Influence of Temperature and Light on Severity of Bacterial Blight of Corn, Oats, and Wheat

N. W. SCHAAD, Associate Professor, Department of Plant Pathology, University of Georgia College of Agriculture Georgia Experiment Station, Experiment 30212; D. R. SUMNER, Associate Professor, Department of Plant Pathology, University of Georgia College of Agriculture Coastal Plain Experiment Station, Tifton 31794; and G. O. WARE, Experiment Stations Statistician, College Station, Athens, GA 30602

ABSTRACT

SCHAAD, N. W., D. R. SUMNER, and G. O. WARE. 1980. Influence of temperature and light on severity of bacterial blight of corn, oats, and wheat. Plant Disease 64:481-483.

Two experiments using five strains of *Pseudomonas avenae* and five day/night temperature regimens were conducted to determine the influence of temperature and light on the severity of bacterial leaf blight of corn, wheat, and oats. The first experiment showed that light had no effect on lesion development. In the second experiment, plant growth data for corn and wheat were recorded also. The effects of temperature on blight severity differed with the host. On corn, lesion development was not affected by temperature but plant growth was significantly reduced at the three intermediate temperature regimens. Average lesion size was significantly greater with strain C-71 than with strain 19860 at temperatures of 22/14 and 18/14 C but not at 30/26, 30/22, or 22/18 C. On oats, *P. avenae* strain significantly affected lesion development and disease was generally more severe at higher temperatures. On wheat, blight symptoms were generally more severe at higher temperatures but *P. avenae* strain had no significant effect. Under Georgia conditions, bacterial blight should be less severe in oats and wheat sown late in the fall season when the temperature is cooler. With corn, plant growth should be less reduced when the mean evening temperature is $\geq$ 22 C. Strains of *P. avenae* should affect the severity of bacterial leaf blight of corn and oats but not of wheat.

Bacterial leaf blight of corn, caused by *Pseudomonas avenae* (4), has been observed sporadically in corn fields in southern Georgia for several years. Severe outbreaks generally occur in late May and early June after periods of overcast and wet weather (7). Mean temperatures in south Georgia during this period are usually 18–24 C (7). The first symptoms are usually observed in early May when corn plants are 0.8–1 m tall. Although bacterial leaf blight of corn has been known for many years (2,8), little information is available on the effects of light and temperature on disease severity. Johnson et al (2) observed in a greenhouse that symptoms were abundant at 29–35 C, few at 24 C, and infrequent or lacking at 21 C. There are no reports of any observations on the effects of temperature on disease severity in oats and wheat.

The objective of our study was to determine the influence of temperature and light on the severity of bacterial blight of corn, oats, and wheat. We wanted to determine if temperature and/or light could also be used to predict disease occurrence.

Experiments were done in environmental chambers at the Southeastern Plant Environmental Laboratory (SPEL), Raleigh, NC, to reduce variation between chambers as much as possible. The tests were repeated in a second experiment in environmental chambers at Experiment, GA, where we also recorded the effect of the disease on plant growth.

Supported by a grant from the Southern Regional Education Board (Alfred P. Sloan Foundation) and by state and Hatch funds allocated to the Georgia Agricultural Experiment Stations.

00191-2917/80/05048103/$03.00/0

MATERIALS AND METHODS

The hosts used were corn (*Zea mays* L. 'Pioneer 3030'), oats (*Avena sativa* 'Georgia 7199'), and wheat (*Triticum vulgare* Vill. 'McNair 1587'). Plants were grown in 10-cm diameter Styrofoam cups in a potting medium of 1:1:8 (peat moss: vermiculite: gravel) mixture, as described elsewhere (1). Corn plants were grown in separate cups (four plants per cup) and wheat and oat plants were grown on opposite sides of the same cup (four plants each per cup). Seeds were germinated in a greenhouse at a day/night temperature of 30/26 C for corn and 30/22 C for wheat and oats for 4 days. The plants were then placed in an environmental chamber at 26/22 C for 6 days. The corn was thinned to two plants per cup and the wheat and oats to four plants (two of wheat and two of oats) per cup, and the cups were placed in their respective controlled-environment chambers for 48 hr before inoculation. All plants were 12 days old and in their third to fourth leaf stage.

In experiment 1, tests were conducted in five walk-in controlled-environment chambers at SPEL Phytotron (1). In experiment 2, tests were conducted in two Percival PG-2 and three Con-Environs PGW-36 walk-in controlled-environment chambers at Experiment, GA. In experiment 1, a completely randomized design was used with 80 cups containing two plants of corn and 80 cups containing two plants each of oats and wheat. Illumination was maintained at 30 klux at cup level. Half the cups in each chamber were covered with enough cheesecloth to reduce light by 50%. In experiment 2, illumination was maintained at 28–30 klux for 9 hr at cup level and a completely randomized design was used with 100 cups containing two plants of corn and 100 cups containing two plants each of oats and wheat. In both experiments, day/night temperature regimens of 30/26, 30/22, 22/18, 22/14, and 18/14 C were used and the photoperiod was 9 hr.

Plants were inoculated by placing a 25-gauge needle into the sheath and injecting approximately 0.1 ml of a suspension containing about 10^6 viable cells/ml (4) of *P. avenae*; sterile distilled water was used in control plants. In experiment 1, two strains of *P. avenae* were used: C-71 and ATCC 19860. Strain C-71 was isolated from corn from Climax, GA, on 23 May 1975. In experiment 2, four strains were used: 19860, C-12, C-138, and C-139. Strain C-12 was obtained from J. M. Miller, Gainesville, FL, and strains C-138 and C-139 were isolated on 6 June 1975 from corn from Tift and Pierce counties, GA, respectively. One plant of corn and one plant of oats and of wheat in each cup were inoculated with *P. avenae* and one with water. Each experimental unit was replicated four times. After inoculation, all plants were placed in the appropriate controlled-environment chamber. Total lesion area (mm^2) was measured after 3 and 7 days and the data were transformed to log 10 for analysis. In addition, in experiment 2, growth of corn and wheat plants was measured by recording the distance from the soil line to the tips of the third, fourth, fifth, and sixth leaves and the third and fourth leaves, respectively.

RESULTS

Lesions were visible on all three hosts 3 days after inoculation. Light had no effect on average lesion size (ALS) on corn, oats, or wheat, and the interaction

of light with temperature and strain was not significant. The effect of temperature and strain on lesion development varied with the host (Tables 1–3). No lesions were observed on any control plants.

Corn. Lesions on corn were linear; initially, lesions were water-soaked but became dry and bleached after 7 days. Lesions only rarely were observed on the oldest (lowest) leaf, and such lesions were never longer than 3–4 mm.

After 7 days, no lesions were observed on any of the newest leaves (fifth or sixth) of plants at 30/26 and 30/22 C. Almost all lesions on the older leaves of plants at 30/26 and 30/22 C were dry and inactive. In contrast, almost all new leaves emerging from the whorl of plants at 22/18, 22/14, and 18/14 C showed symptoms of bacterial leaf blight. In experiment 1, an increase in temperature resulted in a general increase in ALS with strain 19860 but not with strain C-71 (Table 1). Strain C-71 resulted in a significantly greater ALS than strain 19860 at 22/14 and 18/14 but not at 22/18, 30/22, or 30/26 C (Table 1). In experiment 2, neither *P. avenae* strain (Table 2) nor temperature (Table 3) had any effect on lesion development. Plants inoculated with *P. avenae* were significantly smaller than control plants after 7 days at the intermediate temperatures of 30/22, 22/18, and 18/14 C but not at 30/26 and 18/14 C (Table 4).

Oats. Lesions were initially water-soaked and later brown to black and dry; both circular spots and linear lesions were present. In experiment 1, the ALS caused by strain C-71 was significantly greater than that caused by strain 19860 at all temperatures after 7 days (Table 1). Temperature alone had little or no effect on the ALS caused by either strain (Table 1). After 7 days, many of the newest leaves had water-soaked lesions regardless of the temperature. In experiment 2, *P. avenae* strain had a significant effect on lesion development also (Table 2). The ALS was greater at temperatures of 30/26 and 30/22 C than at the lower three temperatures over all strains (Table 3). Data on plant growth were not available because we were not able to include the appropriate number of control plants.

Wheat. Lesions were circular and water-soaked; no linear lesions were evident. *P. avenae* strain caused no significant difference in ALS in experiment 1 (Table 1) or experiment 2 (Table 2). Like oats, many of the newest leaves of wheat plants had water-soaked lesions after 7 days. Temperature had no effect on lesion development in experiment 1, whereas in experiment 2, lesion area was greater at the two higher temperatures than at the lower temperatures over all strains (Table 3). Plants inoculated with *P. avenae* were significantly smaller than control plants at the lowest temperature only (Table 4).

DISCUSSION

The optimum temperature for growth of *P. avenae* on agar media ranges from 30 to 36 C (4). Doubling times (6) of strains 19860, C-10, C-12, and C-13 (4) growing in liquid medium 523 (3) range from 47 to 67, 64 to 91, 100 to 212, and 172 to 310 min at 36, 29, 21, and 15 C, respectively (N. W. Schaad, *unpublished*). The lack of a consistent pattern of temperature effects on disease development in the warm-season corn and the cool-season wheat and oats suggests that temperature does not effect lesion development in plants the same way it effects growth of the bacterium in culture.

Our results with corn failed to support the report (2) that bacterial leaf blight developed rapidly at 25–35 C but slightly or not at all at 21 C. Instead, we found that disease developed as well at the lower as at the higher temperatures. Had we also used only one strain (for example, 19860), we might have observed similar results. Perhaps differences in strains of *P. avenae* and/or relative humidity accounted for the previous results (2) with corn.

Statistical data on differences between any two temperatures for a given strain were not presented because an appropriate error term did not exist, that is, we were not able to use three or more environmental chambers for each temperature. Had we used three replicates, we would have needed more chambers than were available. However, several comparisons between the chambers at SPEL have been made, and the results have shown no significant variation in plant growth between chambers (R. J. Downs, *personal communication*). Although it was not possible to repeat our tests at SPEL at a later date using a different chamber for each temperature, we did repeat the entire experiment in commercial environmental chambers at Experiment, GA. We used one of the same strains (ATCC 19860) used in the first experiment at SPEL, but the other strain (C-71) was lost in culture and not available. Still, the results were similar. For example, a comparison of strain 19860 in the two tests on corn resulted in similar conclusions regarding effect of temperature on ALS. Assuming homogeneity of growth chambers, no significant ($P = 0.05$) difference resulted between temperatures except between the highest and the two lowest temperatures.

Preliminary results (5) and field observations (7) suggest that the rate of lesion development is correlated with plant growth. However, our data do not support such a conclusion. Rather than plant growth rate affecting lesion development, the opposite appears to be

Table 1. Comparison between *Pseudomonas avenae* strains 19860 and C-71 on lesion development in corn, oats, and wheat at five different day/night temperatures in tests at Southeastern Plant Environmental Laboratory, Raleigh, NC

Temperature (C)	Strain	Mean lesion area (mm^2, log 10^a)		
		Corn	Oats	Wheat
30/26	19860	6.34	0.55	0.35
	C-71	6.49	1.37	0.87
30/22	19860	4.52	0.08	0.26
	C-71	5.10	2.12	0.65
22/18	19860	4.20	0.00	0.28
	C-71	6.10	1.63	0.77
22/14	19860	3.96	0.42	0.10
	C-71	6.39	1.28	0.59
18/14	19860	2.72	0.22	0.41
	C-71	6.42	1.39	0.97
LSD 0.05[b]		2.25	0.52	0.59

[a] Eight replicates; data were recorded 7 days after inoculation.
[b] Least significant difference can be used for determining the difference between two strain means at the same temperature only.

Table 2. Effect of strain of *Pseudomonas avenae* on lesion area in corn, oats, and wheat in tests at Georgia Experiment Station, Experiment, GA

Strain	Mean lesion area (mm^2, log 10^a)		
	Corn	Oats	Wheat
19860	2.91	0.59	0.48
C-12	2.96	0.46	0.75
C-138	2.84	1.25	0.59
C-139	2.78	1.03	0.66
LSD 0.05[b]	0.26	0.55	0.55

[a] Eight plants 7 days after inoculation, five different temperatures (40 plants per strain).
[b] Least significant difference, $P = 0.05$.

Table 3. Effect of day/night temperature on area of lesions caused by *Pseudomonas avenae* in corn, oats, and wheat in tests at Georgia Experiment Station, Experiment, GA

Temperature (C)	Mean lesion area (mm^2, log 10^a)		
	Corn	Oats	Wheat
30/26	2.97	1.58	1.29
30/22	3.02	1.38	0.85
22/18	2.91	0.47	0.19
22/14	2.64	0.47	0.43
18/14	2.85	0.65	0.34

[a] Four plants for each of four strains of *P. avenae* 7 days after inoculation. Statistical data not presented because all plants at each temperature were in a single environmental chamber.

Table 4. Effect of *Pseudomonas avenae* at five different day/night temperatures on growth of plants of corn and wheat in tests at Georgia Experiment Station, Experiment, GA

Temperature (C)	Treatment	Growth (cm)[a] Corn	Wheat
30/26	*P. avenae*	87.35	39.51
	Control	93.75	63.40
30/22	*P. avenae*	63.35	49.15
	Control	92.12	41.70
22/18	*P. avenae*	60.07	52.06
	Control	100.07	37.80
22/14	*P. avenae*	53.92	42.68
	Control	93.17	48.25
18/14	*P. avenae*	55.44	69.46
	Control	69.50	31.35
LSD 0.05[b]		22.59	33.51

[a] Growth determined by measuring total leaf length of all plants from soil line to leaf tips 7 days after inoculation. Figures are means of four plants for each of four strains of *P. avenae* (no significant difference among strains) and means of 16 control plants.

[b] Least significant difference can be used for determining the difference between *P. avenae* and control at the same temperature only.

true (Table 4). This negative effect of *P. avenae* on the growth of corn was not expected. Data on the total height of the plant after 7 days suggest that the bacterium could cause severe damage to plant growth under day/night temperatures of 30/22, 22/18, or 22/14. The failure of disease to remain active in older leaves could be due to an inherent resistance of mature tissues.

Although no data were recorded after 7 days, observations that the newest leaves of oats and wheat had new lesions at all temperatures whereas corn had new lesions only at the two lowest temperatures indicate that the disease is potentially more serious at a wider temperature range in oats and wheat than in corn. Also, with oats the ALS was so great in relation to the total leaf area of the newest leaves that little green tissue remained.

If plants of other cultivars of corn react to *P. avenae* as Pioneer 3030 does, plant growth should be significantly reduced during cool, wet periods in early spring but not during the higher temperatures of summer. On the other hand, growth of wheat plants would most likely not be affected. Instead, wheat plants would be adversely affected by the relatively high temperatures during early fall in Georgia. When screening for resistance, plants should be produced under optimum growing conditions and more than one strain of the pathogen should be used for oats and corn. We suggest using two strains that have been freshly isolated from plants growing in an environment similar to where the test plants will be grown.

ACKNOWLEDGMENT

We wish to thank Ruth Donaldson for technical assistance.

LITERATURE CITED

1. DOWNS, R. J., and V. P. BONAMINIO. 1976. Phytotron procedural manual for controlled-environment research at Southeastern plant environment laboratories. N.C. Agric. Exp. Stn. Bull. 244.
2. JOHNSON, A. G., A. L. ROBERT, and L. CASH. 1949. Bacterial leaf blight and stalk rot of corn. J. Agric. Res. (Washington, DC) 78:719-732.
3. KADO, C. I., and M. G. HESKETT. 1970. Selective media for isolation of *Agrobacterium, Corynebacterium, Erwinia, Pseudomonas,* and *Xanthomonas.* Phytopathology 60:969-976.
4. SCHAAD, N. W., C. I. KADO, and D. R. SUMNER. 1975. Synonymy of *Pseudomonas avenae* Manns 1909 and *Pseudomonas alboprecipitans* Rosen 1922. Int. J. Syst. Bacteriol. 25:133-137.
5. SCHAAD, N. W., and D. R. SUMNER. 1976. Effects of temperature and light on development of bacterial blight of corn caused by *Pseudomonas avenae.* (Abstr.) Proc. Am. Phytopathol. Soc. 3:245.
6. STANIER, R. Y., M. DOUDOROFF, and E. A. ADELBERG. 1963. Growth and death of bacteria. Pages 324-328 in: The Microbial World. 2nd ed. Prentice-Hall, Inc., Englewood Cliffs, NJ. 753 pp.
7. SUMNER, D. R., and N. W. SCHAAD. 1977. Epidemiology and control of bacterial leaf blight of corn. Phytopathology 67:1113-1118.
8. ULLSTRUP, A. J. 1960. Bacterial stripe of corn. Phytopathology 50:906-910.