Effects of Temperature and Soil Water Potential on Expression of Barley Stripe Incited by Helminthosporium gramineum

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ABSTRACT

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Effects of day and night temperature on development of barley stripe were tested with artificially inoculated seedlings of barley cultivars Jefferson, Keowee, and N.C. 526, and with naturally infected seedlings of Tenn. 59-15. Jefferson, a resistant cultivar, showed no consistent pattern of temperature effects. With Keowee, greatest disease incidence (more than 50% infected plants) occurred at day temperatures of 6-22 C in combination with night temperatures of 22-30 C. N.C. 526 and Tenn. 59-15 developed greatest disease at 6-14 C day and 14-22 C night temperatures. Naturally infected seedlings of Tenn. 59-15 were grown in soil at three water potential levels. In two tests 15-16%, 64-84%, and 27-36% of the plants developed stripe symptoms in wet (−1.0 bars), intermediate (−7.1 bars), and dry (−12.9 bars) soil, respectively. Carboxin (5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxanilide) seed treatment at 6 g/100 kg slightly reduced stripe incidence (39% in treated, 64% in untreated plants) in soil of intermediate water potnetial. In dry soil carboxin had no effect on stripe, and in wet soil carboxin at 6 g/100 kg caused stunting of plants and resulted in increased disease incidence (33% in treated, 15% in untreated plants).

Additional key words: Hordeum vulgare.

Barley stripe incited by *Helminthosporium gramineum* Rabh. occurs in nearly all countries where barley *(Hordeum vulgare* L.) is grown (3). Infection of seed occurs in the field before harvest, and the pathogen remains dormant in the pericarp until the seed is planted (7). Growth of the fungal mycelium into the seedling is affected by environmental factors during germination and emergence of the seedling (8, 9). Johnson (4) reported that infection was greatest at soil temperatures of 10 to 12 C, and that very little infection occurred at soil temperatures above 20 C. Leukel et al. (7) found that stripe development was favored by soil temperatures below 15 C and soil moisture at less than 40% saturation. Soil temperatures above 20 C and soil moisture above 90% resulted in little or no disease. Percentage saturation, however, is not a uniform measure of availability of water in the soil. Different soil types at the same percentage saturation may have different water potentials (2). Therefore, in the present study, the effects of soil moisture on stripe development were reevaluated using water potential as the measure of available moisture. In addition, the effects of various combinations of day and night temperatures on stripe development were tested in controlled-environment chambers.

MATERIALS AND METHODS

Effects of temperature.—Plants of three winter barley cultivars were artificially inoculated with *H. gramineum* and grown under different temperature regimes in controlled-environment chambers in the Southeastern Plant Environment Laboratory. The three cultivars–Jefferson (C.I. 11902), Keowee (C.I. 11369), and N.C. 526–had been rated resistant, moderately resistant, and susceptible, respectively, to barley stripe in greenhouse tests with artificially inoculated seedlings (5, and D. M. Kline, *unpublished*). An experimental line, Tenn. 59-15 (C.I. 12245), which had been shown by Kline *(unpublished)* in field tests to have 26.8% natural infection, was also grown in the controlled- environment chambers to determine the effects of temperature on disease development.

Jefferson, Keowee, and N.C. 526 seeds were inoculated with a mixture of four virulent isolates of *H. gramineum* by incubating the seeds in flasks containing *H. gramineum* cultures on autoclaved wheat according to the method of Arny and Shands (1). After 5 days, the seeds were removed from the flasks and planted in 10-cm diameter plastic pots (100 seeds/pot) in a 1:3 mixture of

sand and soil that had been sterilized with methyl bromide. Each temperature treatment included eight pots of inoculated and two pots of noninoculated seedlings. Noninoculated seedlings were incubated in flasks with sterilized wheat but without *H. gramineum* for 5 days before planting.

Plants were grown in controlled-environment chambers at 6, 14, 22, and 30 C. Light was supplied at 452 hecto lux for a 9-hour day period. Pots of plants were arranged on carts, so that they could be moved from chamber to chamber for different day and night temperatures. All 16 combinations of the four day and night temperatures were used. Numbers of plants that emerged from the soil were counted on the 15th day after planting. Seedlings were examined each week for the next 4 weeks, and those with stripe symptoms were removed from the pots as they were counted.

Effects of soil water potential.—Barley plants were grown in a mixture of soil, peat moss, and sand (3:2:1, v/v) in 15-, 30-, and 45-cm lengths of polyvinyl chloride sewer pipe (15-cm diameter). A wire screen (1.6×1.4-mm mesh) supported by 3.2-mm mesh hardware cloth was placed under the pipe to hold the soil mix. This assembly was set on corks in a 4-liter plastic bucket that served as a water reservoir. Fertilizer (8-8-8, NPK) was applied at the rate of 250 kg/hectare.

Water potential was measured with soil psychrometers (Wescor, P. T. 51-05) and a psychometric microvoltmeter. A psychrometer was buried 7.5 cm deep in the soil in each pipe. Water potential was measured every 10th day for 9 weeks. Each of the three water potential levels was replicated three times. Experiments were conducted in a controlled-environment chamber at 22 C day and 14 C night temperature. Light was provided at 344 hecto lux for 9 hours per day.

Fifty seeds of Tenn. 59-15 (26.8% stripe infection) were planted in each piece of pipe. Numbers of plants that emerged and numbers with stripe symptoms were

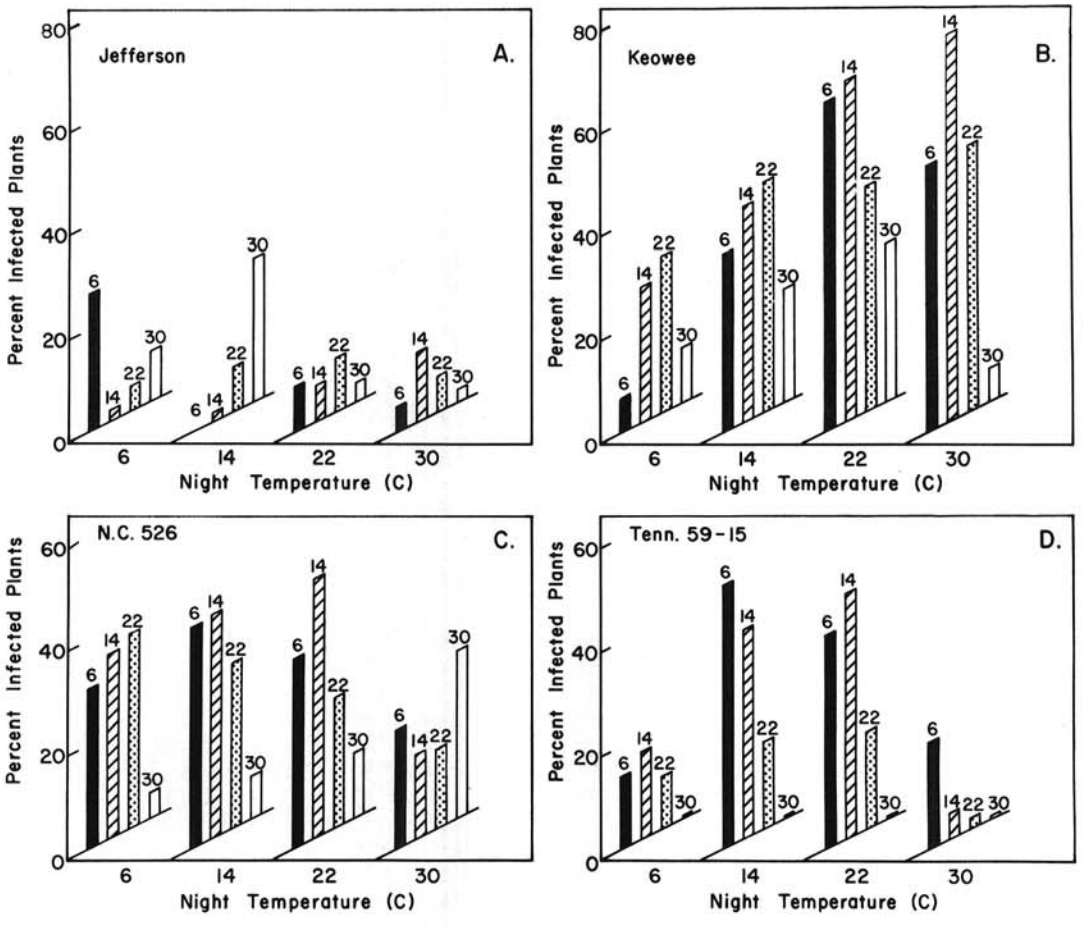

Fig. 1-(A to D). Effects of day and night temperatures on development of barley stripe on seedlings of cultivars **A)** Jefferson, **B)** Keowee, and **C)** N.C. 526 that were artificially inoculated, and **D)** Tenn. 59-15 that was naturally infected with *Helminthosporium gramineum*. Night temperatures of 6, 14, 22, and 30 C are indicated on the *x* axes (horizontal on the page); day temperatures of 6, 14, 22, and 30 C are indicated above the bars on the *y* axes (projecting into the page); and percentages of plants with stripe symptoms are indicated by the height of the bars according to the scales on the *z* axes (vertical on the page).

counted 60 days after planting.

The experiment was repeated with two replications at each moisture level and with Tenn. 59-15 seeds treated with carboxin (5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxanilide) at 0, 3, and 6 g/100 kg.

RESULTS

Effects of temperature.—An analysis of variance of arcsine-transformed data was computed to evaluate differences among cultivars and interactions of cultivars with day and night temperatures. Tests were performed using within day-night treatment replication to estimate experimental error. Differences among cultivars were highly significant ($P = 0.01$), as were interactions of cultivars with day and night temperature.

No consistent pattern of temperature effects was found with the resistant cultivar, Jefferson. Only two treatments, 6 C day/6 C night and 30 C day/14 C night temperature, resulted in relatively high disease incidence (Fig. 1-A). With Keowee, disease was greatest with high night temperatures and moderate to low day temperatures. Greater than 50% infection occurred with night temperatures of 30 C and day temperatures from 6-22 C and with 22 C night and 6-14 C day temperatures (Fig. 1-B). N.C. 526 developed most disease at 6-14 C day and 14-22 night temperatures (Fig. 1-C). The naturally infected Tenn. 59-15 also had greatest disease incidence at 6-14 C day and 14-22 C night temperatures.

Effects of soil water potential.—Average water potentials for soil in 15-, 30-, and 45-cm diameter pipes were −1.0, −7.1, and −12.9 bars, respectively. In the wet soil treatment, water potential remained constant at −1.0 bars, but the water potential increased from −8.0 to −6.5 in the intermediate treatment, and from −13.5 to −12.5 bars in the dry soil treatment over the 60-day experimental period.

TABLE 1. Effects of soil water potential on development of barley stripe incited by *Helminthosporium gramineum*

Soil moisture	Average water potential (bars)	Diseased plants[a] (%)
Wet	− 1.0	15.7
Intermediate	− 7.1	83.8
Dry	−12.9	36.1
LSD (P=0.05)=		12.0

[a]Average of three replications.

TABLE 2. Effects of soil water potential and carboxin seed treatment on development of barley stripe incited by *Helminthosporium gramineum*

Soil moisture	Average water potential (bars)	Carboxin per 100 kg seed (g)	Diseased plants[a] (%)
Wet	− 1.0	0	14.9
		3	12.4
		6	33.3
Intermediate	− 7.1	0	64.1
		3	59.2
		6	39.1
Dry	−12.9	0	26.9
		3	27.4
		6	24.0
LSD (P = 0.05) =			13.8

[a]Average of two replications.

For plants without carboxin treatment, the average percentage of diseased plants was lowest with wet soil and highest with soil of intermediate water potential (Tables 1 and 2). Untreated plants in wet soil were consistently about 15% taller than those in the intermediate soil throughout the experimental period. Plants in dry soil grew slowly and were about 50% as tall as plants in wet soil.

With intermediate soil water potential, 6 g carboxin per 100 kg seed slightly reduced disease incidence (Table 2). Higher rates might have provided more satisfactory control. With dry soil there appeared to be no effect of carboxin at either rate (Table 2). In wet soil, the 6 g/100 kg application caused stunting of plants, curling of leaves, and dying of leaf tips, and resulted in increased disease incidence (Table 2).

DISCUSSION

The effects of temperature on stripe development in this study differed somewhat from those reported by Johnson (4) and Leukel et al. (7). They found greatest disease development at 12-15 C. We found that day temperatures of 6-14 C favored disease in three of the four cultivars, but that greatest disease development occurred when night temperatures were higher (14-22 C for N.C. 526 and Tenn. 59-15, and 22-30 C for Keowee) than the optimum day temperatures. High night temperatures combined with low day temperatures caused leaf tips to turn yellow, and eventually, to die. This reaction may have resulted from an imbalance between high rates of respiration and lower rates of photosynthesis.

Although Johnson (4) and Leukel et al. (7) suggested that the temperature during the period before the seedlings emerged from the soil was the most critical in determining disease development, it is not likely that differences in day and night temperatures would greatly affect seedlings at that stage. According to Smith (9) and Skoropad and Arny (8), the mycelium of the pathogen does not become systemic early in the development of the barley seedlings. Thus, disease development may depend on the balance between growth rates of the host and the fungus. Conditions such as high night temperatures that adversely affect the host but not the fungus may increase disease development even after the seedlings have emerged from the soil.

Leukel et al. (7) found less stripe development with higher soil moisture over a range of 15-95% saturation. They suggested that very wet soil may lack sufficient oxygen for rapid growth of the fungus, and that seeds in wet soil may germinate more rapidly and allow the seedlings to grow away from the fungus. In our experiments, plants in wet soil (−1.0 bars) grew most rapidly and had the lowest level of disease. However, the slowest growing plants, those in dry soil (−12.9 bars), had less disease than those in soil of intermediate water potential (−7.1 bars). Evidently, there are other important factors beside growth rate of the host that

determine disease development. Perhaps the less succulent tissue of seedlings grown in dry soil is less susceptible to *H. gramineum* than the tissue of plants in soil of intermediate water potential. The failure of Leukel et al. (7) to observe a decrease in disease incidence in very dry soil cannot be compared with our results, because Leukel et al. described soil moisture as percentage saturation, but did not describe the type of soil that was used. Unless they used a soil with high clay content, the lowest moisture level (15% saturation) that they tested probably had a higher water potential than the −12.9 bars of the dry soil in our tests.

Carboxin did not effectively control *H. gramineum* in this test, even though Kline and Roane (6) found similar levels of carboxin effective in field tests. The conditions of the growth chamber appeared to be more conducive to disease development than field conditions, as evidenced by the high levels of infection (up to 70%) in these experiments compared to 26.8% stripe found by Kline for the same seed lot in field tests. The data suggest that carboxin may be ineffective in dry soil, and may increase disease development in wet soil by interfering with plant growth.

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