Seed Yield Responses of Five Selections of Tall Fescue Susceptible or Resistant to Stem Rust with or without Propiconazole

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ABSTRACT

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Stem rust caused by *Puccinia graminis* subsp. *graminicola* is a serious disease of tall fescue (*Festuca arundinacea*) grown for seed in the Willamette Valley of Oregon. Between 1991 and 1994, propiconazole was applied to five stem rust susceptible and five stem rust resistant selections to compare seed yield and disease response. When stem rust was observed in mid-May of 1992 and 1994, seed yield and 1,000-seed weights among stem rust susceptible selections were significantly larger ($P < 0.05$) than in nontreated controls in three of five propiconazole-treated selections. Stem rust was not observed until mid-June in 1991 and 1993, and seed yield and 1,000-seed weights among susceptible selections treated with propiconazole were not significantly larger ($P < 0.05$) than those of nontreated controls. Seed yield and 1,000-seed weights among stem rust resistant selections treated with propiconazole were not significantly different ($P < 0.05$) from those of nontreated controls. Dates when stem rust was first observed in stem rust susceptible selections and the rate of stem rust development were different each year. This study determined the influence of stem rust on seed yield in selections of tall fescue resistant and susceptible to stem rust and determined year-to-year variation in seasonal occurrence of stem rust and its influence on seed yield.

Tall fescue (*Festuca arundinacea* Schreb.) is an important forage and pasture grass that grows well during cool winters, survives warm summers, and tolerates soils with poor drainage or low pH. It also produces a heavy turf, making it suitable for lawns and stabilization of road banks (2). In Oregon in 1994, seed of tall fescue, produced on 27,725 ha, was valued at $28 million (6).

In 1987, stem rust, caused by *Puccinia graminis* Pers.:Pers. subsp. *graminicola* Z. Urban, was found for the first time in tall fescue in the Willamette Valley of Oregon (13). In most years, stem rust can be severe and fungicides are commonly used by seed producers for its control. When conditions are favorable for stem rust development, usually beginning in early May, producers apply propiconazole, triadimefon, or chlorothalonil one to three times according to label instructions (5). Reliable procedures were developed to evaluate stem rust resistance in tall fescue cultivars grown in controlled and field conditions (11) and stem rust resistant (SRR) germ plasm is being developed (1). However, data are not available from field studies to estimate seed yield losses due to stem rust. Several models have been developed to estimate losses due to stem rust in wheat by relating rust severity at different crop stages and by estimating area under the disease progress curve (8). This study was initiated to determine the influence of stem rust on seed yield of different selections of tall fescue and determine year-to-year variation in seasonal occurrence of stem rust and its influence on seed yield.

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MATERIALS AND METHODS

Plant selection. Stem rust susceptible (SRS) and SRR selections of tall fescue used in the study were originally part of a greenhouse/field study started in 1990 with 20 cultivars and 1,400 plants (12). Plant selection was based on a stem rust infection type assessment when greenhouse-grown seedlings were 5 and 10 weeks old and when adult plants in the field were assessed for severity by the modified Cobb scale on 11 and 23 July 1990. Both methods have been used previously for assessing stem rust in tall fescue (12) and perennial ryegrass (11) and are similar to methods used to assess stem rust infection type and severity in cereal grains (7).

From each of three forage cultivars (Arid, Forager, and Kentucky 31) and two turf-type cultivars (Rebel II and Shortstop) we selected one resistant plant and one susceptible plant. The SRS selections had an infection type 4 (large lesion with abundant sporulation) in the seedling stage and 100% severity as adults. The SRR selections had an infection type 0 (no lesion or a hypersensitive fleck without sporulation) as seedlings and 0% severity as adults. Stem rust was severe in the field during spring and summer of 1990 and provided an opportunity for reliable disease assessments. This field study continued for 2 additional years and stem rust assessments in 1991 and 1992 were consistent with assessments made in 1990 (12).

In August 1990, single tillers were removed from SRS and SRR selections of each cultivar and transplanted into single cone-shaped plastic containers (3.8 × 10 cm) containing fine vermiculite. Cones were placed in a mist chamber in a greenhouse at 20 ± 5°C for 7 days until plants were well rooted. The cones were then removed and plants grown about 5 weeks on another bench in the same greenhouse. Plants were watered daily and fertilized weekly with 2.4 g/liter of 20-20-20 (N-P-K) liquid fertilizer (Peters) to maintain vigorous growth.

Field plots. Paired tillers of each selection were transplanted side-by-side on 1 m centers into field plots on 1 October 1990. Each plot contained 20 plants (5 SRS and 5 SRR selections × 2) with location of each selection within each plot assigned at random. Twelve plots were prepared and divided into six replications of two plots each, with 3 m between plots. One plot in each replication was treated with propiconazole; the other plot served as the nontreated control. Each year, the plot receiving the fungicide treatment was selected at random. The experiment was arranged in a split-plot design: with-or-without fungicide was the whole plot treatment and plant selection was the split-plot treatment. The experiment contained 240 plants (2 whole plots × 10 split-plots × 2 plants × 6 replications).

At transplanting, each plant received 30 cm^3 of 18-18-18-2 (N-P-K-Fe) and irrigation was applied to establish the plants.

Each year, the field was limed and fertilized with 16-20-0 (N-P-K) according to soil test recommendations (about 60 kg/ha of N in the fall and 120 kg/ha of N in the spring). Weeds were controlled by mechanical cultivation or commonly used herbicides throughout the study. Stem rust inoculum was provided from natural sources or from latent infections in plants overwintering in the study. Insects were not a problem and insecticides were not used. Beginning in late April of each year propiconazole was applied to fungicide-treated plots. Stem rust was allowed to develop in the nontreated controls.

Fungicide application. In all applications, propiconazole (Tilt, 3.6 EC) was mixed at 126 g a.i./ha (4 fl oz of product per acre) with water and applied at 280 liters/ha (30 gal/acre) at 172.4 kPa (40 psi) with a spray boom fitted with flat-fan nozzles (type 8004). Sprays were applied at dawn on days without wind to provide thorough coverage and continued at 14- to 21-day intervals until flowering. Sometimes rain delayed applications beyond 21 days and traces of stem rust developed in fungicide-treated plants of SRS selections.

Disease assessment. Stem rust was assessed by the modified Cobb scale one or more times during the growing season. Assessments for each selection were made either on the penultimate leaf, flag leaf, or panicle, depending on the growth stage of the plant at the first appearance of stem rust. Means were calculated for 10 randomly selected leaves for each plant. Final stem rust assessments were made on panicles. In years when stem rust was slow to develop, assessments were made on panicles not harvested for seed yield.

Stem rust developed slowly in 1991 and a single assessment for severity was made on 15 July, 13 days after seed harvest. In 1992, stem rust severity was assessed on 8, 14, and 28 May, with the last assessment made 1 day before the first harvest. In 1993, severity was assessed on 18 and 28 June and 2 July, with the last assessment made 4 days after the last harvest. In 1994, severity was assessed on 5 and 19 May, and 1, 10, and 24 June, with the last assessment made 3 days before the first harvest.

Seed yield. At harvest, 100 panicles were cut from each plant with a hand-sickle. In 1991, panicles from all selections were harvested on 2 July. In subsequent years, harvests were done when seed moisture content reached 40 to 45% (dry weight basis). This occurred between 29 May and 16 June 1992, between 17 and 28 June 1993, and between 15 and 28 June 1994. Seeds were threshed, cleaned, and air dried to 10% moisture. Seed yield for SRS and SRR selections treated or not treated with propiconazole was estimated by the weight of 1,000 seeds and by total seed weight per 100 panicles. In this report, seed yield from 100 panicles hereafter will be referred to simply as yield.

Data analysis. As described previously, the study was arranged in a split-plot design. In split-plot experiments variation among split-plot treatments is expected to be less than variation among whole plot treatments (9). In this study, large variation was expected between whole plots and also among split-plots (SRS and SRR selections) because plant selections were made on the basis of a dissimilar response to stem rust. Variation within SRS and SRR selections was also expected because each selection originated from an open-pollinated tall fescue parent that could be expected to differ genetically. For these reasons, a split-plot analysis of variance (ANOVA) was not used to compare data. Instead a two-way ANOVA was used to compare the effects of stem rust on yield and 1,000-seed weight for each SRS or SRR selection with and without fungicide treatment. Data compared were means of 12 plants (1 selection × 2 plants × 6 replications).

RESULTS AND DISCUSSION

Stem rust. Stem rust severity and the date on which it was first observed differed among SRS selections and years (Fig. 1). In 1991, trace amounts of stem rust were observed in SRS selections at harvest and these data were not included in Figure 1. Generally, stem rust first appeared and was most severe in the selection from Kentucky 31, followed by Arid, Forager, and Shortstop. Stem rust developed latest in the selection from Rebel II.

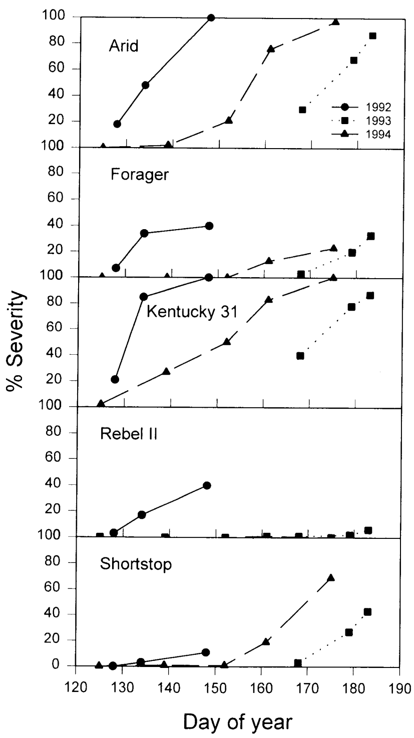

Fig. 1. Response of five single-plant selections from cultivars of Arid, Forager, Kentucky 31, Rebel II, and Shortstop tall fescue susceptible to stem rust in 1992, 1993, 1994.

The rate of stem rust development also differed among SRS selections. For example, in 1994, stem rust severity increased from 2 to 100% in 50 days in the selection from Kentucky 31 and from 2 to 97% in 36 days in the selection from Arid. These differences in expression of stem rust are most likely related to interactions among the selection of the rust, the selection of the host, and variation in environment, as has been discussed for cereal rust diseases (3,10).

Late stem rust appearance and slow rate of development in Rebel II was consistent during the 4 years of the test. A review of field notes from the earlier study (12) confirmed this selection of Rebel II as susceptible to stem rust. As 5- and 10-week-old plants, the selection received an infection type assessment of 4 in the greenhouse tests and stem rust assessments of 100% on 23 July 1990, 40% on 11 July 1991 (a year when stem rust was not severe), and 100% on 29 May 1992 (a year when stem rust was severe) in the field.

Stem rust developed occasionally in SRS selections in plots treated with propiconazole (June 1993 and 1994) when rain or work schedules delayed fungicide applications. However, propiconazole application delayed further development of stem rust. No stem rust was observed in

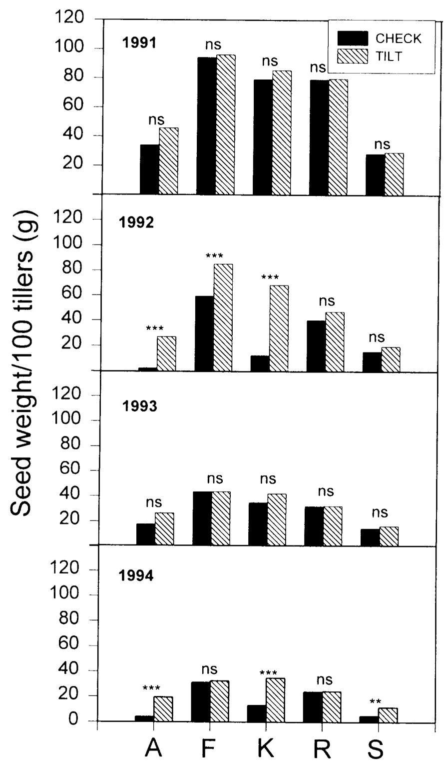

Fig. 2. Seed yield (grams per 100 tillers) of five selections of tall fescue susceptible to stem rust without (check) or with Tilt (126 g a.i., propiconazole) in 1991 to 1994. Selections were made from five cultivars: A = Arid; F = Forager; K = Kentucky 31; R = Rebel II; and S = Shortstop. Yield differences were compared by F values; $P < 0.05$ = ns (nonsignificant difference); $P \geq 0.05$ = *; $P \geq 0.01$ = **; and $P \geq 0.001$ = ***.

SRR selections with or without propiconazole treatment.

Seed yield. Seed yield from plots treated with propiconazole versus nontreated controls among the five SRS selections in 1991 and 1993 (Fig. 2) were not different statistically ($P = 0.05$). However, seed yields from treated SRS selections from Arid, Forager, and Kentucky 31 were significantly larger than from nontreated controls in 1992 ($P = 0.001$). In 1994, SRS selections from Arid and Kentucky 31 ($P = 0.001$) and Shortstop ($P = 0.01$) were significantly larger than from nontreated controls. Propiconazole treatment never had an effect on seed weights for the SRS selection from Rebel II. Propiconazole treatment did not improve seed yield of any SRR selection (Fig. 3).

Comparing 1,000-seed weights for SRS selections treated or not treated with propiconazole showed no significant differences in 1991 and 1993, but showed significant differences in 1992 and 1994 (Fig. 4). These responses measured by 1,000-seed weights were generally similar to seed yield responses among SRS selections (Fig. 2). A different response was found in 1992 for the SRS selection from Rebel II with or without propiconazole treatment. Seed yields from plots treated or not treated with propiconazole were statistically similar, whereas 1,000-seed weights from propiconazole-treated plants were significantly larger than those from nontreated controls. Stem rust severity in SRS Rebel II was 40% on 28 May 1992 and was higher in this year than in any other year. The response of significantly larger 1,000-seed weight to fungicide in this selection is likely related to a higher stem rust severity assessment in 1992.

Another exception occurred in 1994 when seed yield of the SRS selection from Shortstop treated with propiconazole was significantly larger than from the nontreated control, whereas 1,000-seed weights for the propiconazole-treated and nontreated control were statistically similar. Again, stem rust severity (69% on 24 June) was greater in this SRS selection in 1994 than in any of the other years. Other differences for both yield components were noted among other SRS selections, but they differed only in the statistical level of significance between fungicide treatments. No statistically significant differences were found in 1,000-seed weights among SRR selections with and without propiconazole in any of the 4 years (Fig. 5). These results were similar to those for seed yield (Fig. 3).

A lack of yield response of the SRS selection from Rebel II is consistent with a delayed appearance and a slow rate of development of stem rust in each of the 4 years. This study does not explain why selections from Rebel II that consistently scored susceptible to stem rust in both controlled greenhouse inoculations and field conditions in 1990, 1991, and 1992 did not respond to fungicide control of stem rust with a seed yield response. Perhaps the lack of measurable differences in seed yield of SRS Rebel II was because stem rust was slow to develop and severity was low.

In 1992 and 1994, stem rust developed by mid-May. Seed yield and 1,000-seed weights were significantly larger for three of five SRS selections when treated with propiconazole, compared with those of the nontreated controls. In 1991 and 1993, when stem rust did not develop until mid- to late June, seed yield and 1,000-seed weight did not differ between treated and control plots for SRS selections. Such year-to-year variation in occurrence and development of stem rust makes timing fungicide applications complicated and costly, because in some years fungicide treatment provides no benefit.

Seed yield among SRS and SRR selections treated with propiconizole decreased each year (Figs. 2 and 3). Although stem rust reduced seed yield of the SRS selections in nontreated controls, seed yield of SRR selections from nontreated controls

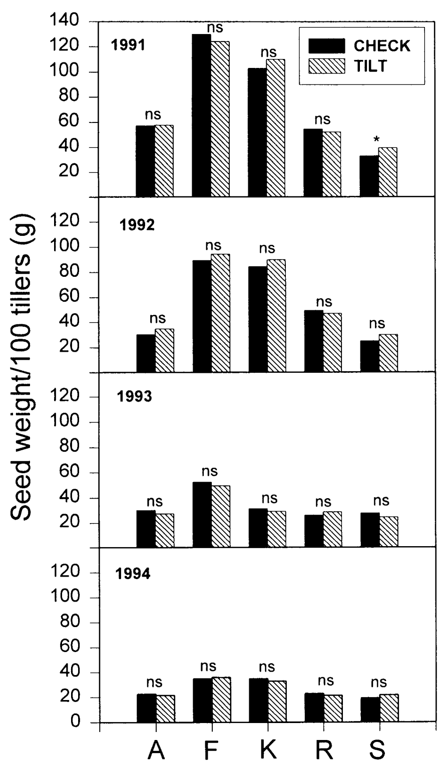

Fig. 3. Seed yield (grams per 100 tillers) of five selections of tall fescue resistant to stem rust without (check) or with Tilt (126 g a.i., propiconazole) in 1991 to 1994. Selections were made from five cultivars: A = Arid; F = Forager; K = Kentucky 31; R = Rebel II; and S = Shortstop. Yield differences were compared by F values; $P < 0.05$ = ns (nonsignificant difference).

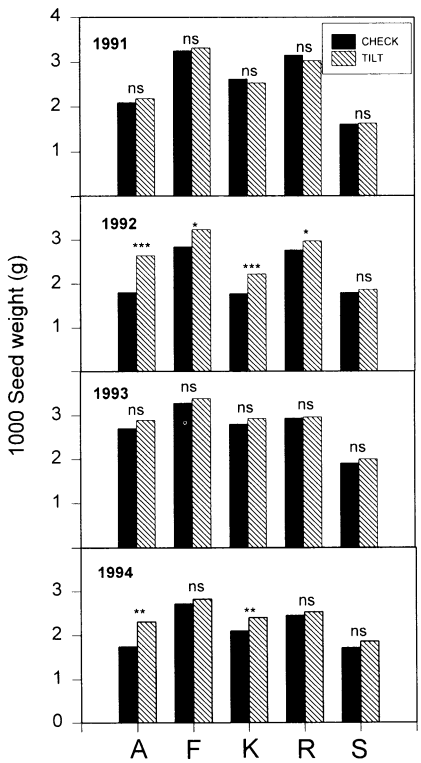

Fig. 4. Thousand-seed weight (g) of five selections of tall fescue susceptible to stem rust without (check) or with Tilt (126 g a.i., propiconazole) in 1991 to 1994. Selections were made from five cultivars: A = Arid; F = Forager; K = Kentucky 31; R = Rebel II; and S = Shortstop. Thousand-seed weights were compared by F values, $P < 0.05$ = ns (nonsignificant difference); $P \geq 0.05$ = *; $P \geq 0.01$ = **; and $P \geq 0.001$ = ***.

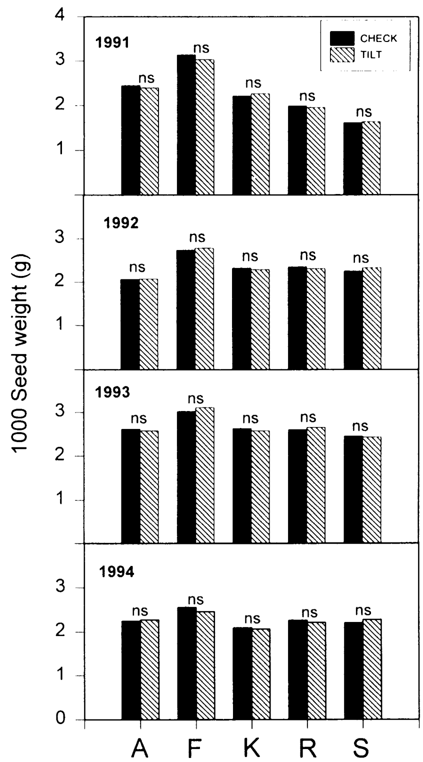

Fig. 5. Thousand-seed weight (g) of five selections of tall fescue resistant to stem rust without (check) and with Tilt (126 g a.i., propiconazole) in 1991 to 1994. Selections were made from five cultivars: A = Arid; F = Forager; K = Kentucky 31; R = Rebel II; and S = Shortstop. Thousand-seed weights were compared by F values, $P < 0.05$ = ns (nonsignificant difference).

also decreased over time. Ranking selections for seed yield from highest to lowest was generally similar each year: Forager > Kentucky 31 > Rebel II > Arid > Shortstop. In 1993 and 1994, seed yields of Arid and Shortstop were similar. Mean seed yield of five SRS selections treated with propiconazole was 67.4 g in 1991, 49.4 g in 1992, 32.1 g in 1993, and 23.9 g in 1994. Mean seed yield of five SRR selections treated with propiconazole was 76.8 g in 1991, 59.4 g in 1992, 31.9 g in 1993, and 26.7 g in 1994. Reasons for this decrease in seed yield over time were not examined in this study. However, removal of crop residue by close clipping and sweeping or field burning has been shown to maintain seed yield by eliminating older, nonreproductive tillers. Residue removal creates a favorable microenvironment to enhance tillering and floral initiation (4). Plants in this study were close-clipped, but not swept or burned.

Year-to-year variation in stem rust development emphasizes the need for developing SRR cultivars to reduce dependency on fungicides for disease control and stabilize production of tall fescue seed. Important questions remain concerning how the host, pathogen, environment, and time interact to alter disease development and influence seed yield losses. Such information would be useful in developing models to predict stem rust occurrence and development.

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