3 (2 to 6)	3 (1 to 3)	8 (7 to 9)
Michigan Amber ^d	CI 11379	1 (0 to 1)	1 (0 to 1)	0 (0 to 1)
Morex	CI 15773	9 (8 to 9)	9 (8 to 9)	9 (8 to 9)
Sakigake	PI 190744	1 (1 to 3)	0 (0 to 1)	2 (1 to 3)
Sussex	PI 471914	9 (7 to 9)	9 (8 to 9)	9 (8 to 9)
Tambar 401	CI 13778	1 (0 to 3)	2 (1 to 3)	2 (2 to 3)
Topper	NIC	9 (7 to 9)	9 (7 to 9)	9 (8 to 9)
Varunda	PI 410865	2 (1 to 2)	2 (0 to 2)	7 (5 to 9)

^a The cultivar Abed Binder 12 has a single gene for resistance to *P. s. f. sp. hordei* (13). The cultivars Abyssinian 14, Astrix, Bigo, Cambrinus, Emir, Fong Tien, Heils Franken, I5, Mazurka, Topper, and Varunda are European differentials (21). BBA 806 is a cultivar from Germany with resistance to *P. s. f. sp. hordei* race 24. The authors added Morex spring barley and Sussex winter barley as North American susceptible checks, and Tambar 401 as a locally adapted resistant check.

^b Accession number is that from the USDA National Small Grains Collection, Aberdeen, Idaho. NIC = Not listed in USDA collection.

^c Infection types are interpreted as 0 to 3 = resistant reaction; 4 to 6 = intermediate reaction; and 7 to 9 = susceptible reaction (11). The first number represents the predominant infection type observed. In parentheses is the range of infection types observed for each host/race combination.

^d Michigan Amber is a wheat (*Triticum aestivum* L.) that is highly susceptible to the wheat stripe rust pathogen, *P. striiformis* f. sp. *tritici*.

plants of *H. jubatum* and *H. leporinum* in the Uvalde area were found to be infected with *P. s. f. sp. hordei*. It was noted that *H. pusillum* was also prevalent in the Uvalde area, yet all *H. pusillum* plants examined were free from stripe rust. In the fall of 1991 after planting, we monitored barley breeding nurseries at 12 locations in Texas, as well as commercial production fields throughout the state (Fig. 1) for stripe rust. We found no infections in the fall of 1991. The first sighting of barley stripe rust in Texas in 1992 was on 12 February, at the breeding nursery at Uvalde. During the remainder of 1992, and throughout 1993, stripe rust was widespread over much of Texas, southwestern Oklahoma, and northeastern New Mexico, although severities in commercial fields remained low. Progress of stripe rust was

followed in commercial fields of Post and Tambar 500 at both Winters and Era in 1992, 1993, and 1994 (Fig. 2). As measured by AUDPC values, stripe rust development was significantly greater on Post than on Tambar 500 in 1992 at Era, and at both locations in 1993. Yet, the highest severity of stripe rust found in commercial fields was only 8% on Post at Winters in 1993 (Fig. 2). We were unable to find stripe rust in any commercial barley fields in 1994.

Stripe rust was found on barley at all our nursery locations except Beeville and Overton (Fig. 1) in both 1992 and 1993. Severities were low (less than 10% at soft dough stage), even on the most susceptible barley lines at nurseries in Bushland, Chillicothe, Ft. Stockton, and Winters. However, at Dallas, Era, Howe, McGregor,

Prosper, and Uvalde (Fig. 1), susceptible barley lines often reached 100% severity by the soft dough stage in both 1992 and 1993 (Fig. 3). Based on stripe rust severities in the nurseries, we considered Post to be moderately susceptible and Tambar 500 moderately resistant to stripe rust, when compared with the highly susceptible barley cultivars Perkins, Sussex, and Wintermalt (Fig. 3). In contrast, during the 1993 to 1994 season, stripe rust was found only in trace amounts on highly susceptible barley lines at Uvalde and Prosper. The disease was not detected at the other breeding nurseries in 1994.

Virulence of *P. s. f. sp. hordei*. Over the 4 years of this study, we tested a total of 273 *P. s. f. sp. hordei* isolates for virulence on the differential set (Table 2). Fourteen isolates were like race 23, 255 were like race 24, and 4 were different from either race 23 or race 24, yet similar to each other. We designated these four isolates as the TXG (Texas germ plasm) race. Most of the race 23 isolates came from barley breeding lines in nurseries, although two race 23 isolates were from commercial fields of Post near Winters in 1992. Race 24 constituted nearly 94% of all isolates collected and 98% of the isolates from commercial barley fields. Race 24 was the only virulence type found on wild *H. jubatum* and *H. leporinum* (Table 2). The four isolates of the TXG race all were found on a group of related barley breeding lines at Uvalde and had the pedigree Tambar 402/Morex//Goliad. All of the isolates in 1994 were collected from barley nurseries and all were race 24 (Table 2). We did not find any stripe rust on wild *Hordeum* spp. in 1994.

Even though the inoculation, infection, and incubation procedures were conducted under the same controlled conditions over the course of these experiments, some variation in infection type was evident. However, the amount of variation typically did not result in a shift between the resistant, intermediate, and susceptible categories. The exceptions to this occurred with the differential cultivars Bigo and Varunda, inoculated with the four isolates of the TXG race (Table 1). These host/isolate combinations resulted in intermediate instead of susceptible reactions on several plants, even when repeated up to nine times. The other exception was with some isolates of race 23 inoculated onto Mazurka, where some plants had intermediate reactions, instead of the susceptible reactions of the majority of plants. Younger leaves were more susceptible than older, primary leaves with some race 24 isolates inoculated onto Astrix, Bigo, Cambrinus, and Mazurka. However, this increase in susceptibility was not consistent over repetitions of the experiments. No difference in reaction was found between primary and secondary leaves of plants inoculated with race 23 or TXG race isolates.

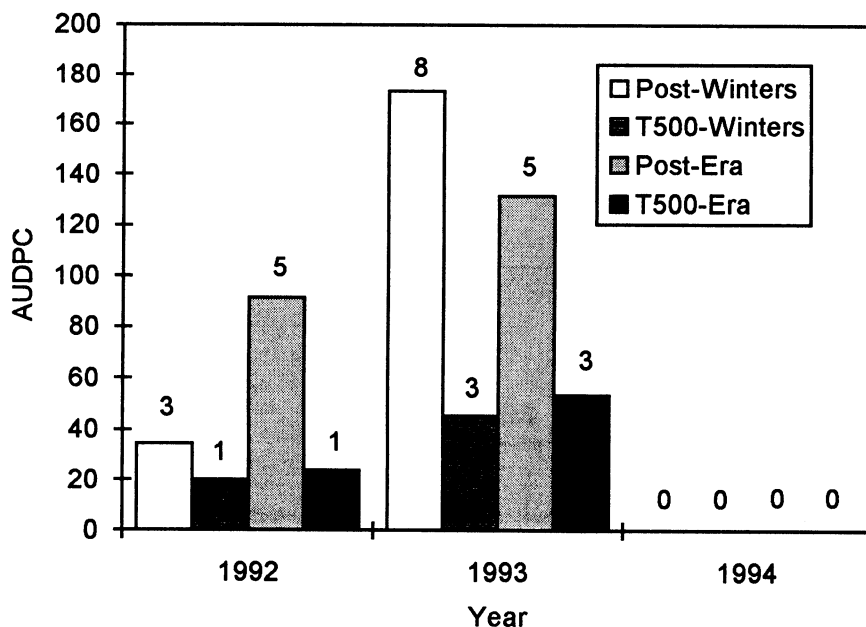


Fig. 2. Area under the disease progress curve (AUDPC) for stripe rust on Post and Tambar 500 barley in commercial fields at Winters and Era, Texas, from 1992 to 1994. Number above each bar is percent stripe severity at the soft dough development stage. For AUDPC, the least significant difference = 19.7 at $P < 0.05$.

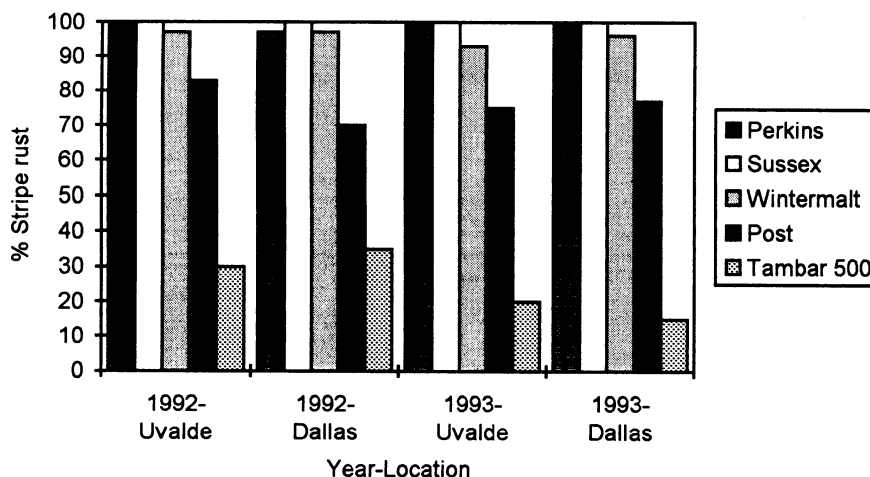


Fig. 3. Barley stripe rust severity at soft dough development stage on five barley cultivars grown in nurseries at Uvalde and Dallas, Texas, in 1992 and 1993.

Yield loss in barley. The severity and progress of stripe rust varied over year, location, and cultivar in our fungicide experiments (Table 3). Based on stripe rust severity at soft dough stage and AUDPC, it was clear that Perkins and Sussex were highly susceptible, Hundred and Steptoe were moderately susceptible, Kold and Tambar 500 were moderately resistant, and Tambar 401 was resistant to *P. s. f. sp. hordei*. Grain yield was significantly different between treatments for Steptoe and Sussex at both locations; for Hundred at Prosper, and for Perkins at Uvalde (Fig. 4). Yield loss of the untreated checks (determined by the difference in yield between the untreated check and the highest-yielding treatment, divided by the yield of the highest-yielding treatment in each cultivar-location-year combination), and expressed as a percentage was 72% for Perkins at Uvalde; 15 and 32% for Sussex at Prosper and Uvalde, respectively; 26 and 20% for Steptoe at Prosper and Uvalde, respectively; and 19% for Hundred at Prosper (Fig. 4). The treatment with the highest yield always had the lowest severity of barley stripe rust. Tambar 401 had no yield loss caused by stripe rust. For Kold and Tambar 500, yield loss was 5% or less and not significantly different between treatments at both locations (Fig. 4). Both of these cultivars exhibited stripe rust susceptibility prior to flag leaf emergence, yet were moderately resistant to stripe rust by the soft dough stage. Thus, Tambar 500 at Prosper, and Kold at Uvalde had no stripe rust at the soft dough stage, yet had AUDPC values of 15.5 and 25.2, respectively (Table 3).

Over all cultivars (in those experiments in which grain yield was significantly different between treatments), the average yield loss of the unsprayed checks was 31%, which was significantly higher than that of any of the fungicide treatments (Fig. 5). The most effective fungicide treatment varied somewhat with each cultivar, however; over all cultivars, the triadimefon + mancozeb treatment averaged 8.7% loss; propiconazole, 6.7%, tebuconazole, 6.2%, and flusilazole, 2.9% loss (Fig. 5).

DISCUSSION

The cereal rust diseases are generally thought of as being ubiquitous in cereal production areas; however, stripe rust has been slower to spread throughout the world than the other rusts. For example, *P. s. f. sp. tritici* was not found on wheat in Australia until 1979 (14), and not in New Zealand until 1982 (2). In the U.S., severe outbreaks of wheat stripe rust are more common west of the Rocky Mountains, particularly in the cool, moist environment of the northwest. However, epidemics of wheat stripe rust have occurred in Texas (5,6) as well as in other states east of the Rockies. After its discovery in April 1991,

barley stripe rust became widespread in Texas. In 1992 and 1993, barley stripe rust spread rapidly and became severe on susceptible cultivars and breeding lines at our nursery locations in Dallas, Era, Howe, McGregor, Prosper, and Uvalde. Barley stripe rust occurred, but was not severe at nursery locations in Bushland, Chillicothe, Ft. Stockton, and Winters (Fig. 1). We have not found stripe rust in barley nurseries at Beeville and Overton, although other cereal rusts (including wheat stripe rust) typically occur at these two locations. In 1992 and 1993, we found stripe rust in commercial fields of barley in Oklahoma and New Mexico as well. Unpublished reports from other barley researchers, and the USDA Cereal Rust Laboratory, have confirmed barley stripe rust in Colorado in 1992, and in Arizona, California, Idaho, and Montana in 1993. It is likely that the barley stripe rust occurrence in Colorado in 1992 originated from inoculum produced in Texas. However, the occurrence of barley stripe rust in states further west was at least as likely to have originated from inoculum sources in Mexico, as from sources in Texas and Colorado. In 1993, we tested three stripe rust collections from barley in California and two from Idaho, and found that the collections from Idaho and two of the three from California were

P. s. f. sp. hordei race 24. We were able to infect only wheat, not barley, with the third collection from California, thus indicating the collection was probably *P. s. tritici* (D. Marshall and R. L. Sutton, unpublished data). We have been unable to find stripe rust east of Dallas in either cultivated barley or wild *Hordeum* spp. The states to the immediate east and northeast of Texas have little, if any, barley cultivation, yet wild *Hordeum* spp. can be found in those areas. Farther east, barley is grown commercially in parts of Kentucky, and in the states east of the Appalachian Mountains from South Carolina north to Pennsylvania. Barley stripe rust has not been found in these eastern states. Neither has the disease been found in the Great Plains states north of Oklahoma, nor in Canada. Spread of the disease into these other areas will depend largely on the amount of *P. s. f. sp. hordei* overwintering in fall-sown barley, the establishment of the pathogen in wild *Hordeum* populations or other grass hosts, environmental conditions suitable for pathogen establishment and growth, and the cultivation of susceptible barley cultivars (16). There is no known alternate host for *P. s. f. sp. hordei* (15), so variability in the fungus would largely be determined by mutation and somatic recombination.

Table 2. Number of isolates of *Puccinia striiformis* f. sp. *hordei* in each of three races collected from 1991 to 1994

Race and source ^a	Year of collection				Total
	1991	1992	1993	1994	
Race 23					
Field	0	2	0	0	2
Nursery	1	6	5	0	12
Wild	0	0	0	0	0
Race 24					
Field	0	78	31	0	109
Nursery	19	42	40	18	119
Wild	4	9	14	0	27
TXG race					
Field	0	0	0	0	0
Nursery	0	3	1	0	4
Wild	0	0	0	0	0
Total	24	140	91	18	273

^a Race was determined by reactions of 18 differential cultivars. See Table 1.

Table 3. Percent stripe rust severity at soft dough stage and area under the disease progress curve (AUDPC) for unsprayed check treatments of seven barley cultivars

Year and location	Cultivar	Percent stripe rust	AUDPC
1992 – Dallas	Perkins	45	420
1992 – Uvalde	Perkins	100	1,487
1993 – Prosper	Hundred	36	337
1993 – Prosper	Kold	3	31
1993 – Prosper	Steptoe	46	586
1993 – Prosper	Sussex	97	1,707
1993 – Prosper	Tambar 401	0	0
1993 – Prosper	Tambar 500	0	16
1993 – Uvalde	Hundred	46	375
1993 – Uvalde	Kold	0	25
1993 – Uvalde	Steptoe	70	1,323
1993 – Uvalde	Sussex	100	1,824
1993 – Uvalde	Tambar 401	0	0
1993 – Uvalde	Tambar 500	15	125

In 1994, the disease was very difficult to find in Texas. We did not find any commercial barley nor wild *Hordeum* spp. infected with stripe rust in 1994. This was puzzling, given the prevalence of the disease in 1993. Perhaps this decline was related somewhat to the drought conditions over much of the southern Great Plains from January through March of 1994. In fact, all cereal rusts were at very low levels in the southern Great Plains in that year. Nevertheless, given favorable environmental conditions, it is probable that barley stripe rust will remain a hazard to barley production in those areas where it occurs, and could spread into other barley producing areas. In Texas, the most severe stripe rust we have found in commercial barley was an 8% severity level on the cultivar

Post in 1993 at Winters. Because barley is a minor crop in Texas, and because much of the fall and winter plant growth is consumed by cattle (i.e., removed from serving as inoculum sources and sinks), it is unlikely that Texas barley would serve as a major inoculum source for stripe rust on barley grown to the north. Nevertheless, highly susceptible barley cultivars should not be grown in the southern Great Plains in order to minimize potential stripe rust increase and spread.

The role wild *Hordeum* species play as oversummering, and additional overwintering, sources of inoculum is somewhat unclear. The role of wild grass hosts in wheat stripe rust epidemiology in the U.S. has been considered to be important in some areas (7,23), yet of minor conse-

quence in others (9,19,20). In 1992 and 1993, we found widespread stripe rust infection on *H. jubatum* and *H. leporinum* in Texas, thus indicating the potential of these hosts to serve as sources of inoculum of *P. s. f. sp. hordei*. We found only race 24 on wild *Hordeum* spp. Some accessions of *H. marinum*, *H. murinum*, and *H. pusillum* also have been shown to be susceptible to barley stripe rust (16). Even though *H. pusillum* is susceptible to *P. s. f. sp. hordei* under controlled conditions, we were unable to find any *H. pusillum* plants infected in the field.

We identified three races of *P. s. f. sp. hordei* during this study. The majority of isolates we tested were race 24, similar to the race that caused widespread yield loss in South America (4). Some isolates belonged to race 23. Races 24 and 23 were the only two races found on commercial barley, and only race 24 could be isolated from other *Hordeum* spp. The TXG race occurred only at Uvalde, and only on breeding lines with the pedigree Tambar 402/Morex//Goliad. Individually, Tambar 402, Morex, and Goliad are susceptible to *P. s. f. sp. hordei*. The TXG race produced susceptible reactions on Bigo, Emir, I5, Mazurka, and Varunda, thereby having increased virulence over races 23 and 24. However, the race 24 and 23 resistance(s) present in Abed Binder 12, Abyssinian 14, BBA 806, Sakigake, and Tambar 401 was also effective against the TXG race. As opposed to research on many of the other cereal rusts, research into physiologic specialization of *P. s. f. sp. hordei* is not well-developed (21), and thus race nomenclature is not highly refined.

In our fungicide experiments, Hundred, Perkins, Steptoe, and Sussex all lost significant yield to stripe rust. The highest yield loss was 72% on Perkins at Uvalde in 1992. Given that susceptible and moderately susceptible cultivars can lose significant amounts of yield to stripe rust, it is clear that moderately resistant and resistant cultivars should be developed and grown in those areas where the disease could be a problem. Perhaps the adult-plant resistance present in Tambar 500 and Kold could contribute to the management of the disease in terms of not losing significant yield and allowing some reproduction of *P. s. f. sp. hordei*, thereby decreasing the chances of selecting more virulent races, as might occur on completely resistant cultivars.

All of the fungicides treatments resulted in less yield loss than occurred with the unsprayed checks. Flusilazole was the most effective fungicide in terms of protecting yield over all the barley cultivars tested.

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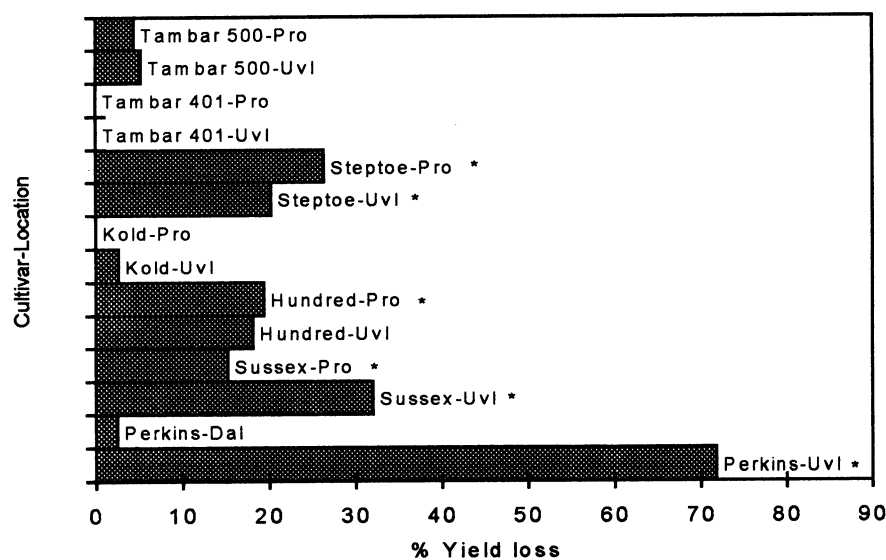


Fig. 4. Percent yield loss caused by barley stripe rust on seven cultivars. Asterisk denotes those cultivar locations where yield loss was significantly ($P < 0.05$) different between fungicide-treated and untreated plots. Yield loss was determined by the difference in yield between the untreated check and the highest-yielding treatment, divided by the yield of the highest-yielding treatment, and expressed as a percentage.

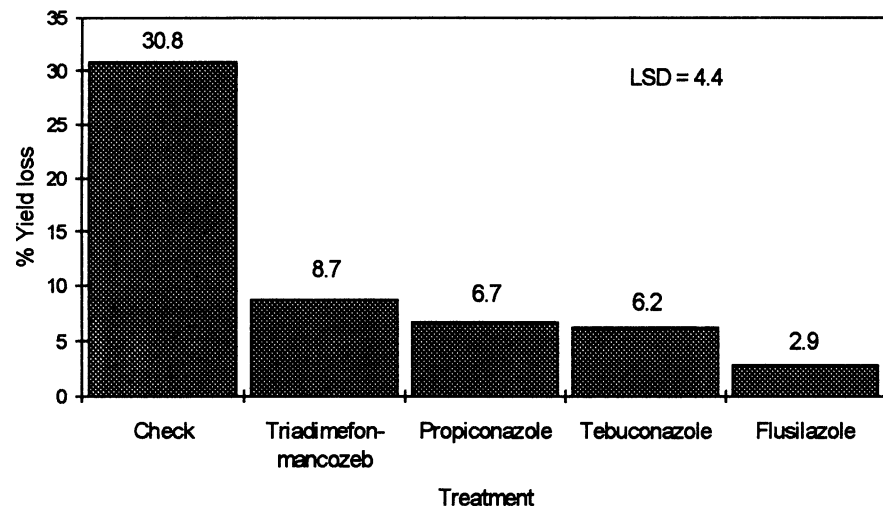


Fig. 5. Percent yield loss caused by barley stripe rust on untreated checks and four fungicide treatments. Number above each bar is percent yield loss. Data are over all cultivars, locations, and years. Location abbreviations are Dal = Dallas; Pro = Prosper; and Uvl = Uvalde.

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