Effects of Controlled Night Temperatures on Incidence of Verticillium Wilt in Field-Grown Cotton

Earl B. Minton, Jack R. Gipson, and J. E. Quisenberry

Plant pathologist, Agricultural Research, Science and Education Administration, United States Department of Agriculture, Cotton Research Laboratory; associate professor, Texas Tech University and the Texas Agricultural Experiment Station; and research geneticist, USDA SEA/AR, Cotton Research Laboratory, respectively, Lubbock, TX 79401.
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ABSTRACT

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Cotton plants grown in field growth chambers developed foliar symptoms of Verticillium wilt after they were subjected to controlled night temperatures ranging from 10 to 27 C. High incidence of disease occurred at 10 and 15 C and lower levels at 20 and 25 C, but symptoms developed in only one of several susceptible cultivars at 37 C. Significant disease symptoms developed on cotton plants grown under 10 and 15 C temperature regimes, even though the maximum day temperatures exceeded 30 C, the level above which the development of Verticillium wilt is inhibited under field conditions. Cultivars with different levels of resistance to Verticillium wilt were more easily separated into disease classes about the middle of September than either earlier or later in the season. Interaction was significant between cultivars and temperatures. Application of methyl parathion to cotton plants did not affect disease development, but the interaction of insecticide and temperature treatments was significant.

Additional key words: Verticillium dahliae, Gossypium hirsutum.

The Verticillium wilt disease of upland cotton (*Gossypium hirsutum* L.) is caused by the fungus *Verticillium dahliae* Kleb. The incidence, severity, and distribution of this disease are increased by temperatures of less than 30 C (5,7–9,12,16,21). Expression of genetic plant resistance also can be altered by varying temperatures (1–6,11,12). The development of the disease in cotton plants grown under controlled temperatures in greenhouses and in growth chambers changed rather significantly over a narrow temperature (22–29 C) range (6,10,15).

The most favorable temperature for the growth of the fungus in culture is between 20 and 27 C (1,3,15). The incidence and severity of Verticillium wilt in cotton in the greenhouse decrease when soil temperature exceeds 25 C (15). Cotton cultivars that varied from resistant to highly susceptible in field evaluations were resistant when grown at 32 C or higher and susceptible when grown at 22 C or lower, but they were distributed among classes ranging from susceptible to resistant when grown at 25 C (1–4,6,12,19). Foliar symptoms of Verticillium wilt in both susceptible and resistant cotton cultivars grown at a low temperature decreased when the plants were grown at 27–30 C in the greenhouse for several additional months (3).

In field evaluations, high daily air temperatures prevented the development of foliar symptoms of Verticillium wilt in resistant and susceptible Acala cottons, but during a cool growing season, the two cottons were easily separated into resistant classes by the difference in percentages of foliar disease symptoms (12). Cotton grown on raised seedbeds, in skip-row planting, and under alternate-furrow irrigation schemes where soil temperatures are higher tend to show reduced disease severity.

High temperature on the High Plains of Texas during July usually prevents the expression of external symptoms of Verticillium wilt, but as temperatures decline in August and September, symptoms generally develop rapidly and plants with various resistance levels may be distinguished in the field (18,20). Severe disease occurs sooner if the temperature declines earlier (18).

Our objective was to evaluate the effects of controlled night temperatures in conjunction with ambient day temperatures on the development of foliar symptoms of Verticillium wilt in cotton plants grown in field growth chambers.

MATERIALS AND METHODS

Controlled night temperature regimes were imposed on cotton growing in the field at the Texas A&M University Agricultural Research and Extension Center at Lubbock in 1966, 1971, and 1972. Night temperature control was maintained in field growth chambers equipped with air conditioners or gas-fired furnaces (13,14). The chambers, mounted on wheels and tracks, were rolled onto the plots at sunset and off at sunrise. No attempt was made to control air temperature during the day. Daily ambient maximum and minimum temperatures recorded during the study were averaged on a monthly basis.

In 1966, night temperature regimes of 10 and 27 C were imposed on cultivars Acala 1517 BR 2, Gregg 35, Lankart 57, Stoneville 7A, and CA 491 from first bloom until frost. Cultivars were replicated twice within each temperature treatment with 30 cotton plants per replication.

In 1971, night temperatures of 10, 15, 20, and 25 C were imposed on Gregg 35 and Deltapine 16, beginning at seedling emergence and continuing until frost. Within temperature regimes, each cultivar was replicated three times in a double row pattern with 20 plants per replication. Methyl parathion [*o,o*-dimethyl *o*-(*p*- nitrophenyl) phosphorothioate] at 0.19 kg/ha was sprayed on one-half of the plants of each cultivar at 10, 12, and 13 days after planting.

In 1972, night temperatures were 13, 25, and 37 C, and two replications were provided by maintaining two growth chambers at each temperature. Each cultivar was planted in a double row pattern with 12 plants per replication. Temperature treatments were imposed on Gregg 35, Deltapine 16, CA 491, CA 1012, CA 1020, CA 1056, CA 1317, and CA 1413 from the first true leaf until frost.

Cultural practices for soil preparation, planting, and irrigation were similar to those used in commercial cotton production. During the growing season weeds were controlled with a hoe.

The Amarillo loam soil used in this study was naturally infested with defoliating and nondefoliating strains of *V. dahliae*. Each year, the test site was relocated to an adjacent area that had been used for commercial cotton production during the previous year.

The number of plants with foliar symptoms of Verticillium wilt was recorded in August, September, and October 1966; in August and October 1971; and in August and October 1972. The percentages of diseased plants were subjected to analysis of variance, and Duncan's multiple range test was used to locate significant differences among means.

TABLE 1. Monthly average maximum and minimum air temperature, Lubbock, TX, in 1966, 1971, and 1972

Year	Temperature extremes	Average temperatures, C					
		May	June	July	Aug.	Sept.	Oct.
1966	Maximum	29	32	37	31	28	25
	Minimum	13	19	23	19	16	7
1971	Maximum	28	32	33	27	25	22
	Minimum	11	18	19	17	15	9
1972	Maximum	26	31	29	29	27	22
	Minimum	17	17	18	17	15	8

TABLE 2. Percentage of plants with foliar symptoms of Verticillium wilt at different controlled night temperatures in field growth chambers[a]

Year	Temperature (C)	Verticillium wilt on				
		8 Aug. (%)	24 Aug. (%)	18 Sept. (%)	3 Oct. (%)	30 Oct. (%)
1966	10	...	14 a	36 a	60 a	...
	27	...	7 a	18 b	36 b	...
1971	10	24 a	...	65 a	...	...
	15	5 b	...	41 b	...	...
	20	4 b	...	25 c	...	...
	25	4 b	...	27 c	...	...
1972	15	15 a	25 a	...	49 a	49 a
	25	14 a	20 a	...	34 b	36 b
	37	1 b	1 b	...	3 c	4 c

[a] In each column for each year, numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

TABLE 3. Percentage of plants with foliar symptoms of Verticillium wilt for different cultivars[a]

Year	Cultivars	Verticillium wilt on:				
		6 Aug. (%)	24 Aug. (%)	18 Sept. (%)	3 Oct. (%)	30 Oct. (%)
1966	Lankart 57	...	20 a	40 a	56 a	...
	Stoneville 7A	...	5 a	34 a	55 a	...
	Gregg 35	...	4 a	28 a	45 a	...
	CA 491	...	7 a	16 b	35 b	...
	Acala 1517 BR 2	...	7 a	18 b	32 b	...
1972	CA 491	7 a	13 a	...	35 a	37 a
	CA 1413	9 a	17 c	...	35 a	35 a
	Gregg 35	12 a	17 a	...	34 a	35 a
	CA 1012	14 a	18 a	...	34 a	34 a
	CA 1317	14 a	24 a	...	31 a	32 ab
	Deltapine 16	8 a	15 a	...	30 a	30 ab
	CA 1056	12 a	14 a	...	17 b	20 bc
	CA 1020	6 a	7 a	...	14 b	15 c

[a] In each column for each year, numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

RESULTS AND DISCUSSION

Temperature. The average monthly maximum and minimum air temperatures at the test site varied among years (Table 1). In July and August 1966, June and July 1971, and June 1972, the maximum temperature exceeded 30 C, the level above which development of Verticillium wilt is inhibited in susceptible cottons grown in the field in California (12). All minimum temperatures were within the range that favors development of the disease. Most foliar symptoms of Verticillium wilt of cotton grown commercially on the Texas High Plains develop after a decline in temperatures about the middle of August. Maximum separation among cotton cultivars with different levels of disease resistance normally occurs about the middle of September (18,20).

In August and September 1966, disease incidence was higher at 10 than at 27 C (Table 2). Wilt percentages from 24 July to 3 October increased faster at 27 than at 10 C. These responses probably were related to the decline in ambient temperatures, especially during the latter part of the growing season. Apparently, lower ambient day temperatures minimized the effects of high night temperatures on disease development, and smaller differentials in disease incidences occurred between temperatures late in the season.

In August 1971, the percentage of diseased plants was significantly higher at 10 than at 15, 20, or 25 C night temperatures, but by September, disease incidence was higher at 15 than at 20 and 25 C (Table 2). On all dates, disease incidences were similar at 20 and 25 C. The correlation coefficient ($r = -0.91$) between temperatures and wilt percentages in September was significant. Maximum lint yield was obtained at 20 and 25 C, where the disease incidences were low (13).

On each date in 1972, disease incidences were indirectly related to low night temperature, and significant correlations (r) -0.96, -0.99, and -0.98 between percentages of wilt and temperatures were obtained on 24 August, 3 October, and 30 October, respectively. During August, wilt percentages were statistically higher at 15 and 25 C than at 37 C, but during October differences occurred among all temperatures (Table 2). At 37 C, the disease was confined to Gregg 35 and did not cause significant economic losses. Growth and fruiting of cotton plants were delayed at 10 and 37 C, but the percentage of both diseased plants and foliage affected was much lower at the high temperature.

The best separation of the effects of a narrow range of night temperatures on wilt development occurred during the middle of September or later. On successive dates each year, the increase in disease incidence followed the general pattern that normally occurs under field conditions when night temperatures are not controlled.

Cultivars. Some resistance to Verticillium wilt was noted among the cultivars tested. The cultivars CA 491, CA 1020, CA 1056, and Acala 1517 BR 2 appeared to be relatively resistant. The percentage of diseased plants varied more among the susceptible cultivars than among the relatively resistant ones.

In 1966, CA 491 and Acala 1517 BR 2 had significantly fewer diseased plants than the other cultivars (Table 3). Both cultivars (Gregg 35 and Deltapine 16) grown in 1971 were susceptible to the disease and percentages of diseased plants were similar. In October 1972, CA 1020 and CA 1056 had the lowest percentages of diseased plants and, on 30 October, slightly lower values were obtained with CA 1317 and Deltapine 16 than with CA 491, CA 1413, and Gregg 35 (Table 3). Observations on disease rankings of the cultivars at 15 and 25 C suggested that they were similar to those observed under field conditions. Deviations in disease rankings in the growth chambers in comparison to commercial cotton production were attributed to low disease incidence in the growth chambers which made it more difficult to rank the cultivars. Levels of varietal resistance are almost impossible to identify when all entries have either a very low or high percentage of diseased plants. The best separation of hosts can be accomplished when the range in disease expression is wide (18,20).

A significant cultivar and temperature interaction occurred on 24 August and 3 October 1972. The disease incidence of each cultivar was inversely related to night temperature. On 24 July, disease incidences were lower for CA 491 and CA 1056 than for the other cultivars at 25 C. On 3 October, disease incidences were lower with CA 1020, CA 1056, CA 1317, and Gregg 35 than with the other cultivars at 25 C. No statistical differences occurred in the percentages of diseased plants on 30 October, but low values occurred for both CA 1020 and CA 1056 at 25 C. On all dates, the lowest percentages of wilt at 15 and 25 C were obtained with CA 1020 and CA 1056, respectively.

Insecticide. In 1971, disease incidences were similar for both methyl parathion and no insecticide (check) treatments. A significant interaction between temperature and insecticide treatments occurred as methyl parathion increased Verticillium wilt at 10 C but caused a nonsignificant reduction at night temperatures of 15, 20, and 25 C.

Our data with different controlled night temperatures are similar to laboratory and field data reported by others (1–6). An inverse relationship occurred between the percentage of diseased plants and night temperatures except for similar responses at 20 and 25 C. At 37 C, foliar disease symptoms occurred only on plants of one susceptible cultivar late in the season when the day temperatures did not exceed the maximum known to suppress the development of foliar disease symptoms. Apparently, low night temperatures on the High Plains of Texas and possibly in other cotton production areas are instrumental in triggering early season Verticillium wilt, provided the maximum day temperatures do not exceed about 30 C. At unusually low night temperatures, Verticillum wilt of cotton can develop at slightly higher maximum day temperatures. Delaying the beginning and buildup of Verticillium wilt of cotton for about 14 days can increase both the quantity and quality of the crop. Thus, cultural practices known to increase the soil temperatures can be used to minimize the disease (12). Also, economic losses can be reduced by growing high plant populations of rapid-fruiting cotton cultivars that mature before the temperature declines to levels that favor development of Verticillium wilt (17).

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