

Recovery from

Freeze Injury

by citrus

Citrus leaves and fruit have recovered from freeze injury, after a short period of low temperatures as in the mid-November freeze in 1958. However, lower temperatures or longer low temperature periods might be beyond the recovery range.

Unusually fine growing conditions prevailed during the fall of 1958. Citrus trees in all districts had extensive growths with large numbers of young unexpanded leaves and unhardened mature leaves as a result of the relatively mild nights up to November 15. These conditions were interrupted suddenly by a freeze that lasted in most areas only during the night of November 16 and the morning of the 17th, and which was so severe that normal leaf drop did not occur. Subsequently, there were few other cool nights during the winter. A period of fine, clear, calm weather with less than $\frac{1}{10}$ " of rain on any one day generally prevailed in southern California until between February 8 and 11. These circumstances permitted a preliminary evaluation right after the frost.

After the rain, the survey was completed. The calibrations of growers' thermometers were rechecked and found accurate to 0.5° F. Estimates of fruit damage were made by cutting from randomly selected trees. Thirty-six groves were studied at 14 locations: Anaheim, Conejo Pass, Corona, Elsinore, Escondido, Hemet, Highgrove, Indio, Oxnard, Pauma, Riverside, San Juan Capistrano, Sunnymead and Ventura. The results obtained in six groves in the Ventura, Indio, and Elsinore areas were typical.

Ventura

At Ventura the air temperature four feet above the ground and near the wind machine base in a Eureka lemon grove was 32°F or below for 11 hours, and 25°F for three hours.

The wind machine consisted of two 85 hp engines—at the fan—oppositely mounted 35' above ground level.

The soil was bare and compact, as weed control and noncultivation methods were used. Although there had been no irrigation for 30 days, the soil was moist. Air temperatures beyond the range of the wind machines are not known but probably were a degree or two lower, as no heaters were used in the grove.

Near the wind machine, despite the long period of low temperatures, there was very little damage to mature leaves or flower buds, slight damage to leaves of the new growth; button fruit, small green fruit, and mature fruit remained on the tree. Beyond the range of the wind machine the tender new growth was killed, flower buds, small green fruit and mature fruit had dropped to the ground. However, studies at Ventura during the past four winters have shown that the wind machine kept leaves and fruit above their minimum undercooling temperatures and air temperatures above the freezing point, except at the base of the machine, even though air temperatures beyond the reach of the wind machine were 25°F or lower. Thus the lemons protected by the wind machine probably never reached their undercooling minimums, and consequently probably did not freeze the night of November 16–17, 1958.

Indio

At Indio there were two cold nights, the night of the 16th and the morning of the 17th and the night of the 17th and the morning of the 18th. Grower records for two grapefruit groves studied—containing Ruby and Marsh grapefruit—show that the air temperature was 32°F at seven o'clock in the evening of November 17, and reached a minimum of 21°F the morning of the 18th. Thus in these two groves there were air temperatures that were below 32°F for 11 hours, as at Ventura. The Indio groves were on light sandy soil, under cultivation, relatively weedless, and under deep furrow irrigation. One grove had 36 hp wind

machines giving 7.2 hp per acre and the other grove had 85 hp wind machines also giving 7.2 hp per acre. The first grove had heaters—not lit the first night—and the second grove had heaters on one side only. The first grove had not been irrigated for 21 days before the frost. Irrigation of the second grove was completed on November 16 and the water was turned on again when it appeared there was to be a cold night.

Near the wind machine in the October irrigated grove, the amounts of damaged foliage and fruit pulps were about half of those found in areas distant from the wind machine. However, all fruit samples from both groves appeared to have been frozen. In the grove under irrigation the leaf and fruit-pulp damage near the wind machine was about one eighth of that found in areas beyond its range. Near the wind machine damage to the fruit and the leaves was negligible. The grove also had three times the percentage of undamaged fruit as the dry grove, but in both groves nearly all the fruit sampled had been frozen.

Elsinore

Eleven hours of air temperatures below freezing occurred at Elsinore just as at Ventura and Indio, but at two Washington Navel orange groves—at lower elevations than the weather station—minimum temperatures of 22°F were recorded when the wind machines and the heaters were in operation. Heaters were spread throughout both groves. There was one cold night with temperatures of 25°F or below for six hours.

Clean cultivation was practiced on light sandy soil in both groves. Furrow irrigation was practiced in one grove, and low sprinklers were used in the other grove. The furrowed grove had been 21 days without irrigation but in the other grove, sprinkler irrigation had been completed two days before the frost.

Each grove had one single-engined wind machine. The machine in the furrowed grove had a 12.5 hp engine, and a 125 hp engine at 2,200 rpm powered the machine in the sprinkler irrigated grove. The trees in the furrowed grove were 28 years old, those in the sprinkled grove were 27 years old, but were larger and thrifter.

Near the wind machine in the furrowed grove, leaf damage was small as compared with the trees in the area unprotected by the machine, but all the fruits—pulp—were frozen and damaged

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Temperature and Bud Development of deciduous fruits

There is a rest period for buds of deciduous fruit trees during which they do not expand into shoots or flowers even though environmental conditions for growth are favorable. Buds enter this period of rest shortly after they are formed in the late spring or early summer and develop only microscopically until after they are exposed to the chilling temperatures of winter. Cold temperatures bring about physiological changes in the bud which end the rest period and enable the buds to expand when conditions for growth become favorable in the spring.

Development of the buds throughout the entire period from their formation in one spring to their bloom in the follow-

ing year is intimately related to temperature. The microscopic development of buds during the rest period is retarded when temperatures are above average. After the rest period is completed, which occurs usually between mid-January and mid-February, the rate of bud development is directly related to the favorability of temperatures for growth. The more favorable the temperatures, the more rapid the growth and enlargement of the buds.

Varieties of fruit differ in the intensity of the rest-period influence and the amount of winter chilling required to end it. The buds of a variety with a low-chilling requirement emerge from the rest period earlier in the winter and

begin to enlarge sooner in the spring than the buds of a variety requiring more cold to break the rest. Flower buds of high-chilling varieties of the stone fruits, such as apricot and peach, may be injured when temperatures are above average during the fall and early winter with the result that the buds drop from the trees, unopened, before bloom.

A growth inhibitor appears to be present in buds during the rest period, and the ability of buds to develop as the rest period ends depends on the relationship of the inhibitor to the naturally occurring growth-promoting substance or auxin present in the buds. The auxin-inhibitor relationships throughout the entire period of bud development, as affected by temperature and in relation to bud drop as it differs in varieties of different chilling requirement, need further study. When such relationships have been explored and are understood, the feasibility of devising means of manipulating trees to hasten the end of the rest period, to prevent bud drop and to promote normal flowering and leafing in orchards in mild-winter areas may be greater than is presently the case.

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whether they were near the wind machine or not. Damage in individual fruit, however, was less near the wind machine.

In the sprinkled grove, near the wind machine, leaf and fruit damage was approximately one-third of the damage on trees distant from the machine. Only 37% of the fruit sampled near the wind machine showed that they had been frozen. Since out of 6,642 boxes picked, there were only 1,046 boxes of culls from all causes, more than half of the 37% frozen fruit must have recovered from freezing without damage. The remarkable condition in this grove is best illustrated by the pack-out of 3,874 cartons of first grade, 540 cartons of choice, and 2,555 cartons of orchard run. The wind machine was not turned on in this grove until the air temperature reached 27°F. The grove might have escaped damage almost entirely if the wind machine had been started when the air was 32°F.

A Valencia orange grove at Elsinore—where air temperatures were similar to those in the Washington Navel orange groves—was irrigated with low sprin-

klers the day preceding and during the night the freeze occurred. The grove suffered considerable leaf and fruit damage. The grove had a cover crop of grass, and was protected by heaters and by a wind machine of small horsepower. Near the wind machine there was very little leaf damage and, although 92% of the fruit was frozen, only 64% was damaged. There was 2-3 times as much leaf damage and individual fruit damage where the trees could not be reached by the wind machine.

In the groves at Ventura, Indio, and Elsinore, there were higher percentages of frozen fruit than damaged fruit near the wind machines except in the furrow irrigated Washington Navel grove at Elsinore.

Lemons drop off the tree when frozen and, therefore, were not included but a comparison of the orange groves suggests that a portion of the frozen fruit recovered without serious pulp damage. Both at Indio and at Elsinore, air temperatures were below the freezing points of leaves, peel and pulp by 0.50°F to 1.50°F for several hours, and must have been below the undercooling temperatures for a considerable period also.

No peel damage occurred, with or without frost protection, probably because of a combination of the very low undercooling temperatures of peel and small surface-weight ratios of the fruit, which would delay their rate of cooling and thus shorten the period at which they were at low temperature.

There was only a relatively small amount of leaf damage in groves protected by wind machines as compared with groves without frost protection.

In leaves, the surface-weight ratio is 75-85 times larger than in fruit and thus the leaves must have been at sub-freezing temperatures much longer than the fruit. Also, because there were fewer damaged fruit pulps than frozen pulps, despite their high undercooling temperature, the wind machines must have been able to effect a certain amount of recovery in leaves and fruit pulps after freezing.

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