Influence of Temperature on the Development of Leaf Symptoms of Satsuma Dwarf Disease

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SATSUMA DWARF is characterized by two kinds of leaf symptoms: boat-shaped or downward-cupped leaves and spoon-shaped leaves. We find both kinds in field trees; the ratio of one to the other seems to vary with climatic conditions, especially air temperature. Satsuma mandarin trees develop the leaf symptoms only in spring shoots, not in summer and autumn shoots. However, indexing in white sesame plants showed that the summer and autumn shoots usually carry the virus. We thought, therefore, that the leaf symptoms were suppressed or masked by the comparatively high temperatures that prevail in summer and autumn. To test our hypothesis, we carried out the experiments described in this

paper. They were conducted in an air-conditioned glasshouse or chamber during the years 1966–68.

Temperature in Relation to Production of Boat-shaped Leaves

EXPERIMENT 1.—Two-year-old potted satsuma trees infected with satsuma dwarf virus were cut back and transferred immediately to a glasshouse or chamber with appropriate air temperatures. Diurnal temperature variations similar to those occurring naturally in the field were provided to determine the effect of temperature on the production of boat-shaped leaves. The temperatures were: (day/night) 13/8, 18/13, 23/23°C series were observed on ment was started on June 9, 1966, and the plants in the 23/18 and 28/23°C series were observed on July 21, Sept. 5, and Oct. 23. Plants kept at lower temperatures grew rather slowly and were observed only on Dec. 19.

Under conditions of comparatively low day and night temperatures, 13/8, 18/3, and 23/18°C, the new leaves were typically boat-shaped. On the other hand, this symptom did not appear on plants at 28/23°C. The results led to the assumption that boat-shaped leaves would not be produced when the infected plants were exposed to temperatures of 28°C or higher for about 12 hours per day, but that they would be produced when infected plants were grown at lower temperatures.

EXPERIMENT 2.—In order to test this assumption, infected plants were kept in the glasshouse at 18/13, 23/18, and 28/23°C, respectively, for 6–8 weeks to allow development of foliage typical for each environment. During this time boat-shaped leaves appeared on plants in the 18/13 and 23/18°C environments; no symptoms developed on plants at 28/23°C. Just prior to moving to new temperatures, the plants were cut back to 1 leaf. The temperatures to which the plants were subjected and the results are shown in Table 1.

The plants that had good leaf symptoms when first grown at 18/13 and 23/18°C did not produce boat-shaped leaves when transferred to the higher temperature range, 28/23°C. Conversely, plants that did not produce boat-shaped leaves at 28/23°C developed good leaf symptoms when transferred to the lower temperature ranges, 18/13 and 23/18°C.

These results demonstrate that the production of the boat-shaped leaf symptom of satsuma dwarf is governed by temperature at the time of leaf enlargement and that the virus may persist in symptomless shoots.

Temperature in Relation to Development of Spoon-shaped Leaves

During some preliminary experiments, we found that the spoon-shaped leaf symptom appeared when the diurnal temperature difference was 15°C or more, even in the case of high daytime temperatures of about 30°C. To study the temperature conditions that lead to produc-

TABLE 1. PRODUCTION OF BOAT-SHAPED LEAVES IN SATSUMA-DWARF-VIRUS INFECTED TREES EXPOSED TO ONE TEMPERATURE AND SUBSEQUENTLY TRANSFERRED TO ANOTHER

Temperature (°C)	Symptoms		Subsequent temperature[a] (°C)	Symptoms
18/13	Boat-shaped leaves	Cut back	28/23	None
23/18	Boat-shaped leaves	Cut back	28/23	None
			18/13	Boat-shaped leaves
28/23	None	Cut back	23/18	Boat-shaped leaves

a. In 3 pots at each temperature range.

TABLE 2. INFLUENCE OF MAXIMUM AND MINIMUM TEMPERATURE AND DIURNAL VARIATION ON THE PRODUCTION OF LEAF SYMPTOMS OF SATSUMA DWARF

Day/night temperature (°C)	Diurnal variation (°C)	Symptoms
23/18	5	Leaves mostly boat-shaped
28/23	5	None
23/8	15	Leaves mostly boat-shaped, some (top leaves) spoon-shaped
28/13	15	Leaves either spoon-shaped or boat-shaped, in equal proportions
28/8	20	Leaves mostly spoon-shaped, some (lower leaves) boat-shaped
30/10	20	Leaves mostly spoon-shaped
35/15	20	None

tion of spoon-shaped leaves, the following experiment was conducted.

Two-year-old infected plants were used in this experiment. The general procedures were the same as in the first experiment. Temperatures were adjusted so that differences between day and night were 5, 15, and 20°C, respectively; various maximum and minimum temperatures in the range of 8–35°C were used to achieve these diurnal variations. After about 60 days, symptoms were observed on newly developed leaves. The results are given in Table 2.

The data indicate that temperatures of 30/10 and 28/8°C, with a daily difference of 20°C, lead to good production of the spoon-shaped leaf symptom and to reduced production of the boat-shaped leaf symptom. A temperature of 28/13°C, with a daily difference of 15°C, is also comparatively favorable for development of spoon-shaped leaves.

Indexing trials and treatment of the same plants in two different temperature environments have shown that the virus may persist in symptomless growth developed during the relatively high temperatures.

Discussion

The results agree with our field observations of satsuma dwarf disease.

Several investigators have reported that comparatively low temperatures favor the production of symptoms in diseases caused by citrus viruses. These reports include the work of Grant and Corbett (2) on infectious variegation, of Kishi and Tanaka (3) on satsuma dwarf in white sesame plants, of Dauthy and Bové (1) on crinkly leaf, and of Schwarz (5) on greening disease in field planting where an insect vector is involved. On the contrary, Olson and Rogers (4) reported that symptoms of stubborn disease appeared on leaves and shoots of citrus at relatively high temperatures, 25–27°C, and were masked in plants grown at temperatures below 23°C.

It is evident that temperature conditions favoring the production of symptoms vary with the pathogen.

The symptoms of satsuma dwarf vary with temperature: 8–23°C is favorable for the boat-shaped symptom; temperatures above 28°C in daytime and below 13°C at night favor spoon-shaped symptoms.

We conclude that the production of the two kinds of leaf symptoms of this disease is directly influenced by maximum and minimum air temperatures during leaf expansion and by the extent of the diurnal range in temperatures.

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