

# Effect of Temperature on Incidence and Severity of Anthracnose on White Bean

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## ABSTRACT

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In southern Ontario, summer temperatures are generally favorable for infection of beans (*Phaseolus vulgaris*) by *Colletotrichum lindemuthianum* if free moisture is present on white bean foliage. Symptoms did not develop on inoculated plants held at constant temperatures of 28 and 32 C, but did if night temperatures were lowered. Symptoms readily occurred in the field because such high temperatures usually lasted only a few hours during daytime. Plants held at 28 and 32 C continuously for 2-3 days prior to inoculation were only slightly less susceptible. Increases in high day temperatures as the summer advanced prolonged the incubation period and slightly decreased disease severity.

Development and severity of bean anthracnose, caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Briosi & Cav., are often reduced by high temperatures (3,5,6,8). However, high temperatures appear to have little effect on the disease in fields of white beans (*Phaseolus vulgaris* L.) in southern Ontario.

Infection of white beans by the delta race of *C. lindemuthianum* has been reported in southern Ontario since 1975, with the disease reaching epidemic levels in 1976 and 1977. Previous work (7) confirmed that infection by *C. lindemuthianum* did not occur when the inoculated plants were incubated in a moist environment at temperatures above 28 C. In the field, daytime temperatures above 28 C are common in southwestern Ontario, yet new infections occurred in 1979 and 1980. This suggests that nighttime temperatures can moderate the effect of high daytime temperatures.

The purpose of this study was to determine the effects of several temperature variables on infection by *C. lindemuthianum* and on symptom expression on white beans. The variables examined were preinoculation temperature, temperature during infection, temperature during incubation, and interaction of low night temperatures and high day temperatures.

## MATERIALS AND METHODS

Seeds of Black Turtle and Fleetwood white beans were sown in a steamed soil preparation of loam, silt, and sand (2:1:1)

in 10-cm peat pots, five seeds per pot. The pots were held in a greenhouse (20-24 C) until seedlings reached the primary leaf stage.

Spore suspensions were prepared from 3-wk-old colonies of *C. lindemuthianum* (race delta) on Mathur's agar (2). Five milliliters of sterile water was added to each plate, and the surface of the culture was scraped with a transfer loop to dislodge spores. Spore suspensions from several plates were pooled, filtered through cheesecloth, and adjusted to  $1 \times 10^7$  spores per milliliter of water. Bean seedlings at the primary leaf stage were inoculated by brushing the spore suspension onto the stem and leaves. Inoculated plants were covered for 48 hr with transparent plastic bags to maintain a film of moisture (1,7) and held in a growth chamber at 20 C with 14 hr of light per day (15 klux at pot level) and 80% relative humidity. The light was emitted from cool-white fluorescent tubes and incandescent bulbs. Temperatures were varied according to the specific experimental design. Disease severity was rated 1 wk after inoculation on a scale of 0-9, where 0 represented no symptoms and 1-9 represented the proportion of total leaf veins with disease symptoms (1 = 10% or less, 2 = 11-20%, etc.).

Twenty sets of inoculations were made between 13-26 July 1978 and 1979 in a screenhouse to determine whether infection and symptom development occurred at high temperatures. Twenty plants each of Black Turtle and Fleetwood beans were inoculated in the morning (0800-1000 hr), covered with plastic bags for 2 days, and kept in the screenhouse. Temperatures during this moist period were recorded. After removal of the bags, half of the plants were moved into a growth chamber maintained at 20 C, and the other half were kept in the screenhouse. Plants were examined for symptoms 6 days after inoculation.

In another experiment, two groups of 60 plants each of Black Turtle and Fleetwood beans were inoculated to determine the effect of incubation temperature on infection and symptom development. After inoculation, one group was kept at 20 C during the 48-hr moist period, then divided into six subgroups of 10 plants of each cultivar that were incubated for 4 days at 12, 16, 20, 24, 28, or 32 C. The other group was divided immediately after inoculation, and the subgroups were incubated at the six temperatures during the 48-hr moist period. Plants were then moved to a growth chamber and held at 20 C for 4 days before recording symptoms. The experiment was repeated once.

To determine the effect of preinoculation high temperature on symptom expression, 10 plants each of Black Turtle and Fleetwood beans were incubated at 24, 28, and 32 C for 1, 2, or 3 days before inoculation. After inoculation, all plants were incubated at 20 C during and after the 48-hr moist period. The experiment was repeated once.

To determine the influence of cool nights after hot days on symptom expression, two experiments were performed in controlled environmental chambers programmed for 14 hr of daylight. In one experiment, the temperatures were 20 and 32 C and in the other 16 and 28 C. In each experiment, one group of plants was maintained constantly at the high temperature, a second group was held constantly at the low temperature, and the third group was maintained at the high temperature during daylight hours and the low temperature at night. Each group of plants at each regime consisted of 10 Black Turtle and 10 Fleetwood plants.

Data were subjected to analysis of variance and tested for significance by Duncan's multiple range test.

## RESULTS

Results of the 20 sets of inoculations made in the hot summer days between 13 and 26 July 1978 and 1979 provided an overview of the effects of temperature (during infection and incubation) on disease incidence and severity, and are arranged in ascending order of the mean temperatures in Figure 1. Although all inoculations resulted in infection, symptom expression was affected by temperatures during infection and incubation and by cultivar. Fleetwood had a lower disease rating than Black

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Turtle in the screenhouse and growth chamber, and the differences were greater for plants kept in the screenhouse than in the growth chamber. Temperatures frequently reached 25–35 C for short periods in the daytime, but they had little

effect on infection. It also appeared that disease severity was inversely related to temperature during infection.

The significance of these observations was ascertained by analysis of variance for each of the variables. Variation

among replicates within cultivars was small, accounting for 6% of the total sum of squares, and was not significant. For all three variables, there was significant ( $P = 0.01$ ) variation due to temperature (during infection and during incubation) and cultivar differences. There was a significant interaction effect between cultivars and incubation temperatures. Other interactions among the variables were not significant.

When inoculated plants were subjected to different temperatures during the 48-hr moist period and then maintained at 20 C, those incubated at 28 and 32 C during the moist period developed few or no symptoms (Table 1). When inoculated plants were held at 20 C during the 48-hr moist period and then incubated at different temperatures, those incubated at 12 C developed no symptoms. The disease was most severe at 20–24 C and least severe at 16 C; however, disease severity was greatly reduced at 28 and 32 C.

Analysis of the data in Table 1 showed that disease severity ratings differed significantly ( $P = 0.01$ ) between cultivars and among temperatures. Although Fleetwood and Black Turtle are both susceptible to race delta of *C. lindemuthianum*, differences in symptom expression were apparent when incubation temperatures were near the extremes of the temperature range tested.

Of the three preinoculation temperatures tested, 24 C had no apparent effect on disease severity (ratings ranged from 8.2 to 8.8) regardless of duration of the treatment, and differences in disease severity between Fleetwood and Black Turtle were not significant. Disease severity following prolonged exposure (more than 2 days) at 28 or 32 C was significantly lower than that at 24 C; eg, disease ratings on plants subjected to 3 days of preinoculation treatment at 28 C ranged from 7.1 to 7.4. Differences in disease severity between the two cultivars were not significant.

Inoculated plants maintained at 28 or 32 C developed few or no symptoms, those maintained at 16 or 20 C were severely affected, and plants on a 28 C (day)/16 C (night) or 32 C (day)/10 C (night) cycle were moderately diseased (Table 2). Analysis of variance indicated that there was a significant difference between the two temperature sets (32/32, 32/20, and 20/20 vs 28/28, 28/16, and 16/16) and that symptom expression at different temperatures differed with the cultivar.

## DISCUSSION

In this study, *C. lindemuthianum* infected beans any night throughout the summer in southern Ontario; temperatures were not a limiting factor. Although daytime temperatures in July and August frequently reach 25–35 C, these high temperatures usually last only a few hours. The low nocturnal temperatures

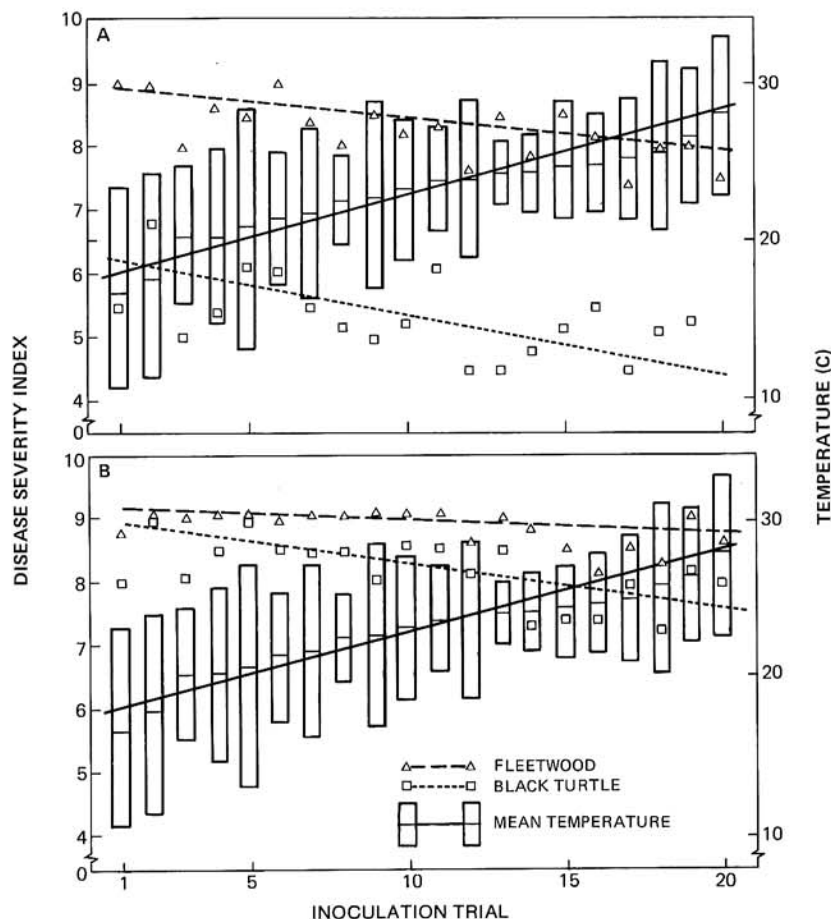
**Table 1.** Effect of temperature on incidence and severity of anthracnose on *Phaseolus vulgaris* plants inoculated with *Colletotrichum lindemuthianum*

Set <sup>x</sup>	Cultivar	Temperature (C)					
		12	16	20	24	28	32
		<b>Disease severity<sup>y</sup></b>					
I	Fleetwood	8.1 a	7.0 b	8.3 a	8.4 a	0 c	0 c
	Black Turtle	8.7 df	8.2 ac	8.5 aef	9.0 d	0.3 g	0 c
		<b>Plants with symptoms (%)<sup>z</sup></b>					
I	Fleetwood	100	100	100	100	0	0
	Black Turtle	100	100	100	100	5	0
		<b>Disease severity<sup>y</sup></b>					
II	Fleetwood	0 a	2.4 b	7.5 c	7.5 c	2.1 b	0.2 a
	Black Turtle	0 a	5.0 d	8.5 e	8.6 e	2.7 f	1.1 g
		<b>Plants with symptoms (%)<sup>z</sup></b>					
II	Fleetwood	0	100	100	100	100	100
	Black Turtle	0	100	100	100	100	100

<sup>x</sup>Set I: Plants were incubated at various temperatures for 48 hr in a moist environment, then held at 20 C. Set II: Plants were incubated at 20 C for 48 hr, then held at various temperatures.

<sup>y</sup>Values are average disease ratings (0–9 scale) for 20 plants in two experiments. Values within each cultivar and between cultivars followed by the same letter do not differ significantly ( $P = 0.01$ ) according to Duncan's multiple range test.

<sup>z</sup>Each value is an average for 20 plants in two experiments.



**Fig. 1.** Effect of temperature during infection or incubation on incidence and severity of anthracnose on *Phaseolus vulgaris* 'Black Turtle' and 'Fleetwood': (A) Plants were inoculated and incubated in a field screenhouse. (B) Plants were inoculated in a field screenhouse and incubated at 20 C in a growth chamber.

**Table 2.** Effect of day and night temperatures on incidence and severity of anthracnose on *Phaseolus vulgaris*

Cultivar	Temperature (C) day/night <sup>y</sup>					
	32/32	32/20	20/20	28/28	28/16	16/16
	<b>Disease severity<sup>z</sup></b>					
Fleetwood	0 a	5.3 b	8.2 c	0 f	6.1 g	8.5 h
Black Turtle	0 a	7.1 d	8.6 e	0.3 f	7.8 i	9.0 j
	<b>Plants with symptoms (%)</b>					
Fleetwood	0	100	100	0	100	100
Black Turtle	0	100	100	5	100	100

<sup>y</sup>14-hr day/10-hr night.

<sup>z</sup>Values are average disease ratings (0–9 scale) for 10 plants in two pots. Values within each cultivar and between cultivars followed by the same letter do not differ significantly ( $P=0.01$ ) according to Duncan's multiple range test.

permit infection to occur. Infected plants develop symptoms even though the incubation period is lengthened by high daytime temperatures in the summer. The delayed symptom expression may be due to slower mycelial growth in infected tissue under high temperatures. Optimal temperature for mycelial growth of *C. lindemuthianum* is near 22 C and maximal is between 32 and 34 C.

My data suggest that only prolonged and continuous high temperatures suppress symptom development. Failure of inoculated beans to develop disease at constant high temperature agrees with previous observations of Zaumeyer and Thomas (8) and Martinez Salazar and

Anderson (3). Rahe (4) and Rahe and Kuc (5) have shown that the depressing effect of high temperature on symptom development results from the production of phytoalexin in infected plants under prolonged periods of high temperature. However, such temperature conditions do not occur in southern Ontario.

The cultivars Fleetwood and Black Turtle differed slightly in their response to high temperatures. Although both cultivars were highly susceptible to *C. lindemuthianum* race delta and both showed a general decrease in disease severity under high temperatures (28–32 C), the reduction in disease severity was more apparent in Fleetwood than in

Black Turtle. Further investigation is needed to determine whether other cultivar-pathogen combinations are more sensitive to high temperatures in disease expression and whether such knowledge can be exploited as a disease-escape mechanism.

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