Weather Dependence, Yield Losses, and Control of Bacterial Speck of Tomato Caused by *Pseudomonas tomato*

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ABSTRACT

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Field weather (temperature and relative humidity) and bacterial speck of tomato were directly correlated. The disease developed and spread only at temperatures between 13 and 28 C and at high relative humidity with free water on the leaves. Yield losses varied from 75% in plants infected at an early stage of growth to 5% in plants infected later in the season. Copper treatments reduced disease severity and increased yield even at optimal conditions for disease development.

Pseudomonas tomato (Okabe) Alstatt, the causal agent of bacterial speck, causes typical leaf disease only in tomato plants (2). The pathogen, identified in several countries, has caused economic losses in California and Israel (11,12).

Environmental requirements for disease development of bacterial speck have been studied in the greenhouse and in the field (6–10), but no direct correlations between field weather and disease have been reported.

It has been suggested that treatments with copper compounds reduce disease development (3,4,6,11), but the effectiveness of these treatments on tomato yield has not been properly measured in the field.

Disease damage, the influence of weather on disease, and chemical control were studied in experiments during 1978-1979 in tomato fields in Israel.

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MATERIALS AND METHODS

Methods for inoculum preparation, inoculation, and disease index determination were as described previously (1,12). Susceptible tomato plant cultivars VF-198, VF-134-1-2, and Orit (12) were obtained from Hazera Co., Haifa, Israel.

Experiments were performed in winter (November-May) and early spring (February-July) crops in random blocks of five replicates (one 10-m row each) in sandy loam soil of Rehovot, medium heavy soil in Sandala, Yizreel Valley, and heavy soil in Tamra, northwestern Galilee.

The rows (five plants per meter, 1 m between rows) were covered with polyethylene tunnels (30 cm high, 80 cm wide). The plants were inoculated by spraying a suspension of a local isolate of *P. tomato* containing 10^8 colony forming units (CFU) per milliliter (11). In some experiments, in areas that had bacterial speck the previous year, the disease developed from natural inoculum.

Copper hydroxide (Kocide-101) and copper oxychloride (Cupox-50, Machteshim Ltd., Beer Sheva) were sprayed, 0.3–0.5%, w/v, over the leaf cover at 35 L/1,000 m^2.

These compounds were tested in a seedling nursery and field experiments. Plants in the nursery were sprayed with 0.3–0.5% copper hydroxide and 0.3% copper oxychloride 1 day before inoculation with 10^7 CFU/ml of *P. tomato* suspension. The disease index was measured after 8 days. After bacterial speck was detected in the field, the experimental plots were not sprayed for 3 wk to allow the disease to become established. Copper hydroxide (0.5%) or copper oxychloride (0.4%) was applied each week for 7 wk.

RESULTS

Effect of weather. During the past 5 yr the initial appearance of bacterial speck and eventual severity were similar in winter and early spring crops in the areas investigated. The data presented here, however, are from studies done during 1978 and 1979.

The climate data and disease index for March-May 1979 in Yizreel Valley and April-May 1978 in northwestern Galilee were collected from four field experiments. A good correlation was observed between low temperatures (<25 C), high RH (>80%), and disease severity (Fig. 1). In March, temperatures and RH were optimal for disease development, whereas in April the humidity sometimes decreased to a suboptimal level. However, sprinkle irrigation increased humidity within the dense foliage and enhanced the disease. In May, the RH was low and the day temperatures increased to the upper limit for pathogen growth (>30 C). Subsequently, disease severity decreased significantly in the field. New green foliage without specks developed, even in previously infected areas, and remained free of symptoms till the end of the crop in July-August.

Table 1. Tomato yield as affected by plant age at time of infection by *Pseudomonas tomato*

Time after planting (mo)	Location, cultivar	Treatment	Yield (ton/1,000 m^2)[w]	Percent of control
1	Sandala, Orit	Control	2.107 a	100
	Early spring 1979	Copper hydroxide	2.940 b[x]	175
2	Tamra, Orit	Control	5.020 a	100
	Early spring 1978	Copper hydroxide	6.330 b[x]	126
			6.208 b[y]	
			6.281 b[z]	
3	Tamra, VF-134—1-2	Control	6.360 a	100
		Copper hydroxide	6.840 a[x]	107

[w] Each experiment was statistically analyzed separately. Numbers followed by different letters are significantly different ($P = 0.05$) by Duncan's multiple range test.
[x] 0.5% weekly sprays.
[y] Sprays every 2 wk.
[z] Sprays after rain or irrigation.

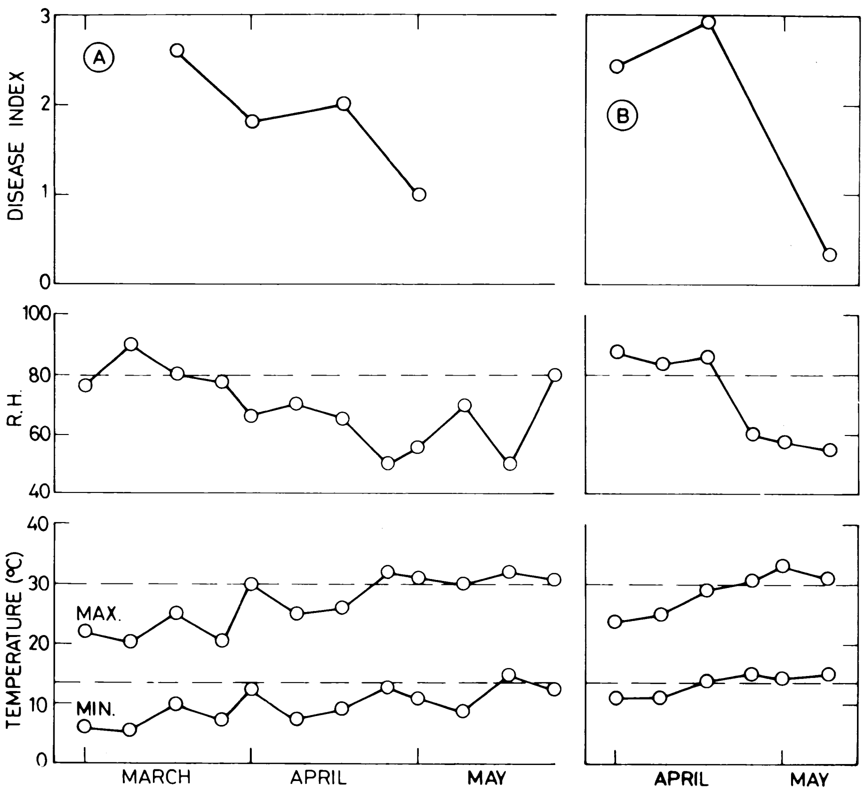

Fig. 1. Relation between temperatures, relative humidities, and bacterial speck disease in the field. Data from **(A)** Yizreel Valley, early spring 1979, and from **(B)** northwestern Galilee, spring 1978. Horizontal lines show critical zones of relative humidities and temperatures. Disease index: 0 = no symptoms, 1 = 2–5 specks together or spread over the leaf, 2 = 6–10 specks, 3 = more than 11 specks per leaf.

Effect of plant age. Disease development was followed in three fields in plants that were infected 1 mo after planting in the first field, 2 mo after planting in the second, and 3 mo after planting in the third. The results clearly show that earlier infection resulted in heavier yield losses (Table 1).

Effect of fruit maturity. In all field experiments, the pathogen attacked only green fruits. The disease showed as superficial specks on the skin. The infection did not penetrate the fruit. Red mature fruits were never infected. To clarify this phenomenon, the pH values of the skin and the flesh were measured in green fruits turning to red and in red mature fruits. The pH of the green skin (6.3) was the only pH suitable for multiplication of *P. tomato*; the pH of the other fruits, ie, red skin (5.2) and green (5.0) or red flesh (4.0), was below the minimum pH required for growth.

Chemical control. Pretreatment with copper compounds clearly reduced infection (Table 2). Copper treatments reduced disease severity (Table 3) and increased yield (Table 1). Plant height and dry weight were significantly greater than in the controls (Table 3). There was also a positive correlation between foliage infection and fruit infection (Table 3). Bacterial speck was controlled better by copper hydroxide than by copper oxychloride (Tables 2 and 3).

In another experiment at Tamra in 1978 with cv. Orit, there were no significant differences in disease index and yield when Kocide 0.5% was sprayed weekly, every 2 wk, or after rain or irrigation. These treatments significantly increased disease control and yield by 26% (Table 1).

In an experiment at Sandala in 1978 with cv. VF-198, treatments with copper hydroxide significantly reduced the disease index and increased yield by 23%.

DISCUSSION

In this study we found, as we did under a controlled environment (1,5), a clear relationship between field temperature,

Table 2. Effect of preventive spraying with copper compounds on bacterial speck severity in a tomato seedling nursery

Treatment[y]	Disease index[z]
Unsprayed	1.26 b
Copper hydroxide	
0.3%	0.44 a
0.5%	0.39 a
Copper oxychloride	
0.3%	0.26 a

[y] Experiments were performed in three replicates; plants were sprayed with chemicals 1 day before inoculation with 10^7 colony forming units of a *Pseudomonas tomato* suspension.

[z] Disease index (0 for healthy plants to 3 for leaves with more than 11 specks) was measured after 8 days. Numbers followed by different letters are significantly different ($P = 0.05$) by Duncan's multiple range test.

Table 3. Effect of copper compounds treatment on bacterial speck development in the field[y]

Treatment	Disease index at harvest	Plant height[z] (cm)	Dry weight[z] (g)	Fruit disease index[z]	Percent diseased fruits[z]
Control	1.5 b	22.1 b	20.0 b	1.05	52
Copper hydroxide, 0.5%	0.25 a	35.7 a	48.2 a	0.32	26
Copper oxychloride, 0.4%	0.65 a	32.4 b	55.5 a	0.8	53

[y] Experiment was performed in Sandala, cv. Orit, early spring 1979, at random blocks in five replicates. Different letters in the same column represent significant differences at $P = 0.05$.

[z] Measurements at harvesting time. Plant height represents means of 20 plants from each plot. Dry weight represents means of five plants from each plot dried at 80 C for 1 wk. Fruit disease index and percent of diseased fruits represent measurements of 100 fruits selected at random from each plot.

humidity, bacterial speck severity, and tomato yield. Chemical control with copper compounds reduced disease severity and increased yield. The disease was enhanced by temperatures below 25 C and above 13 C and by high RH that caused water condensation on the leaves, mainly at night. In contrast, when one of these conditions was unfavorable for the disease for at least 1 wk, the disease severity decreased and new speck-free foliage developed, thus decreasing damage to the crop.

The losses in plants infected at earlier physiologic ages (two to three leaf seedlings, 75% loss) corroborate those of Schneider et al (11), who found 13% loss in tomatoes infected at the three-leaf stage and much higher losses when younger seedlings were infected.

Although the losses in yield were heavy, the direct damage to the fruits that developed was minimal because *P. tomato* could not grow at the low pH of both skin and flesh of red mature fruit or flesh of green fruits.

Spraying with copper compounds just before or immediately after infection, even at the optimal conditions for disease development, reduced disease severity in the field and increased yield. When weather conditions do not favor the disease, however, sprayings are not necessary, because infected plants recover without treatment. Furthermore, spraying only after rain or irrigation gave the same results as weekly treatments.

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