Effect of Soil Temperature on Resistance of Tomato Cultivars to Bacterial Wilt

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We express our thanks to S. H. Ou of the International Rice Research Institute for his many valuable suggestions.
Journal Paper No. 9 of the AVRDC.
Accepted for publication 5 January 1977.

ABSTRACT

MEW, T. W., and W. C. HO. 1977. Effect of soil temperature on resistance of Tomato cultivars to bacterial wilt. Phytopathology, 67:909-911.

Resistance to bacterial wilt (caused by *Pseudomonas solanacearum*) in some tomato cultivars was influenced by changes in soil temperature. The cultivar VC 48 was not affected by the different temperature treatments and maintained a moderate resistance (20-40% wilted plants) to *P. solanacearum* at 26, 30, and 32 C. Cultivars VC 8 and VC 11 were resistant (1-20%) at 26 C, but became moderately susceptible (40-60%) and susceptible (more than 60%), respectively, at 32 C. The rate at which the plants wilted also differed among the cultivars at different soil temperatures. At 26 C there were no significant differences among the four resistant cultivars, whereas at 32 C more than 50% of the VC 9 and VC 11 plants wilted in 5 or 6 days, a rate similar to that of the susceptible checks. Cultivar VC 48 still was moderately resistant at the end of 19 days at all temperatures. Cultivars Kewalo and KL 1 also differed in reactions to wilt at different soil temperatures. At 26 C initial wilt symptoms were observed 11 days after inoculation in Kewalo and after 7 days in KL 1. At soil temperatures of 30 and 32 C both cultivars succumbed rapidly.

Additional key words: *Lycopersicon esculentum*.

Resistance to bacterial wilt of tomato is known to be affected by soil temperature. Resistant cultivars [e.g., Venus and Saturn which were developed by the North Carolina Agricultural Experiment Station (4)] often are susceptible when planted in the warm, humid tropics. In fall plantings (beginning in October in Taiwan) at the Asian Vegetable Research and Development Center (AVRDC) several cultivars including Venus and Saturn apparently were resistant, whereas in summer plantings (June to August) they were either moderately resistant or moderately susceptible (7).

As early as 1944, Vaughan (8) showed that wilt symptoms did not develop when soil temperatures were below 21 C. Disease incidence increased with each increase in soil temperature. Infection could be initiated at soil temperatures as low as 13 C, but wilt symptoms did not develop unless soil temperatures were higher than 21 C for several days. Findings in Hawaii showed that at 31 to 33 C resistant cultivars were not stable in their reaction to bacterial wilt infection, and plants eventually died from the disease (3). A recent report by Krausz and Thurston (6) demonstrated the breakdown of bacterial wilt resistance in tomatoes grown at 32 C in a growth chamber.

Air temperatures have less influence than soil temperatures on the development of wilt symptoms (2). At high soil temperatures, the development of wilt symptoms may be speeded up and become more severe when the air temperatures are also high, but not otherwise. The general effect of soil temperatures on varietal resistance to other wilt diseases of tomato and other crops is well recognized (9).

In developing tomatoes with resistance to bacterial wilt for the lowland tropics, it appears essential to have detailed information on the relation between soil temperature and bacterial wilt. Our studies at AVRDC have identified a type of resistance to bacterial wilt that is independent of soil temperature.

MATERIALS AND METHODS

In a previous study (7), four tomato cultivars VC 48-1 (referred to here as VC 48), VC 9-1 (VC 9), VC 11-1 (VC 11), and VC 8-1-2-1 (VC 8) were identified as resistant in a bacterial wilt nursery. The four cultivars are original selections made in The Philippines as a result of crosses made between UPCA 2029, a source of heat-tolerance, and UPCA 1169, a source of bacterial wilt resistance. Breeding line UPCA 1169 was the result of a cross made between Venus and CA-64-1169 (J. R. Deanon, *personal communication*). The cultivars Kewalo and KL 1 were susceptible in both summer and fall plantings in the nursery and when inoculated. These six tomato cultivars were used in the present experiments.

Tomato seeds were germinated in a seedling box. Three wk after sowing, healthy and uniform seedlings were transplanted to stainless steel pots ($54 \times 27 \times 15$ cm^3) containing steamed field soil. Each pot was planted with 18 seedlings at 10-cm spacings. Six pots (one pot per cultivar) were then placed at random in a soil-temperature tank constructed in a greenhouse according to instructions kindly provided by A. Kelman, Department of Plant Pathology, University of Wisconsin, Madison, WI 53706. Three soil temperatures, 26, 30, and 32 C, were maintained, and the mean ambient air temperature during each experiment was measured. In addition, the soil temperature at different depths was checked three times each day with a TM54 soil thermometer (Weather Measure Corporation, Sacramento, CA 95841). The experiments were first conducted from May to July 1974 and repeated during the same period in 1975.

Cultures of *P. solanacearum* were isolated from diseased tomatoes in farmers' fields of Central Taiwan and maintained in sterile distilled water at 4 C. Inoculum was prepared from fluidal colonies on tetrazolium medium (5) at a concentration of 10^7 to 10^8 viable cells/ml. Maximum growth of the isolates was at 30 C; cultures were incubated at this temperature for 72 hr prior to inoculum preparation. Inoculations were made with a hypodermic syringe, injecting approximately 0.01 ml of the inoculum into the stems slightly below the petiole of the first true leaf. Inoculations usually were made 2 weeks after transplanting.

In general, each plant was examined daily for 15 to 20 days. Although initial wilt symptoms were characterized by epinasty of the petioles, the disease score was based on the total collapse of the plants. Percentage wilt values represented the mean of two experiments, each experiment based on observations of 18 plants of each cultivar at each temperature.

RESULTS

Except in VC 48, wilt incidence in the tomato cultivars increased as the soil temperature increased (Fig. 1). Rates of disease development, however, differed widely among the resistant cultivars. The wilt incidence for VC 9 and VC

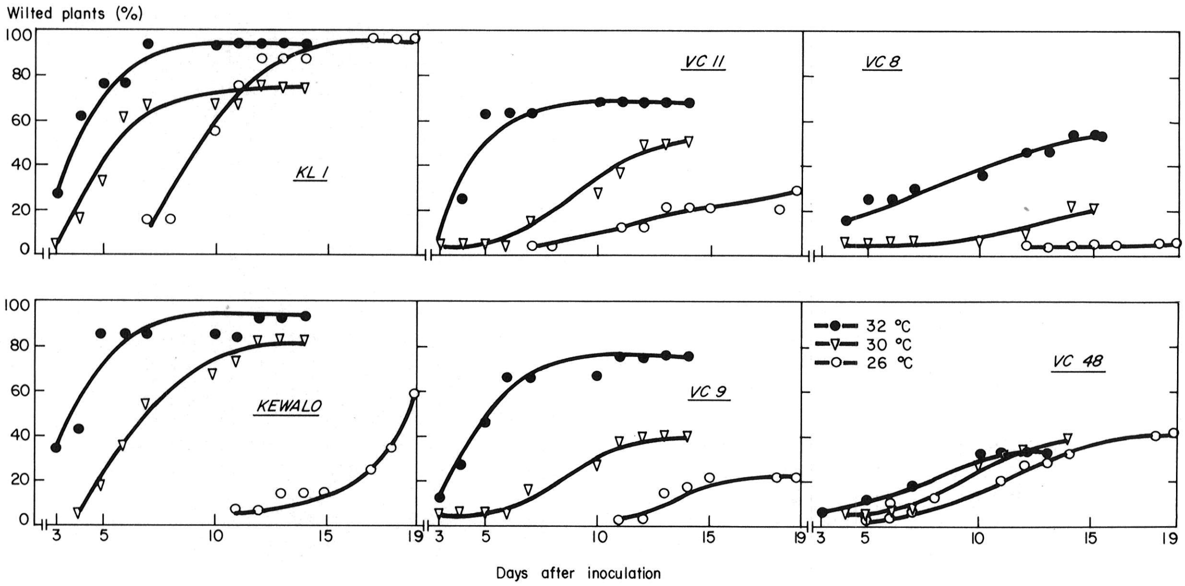

Fig. 1. Incidence of bacterial wilt (%) in different tomato cultivars grown at different soil temperature. LSD = 14.74 (P=0.01) and 10.74 (P=0.05) for percentage values between the temperature treatments; LSD = 20.72 (P=0.01) and 15.19 (P=0.05) for percentage values within each temperature.

TABLE 1. Effect of soil temperatures[a] on bacterial wilt incidence in tomato cultivars

Cultivar	Disease reaction[b]	Time (days) for 50% or more plants to show wilting symptoms		
		26 C	30 C	32 C
KL 1	S[c]	10 (S)[d]	6 (S)	4 (S)
Kewalo	R	19 (MS)	7 (S)	4 (S)
VC 9	R	[e] (MR)	12 (MS)	6 (S)
VC 11	R	... (MR)	12 (MS)	5 (S)
VC 8	R	... (R)	... (MR)	14 (MS)
VC 48	R	... (MR)	... (MR)	... (MR)

[a]The mean ambient air temperatures were 31, 30.9, and 29.9 C at 26, 30 and 32 C soil temperatures, respectively.
[b]Evaluation is based on 150 plants in summer planting in a bacterial wilt nursery.
[c]Resistant (R) = fewer than 20% plants collapsed; moderately resistant (MR) = 20 to 40% plants collapsed; moderately susceptible (MS) = 40 to 60% plants collapsed; and susceptible (S) = more than 60% plants collapsed.
[d]Letters in parentheses denote final disease ratings.
[e]Fewer than 50% of the plants showed wilting symptoms before the end of the 19-day period of observation.

11, as well as the time required for the appearance of wilt symptoms, was accelerated as temperature increased; their resistance broke down (more than 60% wilted plants). High temperatures had a less marked effect on VC 8; it was moderately resistant (20-40% wilted plants) at 30 C, but moderately susceptible (40-60% wilted plants) at 32 C. High soil temperatures, however, had little effect on VC 48; it was moderately resistant at all three temperatures. The two most susceptible cultivars also differed in response to the lowest soil temperature. Wilt development in both cultivars was rapid at both 30 and 32 C.

When the days necessary for wilting to appear in 50% of the plants and the general disease rating of each cultivar at various soil temperatures were compared, it was clear that wilting was consistently delayed at a soil temperature of 26, but not at 30 or 32 (Table 1). Wilting of the resistant cultivars was essentially the same at 26 C. However, at 32 C, 50% of the VC 9 and VC 11 plants had wilted within 5 or 6 days after inoculation. Likewise, the disease rating for VC 8 shifted from resistant at 26 to moderately resistant at 30 and moderately susceptible at 32 C, but 50% of the plants wilted only after incubation for 14 days. Apparently, VC 48 was only slightly affected by the increase in soil temperatures. Wilting did not reach the 50% level at any of the soil temperatures even by 19 days after inoculation. On the basis of the final disease ratings, VC 48 was ranked as moderately resistant at all soil temperatures.

DISCUSSION

In a previous study (7) we suggested that there are different types of bacterial wilt resistance in the tomato as evaluated by different methods. In this study, we found that bacterial wilt resistance in the tomato was greatly influenced by soil temperatures, and confirmed the breakdown of resistance in some cultivars such as VC 9 and VC 11. However, resistance of one of the cultivars was not affected by soil temperature. The data thus suggest that there are two types of bacterial wilt resistance: one dependent on, and one independent of soil temperature. The latter type may be more important in developing bacterial wilt resistant tomatoes for the tropics.

Although different maximum and minimum air temperatures were recorded, the mean ambient air temperatures at each soil temperature treatment were similar; i.e., from 29.9 to 31 C (Table 1). Gallegly and Walker (2) indicated that air temperatures have less influence than soil temperatures on the development of wilt symptoms, but at high soil temperatures, the development of wilt symptoms was promoted when the air temperatures also were high. The difference in wilt incidence between VC 48 and other resistant cultivars at the high soil temperatures was significant (Fig. 1). The high ambient air temperatures may have had a direct effect on all resistant plants, but VC 48 was affected less than others. If the resistance in a tomato cultivar is independent of the soil temperature, it also is likely to be independent of ambient air temperature. Whether a high ambient air temperature contributes to the breakdown of resistance which is dependent on soil temperatures in such cultivars as VC 11, VC 9 or VC 8 is not known.

The genetics of bacterial wilt resistance in the tomato are not clear. Acosta et al. (1) found a complex picture of inheritance in which reaction was altered by temperature. Our studies of bacterial wilt resistance at different soil temperatures seem to follow a pattern similar to that demonstrated in the resistance of *Brassica campestris* to cabbage yellows. At a constant sand temperature of 24 C, all susceptible and multigenic-resistant cabbage plants were infected, while those with monogenic resistance survived infection (9). Further studies of the inheritance of bacterial wilt resistance in the tomato, like the studies of cabbage yellows, should take soil temperature into consideration. It appears that 32 C is the critical temperature for separating the two types of bacterial wilt resistance in tomatoes. In the development of bacterial wilt-resistant tomato lines for tropical climates, lines should be screened at soil temperatures of 30 to 32 C.

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