Ecology and Epidemiology

Influence of Root Rot on Winter Survival and Yield of Winter Barley and Winter Wheat

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ABSTRACT

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Winter survival of wheat and barley was reduced by root rot pathogens, particularly *Bipolaris sorokiniana*. Seedborne and soilborne inoculum along with soil fumigation and seed treatments were used to provide different levels of disease. Differences in winter survival were measured as the differences between fall and spring stand counts. Disease was assessed as the proportion of diseased tissue on washed roots and subcrown internodes of surviving plants in the spring. Overall stand reductions, ranging from 11 to 29% in wheat and from 27 to 62% in barley, were attributed to *B. sorokiniana*.

Plants are exposed to various environmental stresses throughout their life cycle and specific responses to these stresses have been documented (4). A major stress on fall-sown cereals is freezing, which influences winter survival. Winter hardiness of wheat and barley depends on traits that protect plants from freeze injury by increasing resistance to injury, modifying stresses that develop as water freezes, or promoting recovery (8). Responses of cereals to these freezing stresses have been described (8,9), and laboratory tests have been used to classify winter-hardy genotypes (6).

Stress factors can predispose plants to disease (15). Freezing can predispose alfalfa (12), barley (16), and wheat (1) to root rot. Conversely, plant pathogens may predispose plants to freezing stress, thereby reducing winter survival (1–3,10,12,17,18).

Several fungi cause root rots of wheat and barley (14), and may be responsible for significant yield losses in Pennsylvania (*unpublished*). A major root rot pathogen is *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem. (anamorph *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex. Dast.) (7,14). Reported yield losses have ranged from 5 to 42% depending on the crop and the environment (7,11). Root rots reduce winter survival of alfalfa (12,18); it is possible that they might contribute to winterkilling and yield loss in barley and wheat.

The purpose of this study was to investigate the influence of root rot on the winter survival of wheat and barley, and to relate this effect to grain yield.

MATERIALS AND METHODS

Four different combination treatments were used to provide different levels of root rot in field plots for this test. The four specific treatment combinations used in this test were: control (C), clean seed treated with fungicide and planted in fumigated, noninfested soil (disease-free check); treatment 1, clean seed treated with fungicide and planted in fumigated soil infested with *B. sorokiniana* (the primary pathogen was *B. sorokiniana*); treatment 2, infested seed with no fungicide treatment, planted in unfumigated and noninfested soil (indigenous inoculum); treatment 3, infested seed with no fungicide treatment, planted in unfumigated soil infested with *B. sorokiniana* (maximum disease pressure).

Infested seed was obtained from field plots in Pennsylvania where wheat and barley plants had a high incidence of *B.*

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sorokiniana, based on root rot and spot blotch symptoms. Seed was tested for seedborne pathogens by surface sterilizing 1,000 seeds and placing them on potato-dextrose agar. Fifty-eight percent of the seed was infested with *B. sorokiniana* and 7% was infested with *Fusarium graminearum* Schwabe, based on microscopic examination. Clean seed was obtained from Aberdeen, ID, where it was grown under irrigation. The seed treatment was a commercial combination of carboxin (17% a.i.) and thiram (17% a.i.; trade name Vitavax 200 [Uniroyal Chemical, Naugatuck, CT]). The application rate was 2.5 ml of product per kilogram of seed. Fumigated plots were treated with methyl bromide at a rate of 393 kg/ha. The fumigated strips were covered with a plastic tarp during the fumigation process and the tarp was removed after 4 days. Plots were planted 5 days after tarp removal. Soil was infested by incorporating grain colonized with *B. sorokiniana* into the seed bed just prior to planting. Barley and wheat isolates of *B. sorokiniana* were pooled and grown on sterilized rye grains for 4 wk. The infested grain was then air-dried, distributed on the soil surface of specific plots (138 g/m^2) with a fertilizer spreader, and incorporated into the soil by raking lightly.

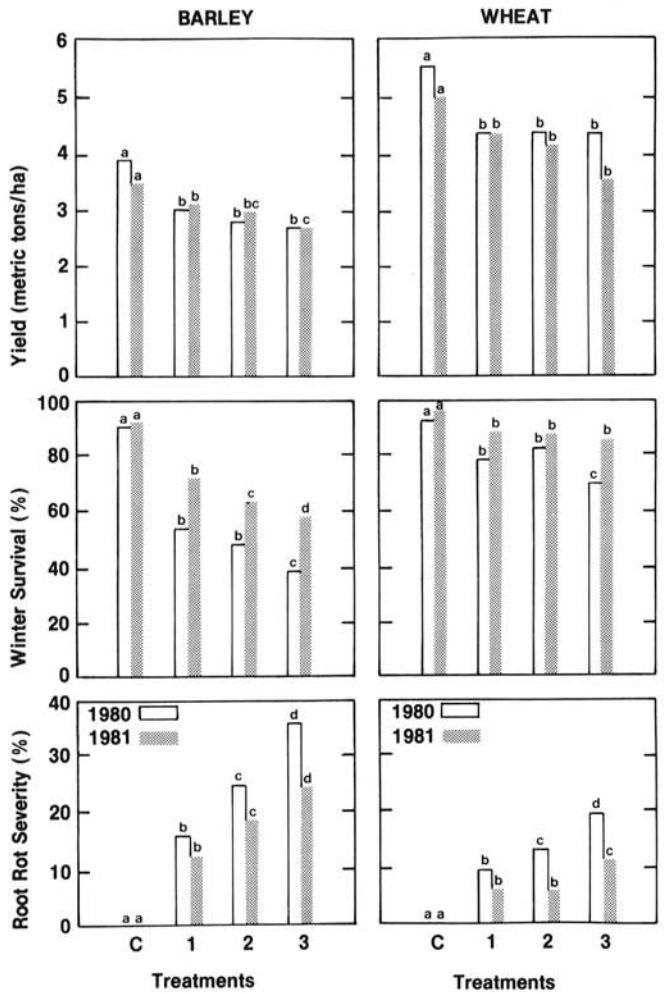

Fig. 1. The influence of root rot on winter survival and yield of barley and wheat plants in Pennsylvania. The four specific treatment combinations used in this test were: Control (C), clean seed treated with fungicide and planted in fumigated, noninfested soil (disease-free check); treatment 1, clean seed treated with fungicide and planted in fumigated soil infested with *B. sorokiniana* (primary pathogen was *B. sorokiniana*); treatment 2, infested seed with no fungicide treatment, planted in unfumigated and noninfested soil (indigenous inoculum); treatment 3, infested seed with no fungicide treatment, planted in unfumigated soil infested with *B. sorokiniana* (maximum disease pressure). Root rot severity = the mean (percent reduction for root system) + (percent disease on subcrown internodes) for 20 plants per plot. Treatment means followed by the same letter within years are not significantly different (Bayes LSD, $k = 100$).

In both years, plots were planted near University Park, PA, in soil planted with wheat in the previous year. The plots were 0.9 m by 3.6 m and were seeded with a five-row cone-type planter at a rate of 167 kg/ha in rows spaced 178 mm. Plots were fertilized with 672 kg of 5-10-10 (N-P-K) per hectare in the fall and topdressed with NH_4NO_3 on 2 April in 1980 and 14 April in 1981. Fumigated plots received 33.6 kg N/ha while non-fumigated plots were topdressed with 67.2 kg. The additional N was added to non-fumigated plots since fumigated plots receive additional N that is released by fumigation (13). A preliminary experiment was conducted in 1979 to determine the fertilizer rate to be used in fumigated plots. The highest N rate that allowed growth without lodging was selected. All plots were sprayed with a tank mix of 2,4-D (0.28 kg a.i./ha) and dicamba (0.14 kg a.i./ha) for weed control. Wheat cultivar Hart (CI 17426) and barley cultivar Maury (CI 15692) were planted in separate tests.

The experimental design was a randomized complete block with four replications and the four treatments previously described. However, the fumigated plots in each replication always were adjacent to each other to facilitate the fumigation procedure. Therefore, the data were subjected to analysis of variance with fumigation treatments as whole plots and the other treatments as subplots in a split plot design. Since the error mean square for error (a) was not significantly different from that for error (b), the data were pooled and analyzed as a randomized complete block.

When plants were in the three-leaf stage, the plants in 1 m of row were counted. Two 1-m sections of row were marked in each plot so that the same sections could be counted in the spring of the next year to determine winter survival. Yield determinations were made from a 0.9 m by 2 m section opposite the survival sampling area in each plot.

When plants reached growth stage 6 (GS-6, Feekes scale) (5), the plants in the 1-m sections were removed from the soil, with care taken to preserve the integrity of the root system, and counted. Soil was removed from the roots by washing with a stream of water. The roots were then placed in a Plexiglas root washer under high pressure mist nozzles for 16 hr (chamber designed by L. W. Burgess, Department of Plant Pathology and Agricultural Entomology, University of Sydney, Australia).

Rotting of roots and subcrown internodes was assessed on these plants. The subcrown internodes were examined and the percent area of the subcrown internode covered with lesions was estimated. Reduction in total root area is a component of the root rot syndrome and should contribute to yield loss so this factor was added to the disease evaluation. The percent reduction in the total root system for each plant was assessed visually by comparing the total size of the root plume to healthy root plumes (five root systems selected randomly from the healthy check plot) and estimating the percent reduction in size. This estimate was added to the estimate for the subcrown internode to provide the final root rot severity for each plant. A total of 20 plants was evaluated for each plot and a mean was calculated. Five subcrown internodes from each plot were placed on low-carbon PDA (0.5% dextrose) and examined after 10 days to determine whether *B. sorokiniana* was the primary pathogen responsible for the lesions on the subcrown internodes.

Plots were harvested at grain maturity with a small plot combine. Yields were calculated as kilograms per hectare after grain moisture was adjusted to 13%. All data were subjected to statistical analysis using an analysis of variance and a Bayes LSD. The survival data were transformed using arcsine transformation prior to analysis.

RESULTS

The winter survival of wheat in control plots (disease free) was 93% in 1980 and 97% in 1981 (Fig. 1). There was no visible root rot in these plots. In both years, there was an increase in root rot and a decrease in winter survival compared to the control when *B. sorokiniana* was added to the soil (treatment 1). Similar results were obtained with indigenous inoculum (treatment 2). When disease pressure was increased by adding inoculum of *B. sorokiniana* to the indigenous inoculum (treatment 3), there was a

further increase in root rot and a decrease in winter survival compared to the other three treatments in 1980. In 1981, the root rot severity increased with treatment 3, but there was no decrease in winter survival when compared to treatments 1 and 2.

The pathogen *B. sorokiniana* was isolated from over 95% of the subcrown internodes in both years when it was the only pathogen added to the soil (treatment 1). For subcrown internodes exposed to indigenous inoculum (treatment 2), *B. sorokiniana* was isolated from 72% of the samples in 1980 and 59% in 1981. *B. sorokiniana* was present in 91% of the samples in treatment 3 in 1980 and 73% in 1981. The only other pathogen consistently isolated from subcrown internodes in treatments with indigenous inoculum (treatments 2 and 3) was a *Fusarium* sp. It was present in 53% of the samples in 1980 and 45% in 1981. The pathogen was identified as *F. graminearum* based on microscopic examination of isolates from 10 subcrown internodes. This species produced a yellow pigment in culture and all cultures had similar pigmentation. No attempt was made to substantiate the species of all other isolates.

Wheat yields decreased approximately 21% in 1980 and 16% in 1981 when *B. sorokiniana* was added to the soil. Similar results were obtained with indigenous inoculum. There was no further decrease in yield with maximum disease pressure (treatment 3).

The winter survival of barley in the control (disease free) plots was 90% in 1980 and 91% in 1981. The effect of treatments on winter survival were similar to the results for wheat (Fig. 1).

B. sorokiniana was isolated from 95% of the subcrown internodes in 1980 and 97% in 1981 when it was the only pathogen added to the soil (treatment 1). With treatment 2, these percentages dropped to 63% in 1980 and 56% in 1981. The subcrown internodes evaluated from treatment 3 had *B. sorokiniana* in 86% of the samples in 1980 and 85% in 1981. As in the wheat experiments, *F. graminearum* was the only other pathogen consistently isolated from the subcrown internodes. It was present in 43% of the samples (treatments 2 and 3) in 1980 and 45% in 1981.

Decreases in barley yields were similar when treatment 1 or 2 was compared to the disease-free control. The decrease was approximately 20% in both years. There was no further decrease in yield with maximum disease pressure (treatment 3).

DISCUSSION

Soilborne pathogens, especially *B. sorokiniana*, can have a major effect on winter survival of wheat and barley in Pennsylvania. The survival rates for the control should reflect the survival of wheat and barley in the absence of soilborne pathogens in central Pennsylvania. The only stresses that should have affected plants in these plots were environmental in nature, such as temperature and ice formation. In both years, the aphid populations were low during the fall growing season, and barley yellow dwarf virus symptoms were not evident. This does not completely eliminate the possibility that virus infection may have contributed to winterkilling, but its effect should have been minor in comparison to the effects of root rot.

While the relationship between the severity of root rot and winter survival was simple, the relationship between root rot and yield was more complex. With both wheat and barley there was a decrease in yield and survival as root rot increased (treatments 1 and 2). However, except for wheat in 1981, when root rot severities were increased to their highest levels (treatment 3), there was another decrease in survival, but yields did not change. The decrease in plant number could, in part, be offset by an increase in tillering in the spring.

Although root rot severities were higher than normal because of the specific treatments, this study demonstrates another potential effect of *B. sorokiniana* on wheat and barley. It may reduce winter survival alone, or in combination with other plant pathogens. When this loss in stand is combined with the root rot that may develop during optimum spring weather conditions, it is apparent that *B. sorokiniana* has the potential to severely reduce the yield of wheat and barley.

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