Frost Protection in Peaches

new model under-tree wind machine tested with and without burners in orchard near Wheatland during winter of 1958–59

Todd V. Crawford and F. A. Brooks

Tower mounted wind machines raise orchard temperatures largely by the forced mixing of cold orchard air with the warmer air overhead. However, tests in an almond orchard in the Chico area—in 1955 and 1957—showed that the air jet from tower mounted machines had difficulty in penetrating the tree canopy—typical of deciduous orchards—formed by the intertwining of branches of adjacent trees. Underneath the tree canopy deciduous orchards are relatively open but growers report that most frost damage occurs in the lower part of the trees.

To investigate whether a near-the-ground wind machine under the tree canopy might be directly effective in preventing the air stratification leading to frost damage in the lower parts of the trees, tests were made during the winter of 1958–59.

An under-tree type of wind machine was placed on the location of a missing tree in a peach orchard between Rio Oso and Wheatland. The orchard was planted on a uniform 22′ square pattern. The trees were about 15′ high with the foliage extending down to about 6′ above the ground.

Instrumentation was installed in the orchard to obtain a reliable understanding of orchard response to this type of machine. Instrumentation included 55 thermocouples for measuring temperatures, eight anemometers for wind speed, two wind direction indicators, three soil temperature recorders, two soil heat flow plates, radiation measuring instruments, 12 glass bulb thermometers, and a complete University micro-station for a continuing record. Recorders were located in a house trailer adapted for field work.

In a test of this type it is difficult to specify what the natural temperature would have been if the wind machine had not been running. However, it is necessary in order to determine the rise produced by wind machines because natural changes in temperature are occasionally as large as those caused by the machines. One method of determining the rise is to average the temperatures before and after the wind machine was operated—assuming enough time was available, after turning off the machine, for the temperatures to return to normal before sunrise—and take that average as the natural temperature during the test. Another method is to establish a control station within the orchard but beyond the area affected by the wind machine. Control station temperatures are correlated with the other orchard temperatures just before turning on the machine and assume the correlation holds throughout the test. This method eliminates offsets in instrument calibrations but does not allow adequate handling of the slight natural area-wise changing temperature relationships.

Temperatures above normal in the winter of 1958–59 and typically variable winds in the Sacramento Valley on nights approaching radiation frost conditions limited the number of good test nights. During the test period, wind speeds in excess of 5 mph at 50′ altitude destroyed any inversions. In effect nature, instead of a wind machine, did the mixing of the cold and warmer air strata. There was not a characteristic wind direction on nights approaching frost conditions. Under light wind conditions, wind directions often varied through all directions on any one night. On those nights when tests were run the winds did not settle down—until 4–5 a.m.—enough to allow the obtaining of interpretable results. As a consequence, the control station method of determining natural temperatures during the test was used.

The data obtained on the mornings of March 20 and March 25 represent the two best tests. At that time a cover crop of oats and vetch was 12″–18″ high, although a little spotty in coverage due to trampling down during test operations. The trees were fully blossomed and the leaves were partially emerged, having just begun to show green about 10 days earlier.

Temperature rises due to the wind machine were calculated by determining the average temperature over the ap-

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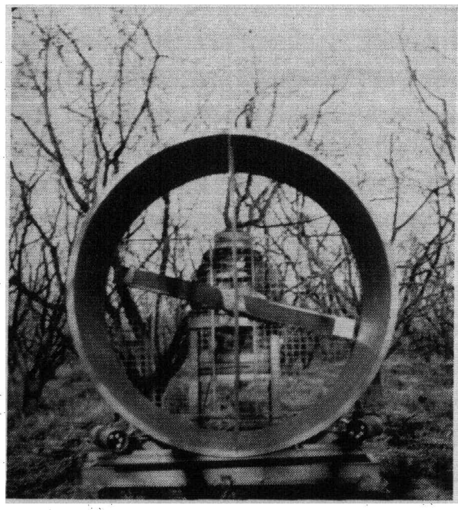
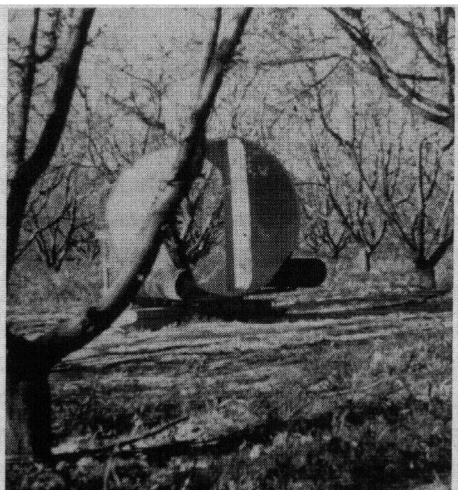
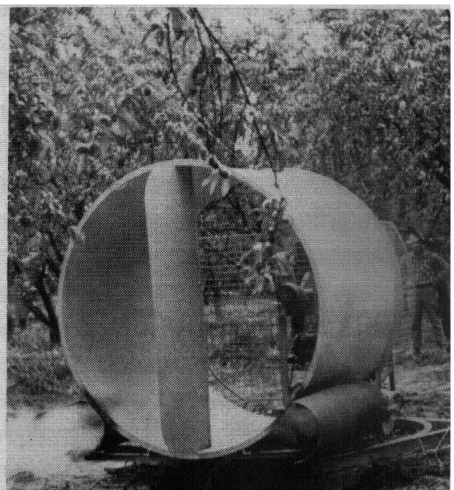
An under-the-tree wind machine powered by a 145 HP engine; 92 BHP is developed at the usual propeller RPM of 2,350 and the unit turns through 360° in 5½ minutes. Two propane burners can be used to add 4,000,000 BTU per hour each to the air jet.

Photos taken: *left*, March 12, 1959; *center*, March 25, 1959; *right*, April 23, 1959.

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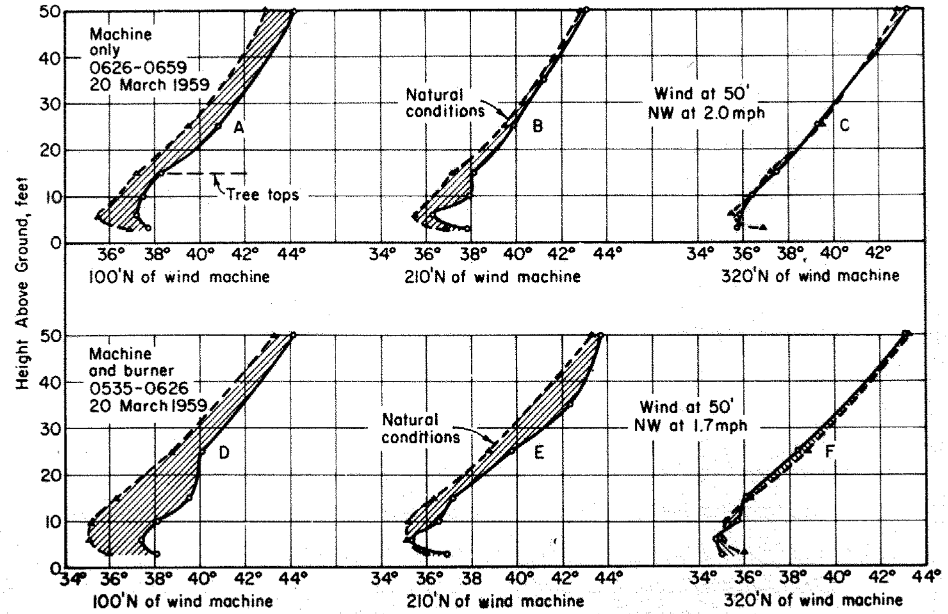
propriate period and subtracting the corresponding average control station temperature adjusted by the correlation established just prior to starting the wind machine. It was assumed that the effective temperature for protection was the average one, realizing that the temperature at any one point varied according to which direction the wind machine was pointing with respect to that point. This was quite marked for points near the wind machine and with the burners lit. On March 20, a 5°F temperature variation—on a glass bulb thermometer 93′ southwest of the wind machine—was noted during a complete revolution of the machine with the burner lit. The temperatures were recorded on strip charts by recording electronic potentiometers capable of reading 12 temperatures in three minutes or 16 temperatures in five minutes. On the recorders with the five minute time cycle, which nearly coincided with the 5½ minute turning time of the wind machine, there was a tendency to record the temperature at a particular place in the orchard characteristic for a given direction of wind machine blast. Thus it was possible, over the necessarily short averaging periods, to get an average temperature that was either too high or too low. Consequently the analysis of some of the data plotted in the following figures has been adjusted.

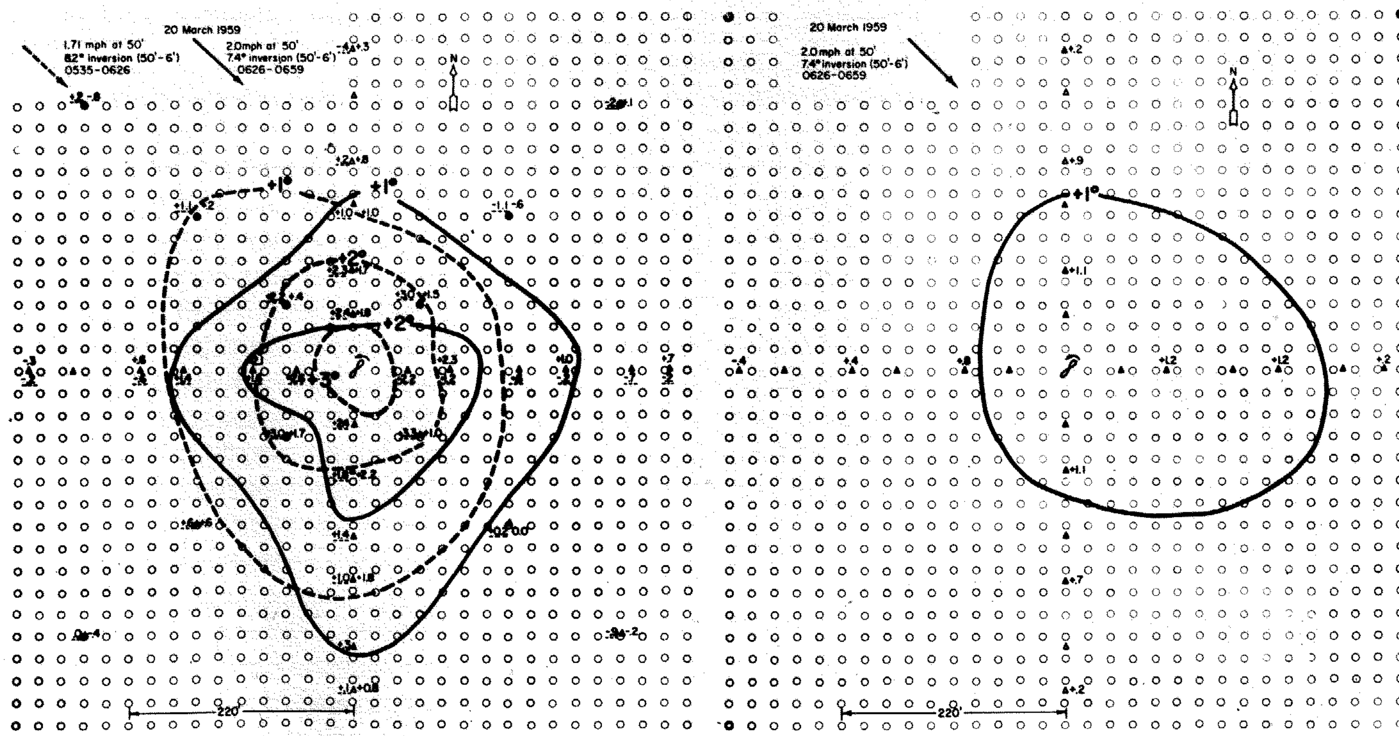


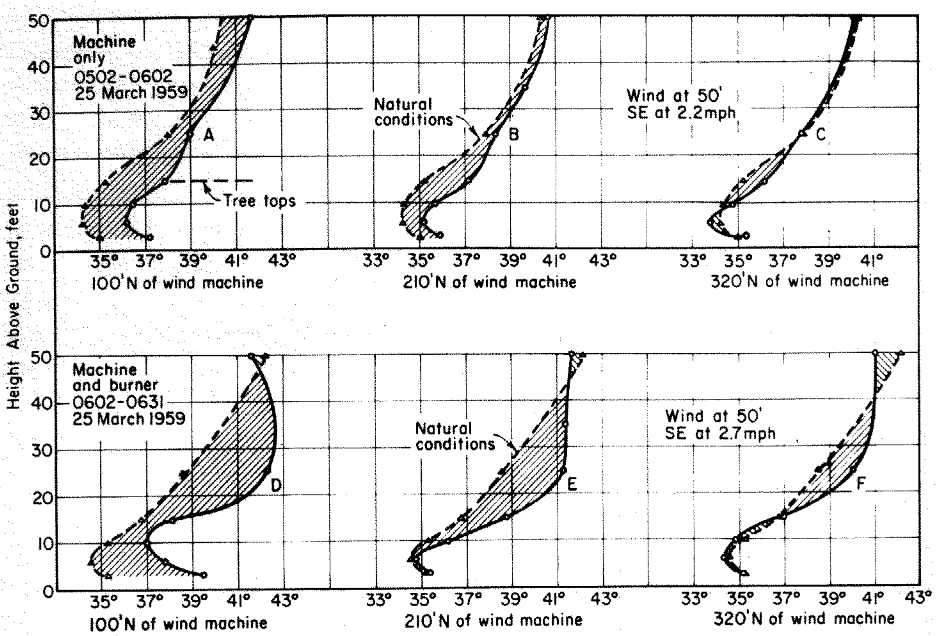
Vertical temperature profile changes due to the wind machine and wind machine-burner combination on March 20, 1959. Note how fast the additional heat is dissipated and lifts out of the orchard from Curve D to E.

The temperature responses obtained March 20 at the 6′ and 15′ levels are indicated in the graphs on this page and the area of coverage in the table on the next page. The wind machine-burner combination gives more protection close in but does not seem to have a significant effect on the areas of one and two degree temperature rise at 6′. It was anticipated that adding a large amount of heat to the air jet at the wind machine would increase the buoyancy of the jet, lifting it into the trees and thus decreasing its length of carry under the tree canopy. That this is so is indicated by visual observations of air movement in the orchard and the effect on seven anemometers along a 50′ mast 210′ north of the wind machine.

The machine effect on wind speed, as indicated by these anemometers, varied according to the direction it was pointing but during the minute after it pointed

***Left*—Six-foot temperature changes on the morning of March 20, 1959. Solid lines are wind machine only (0626–0659) and dashed lines are wind machine plus burners (0535–0626). *Right*—Fifteen-foot temperature changes on the morning of March 20, 1959 for the wind machine only (0626–0659).**





Vertical temperature profile changes due to the wind machine and wind machine-burner combination on March 25, 1959. The rise of the additional heat from the burners above the orchard is well illustrated on Curves D through F.

due north all of the anemometers up to 25′ and occasionally 35′ showed a response with the strongest change in speed at the 6′ level. This indicated some forced mixing extending through the tree canopy which is also borne out by the temperature rise at the 15′ level shown in the graph on page 4. The tree-top level is more exposed to the natural wind and the shape of the response area is distorted accordingly.

Thermocouples along four 50′ masts —one at the control station and three in a line northward from the wind machine —provided data for a study of the changes in the vertical profiles. The graph on page 4 shows these profile changes for March 20.

The natural conditions profile indicates colder temperatures in the foliage layer than near the ground. This indicates that it is the foliage, not the ground, which is exerting the main cooling effect on the air. Then as the trees are colder than the air it is possible to warm the colder fruit or blossoms nearly up to the air temperatures by blowing air against them with a wind machine and thus get more frost protection with wind machines than is indicated by air temperature differences. The magnitude of this added protection is not known. This would not be advantageous, however, if the fruit or blossoms were wet, because then increased air movement would increase evaporation and result in evaporative cooling of the fruit or blossoms.

Curve A on the graph on page 4 shows warming at all levels, indicating mixing was effective up to 50′ and above. Some of the warming at 50′ is probably due to air being drawn downward to replace the air forced outward by the jet. Heating by compression as it descends say 30′ would amount to only 0.16°F. Curve B still shows warming under the trees but little above as the air blast has pretty well dissipated against the natural wind

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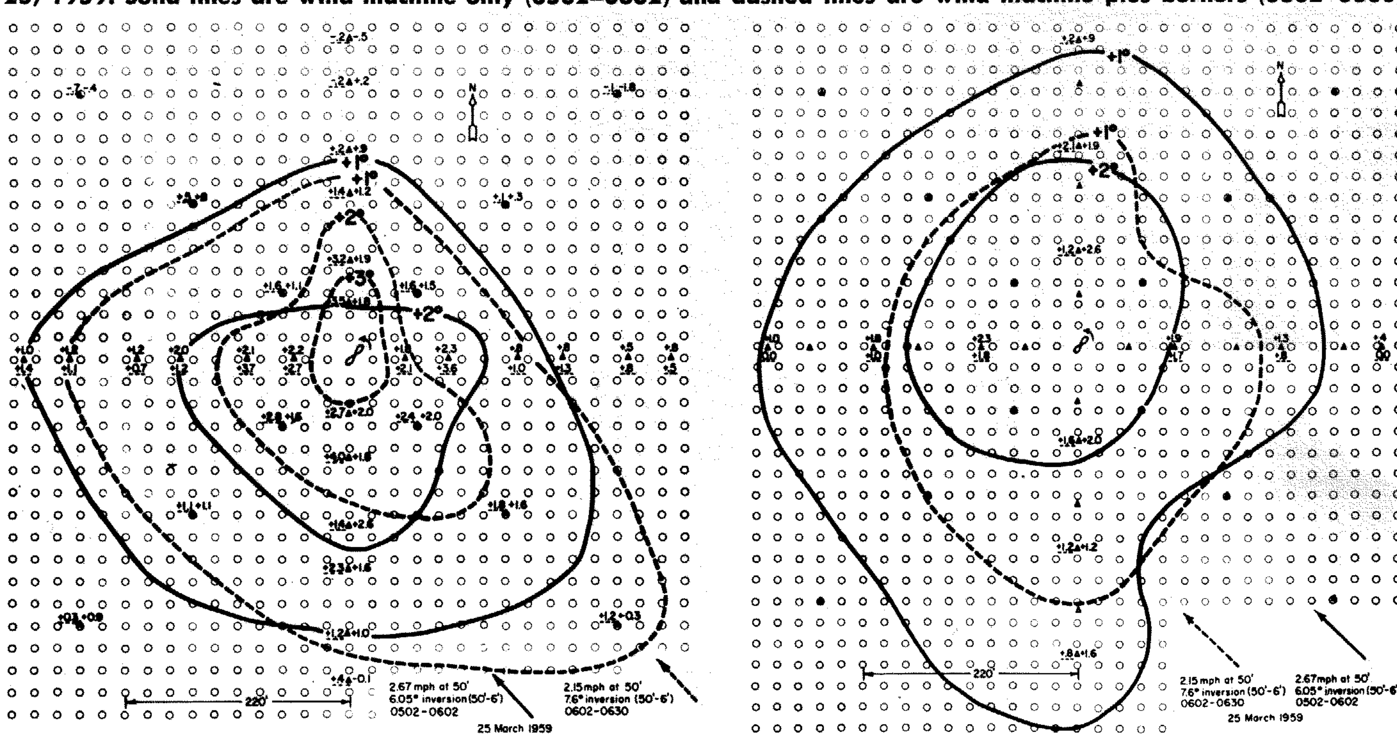
Area of Temperature Rise (Acres)

Temperature rise	March 20, 1959 Wind machine 6′	15′	March 20, 1959 Wind machine + burner 6′	15′	March 25, 1959 Wind machine 6′	15′	March 25, 1959 Wind machine + burner 6′	15′
1°F	2.7	2.2	2.1	No data	3.8	6.1	4.2	2.9
2°	0.6		0.6		1.1	1.6	1.1	
3°			0.1				0.2	

Left—Six-foot temperature changes on the morning of March 25, 1959. Solid lines are wind machine only (0502–0602) and dashed lines are wind machine plus burners (0602–0630). *Right*—Fifteen-foot temperature changes on the morning of March 25, 1959. Solid lines are wind machine only (0502–0602) and dashed lines are wind machine plus burners (0602–0630).



New Winter Rye

productive winter annual cereal grain has high fertility in California tests

Coit A. Suneson

The first California certified seed of Svälof Fourex spring rye—introduced from Sweden—is expected to become available for commercial use after the 1959 harvest.

Svälof Fourex is a very productive winter annual cereal grain that does best on lighter soils; excels in total dry matter production, straw stiffness and plant height; and makes a good winter cover crop or a winter forage crop. However, it is not likely that Svälof rye will compete with barley or wheat in the production of grain for food or feed in California.

Neither yellow-dwarf virus nor common root rots, which are the most troublesome diseases in early fall sown cereals, have damaged Svälof Fourex seriously in tests at Davis and elsewhere in California.

Svälof Fourex resulted from 15 years of progeny test breeding in Sweden that first produced a new diploid spring rye that was, in some respects, superior to the leading Swedish variety. Tetraploids—plants with double the usual number of chromosomes—were obtained from the diploid plants by colchicine treatment. Finally, tetraploids were selected for high fertility as they normally produce large plants and also have large, but fewer, seeds.

Svälof Fourex has better fertility in the mild California climate than was expected from Swedish experience, a phenomenon presently under joint technical investigation by researchers in Sweden and at Davis.

Spikes and seed of Merced—diploid—and Svalof Fourex—tetraploid—spring rye showing the size differences which are characteristic of all plant parts.

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The above progress report is based on Research Project No. 176.

Dr. O. Tedin and Dr. A. Hagberg of the Swedish Seed Association developed and named the new spring rye.

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before reaching this point. The minor variations in Curves C and F are not significant.

The marked warming between the surface and 20′ on Curve D is due to the heat added by the burners being well mixed in this layer by the opposing natural wind before reaching this mast. The added buoyancy of the air jet caused the main part of the warm air to rise above the orchard and show up as a much weaker maximum temperature response at 35′ on Curve E. That portion of the warm air jet under the tree canopy on Curve D had risen into the trees and damped out before reaching 210′ north so that there was no noticeable rise in the lower temperatures at this location. The minimum temperature in the orchard that morning was 34°F.

Similar handling of the data for March 25 produced about the same results, as indicated in the graphs and the table on page 5. Here data was also available for the 15′ temperatures during a wind machine plus burners test. At the 15′ level protection is less with the burners going than without because the extra heat rose above the 15′ level. In the graph on page 5 Curves A through C are very similar to those of March 20 even though the natural wind direction is different. The effect of the natural wind helping to blow the warm air rapidly from the wind machine toward the 50′ masts shows up in Curves D through F. With the natural wind helping, the warm air arrives at 100′ north quicker and with less mixing than before. In effect it appears that the warm air jet was split; some going under and some above the foliage due to the added frictional resistance of the foliage. The warm jet under the trees lifted into the foliage before reaching the mast at 210′ north and caused a little temperature rise at foliage level but none below. Curves E and F indicate maximum temperature responses at the 25′ level although decreasing in magnitude with distance. Evidently the natural wind carried the warm air past the mast before its additional buoyancy could lift it much higher. The minimum temperature was 33°F on the morning of March 25.

Although these interpretations have been the results of only two test nights, the area responses are considered representative for the under-tree wind machine under the test conditions. It is not possible to know how well this machine would have done mounted on a tower. However, rough comparisons can be made with tower machines tested in almonds at Chico. Tests in 1955 on a 25 BHP wind machine, 42′ above the ground, which turned through 360° in about four minutes showed a 1°F response over 1.8 acres at 10′ above the ground in a weak inversion of 4.5°F. A conventional wind machine with dual gasoline engines of 75 BHP each, 40′ above the ground, was tested in the same almond orchard in 1957. With a 7.3°F inversion it gave a 1°F gain over 14 acres, 2°F over 6.9 acres, and 3°F over 2.7 acres. The under-tree wind machine area responses fall between those of the two tower units. As air movement under the tree canopy is much stronger with the under-tree unit it should be more efficient in redistributing the heat from a few scattered orchard heaters. Although not yet tested it is thought that the combination of orchard heaters and an under-tree machine would be the most effective.

The addition of a large amount of heat from the burners on the low mounted wind machine causes the air jet to lift out of the orchard and the additional temperature gain in close to the machine does not seem to be worth the cost of the burner equipment and propane fuel.

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Rodney Vertrees provided the test peach orchard and the under-tree wind machine and assisted on test nights.

C. E. Barbee, Fred Lory, and Richard Miller of the Department of Agricultural Engineering, University of California, Davis, assisted in these studies.

Joe Ganser and Tom Beecroft, United States Weather Bureau, also assisted with forecasts and participation in the tests of March 20 and 25.

The above progress report is based on Research Project No. 400-U.