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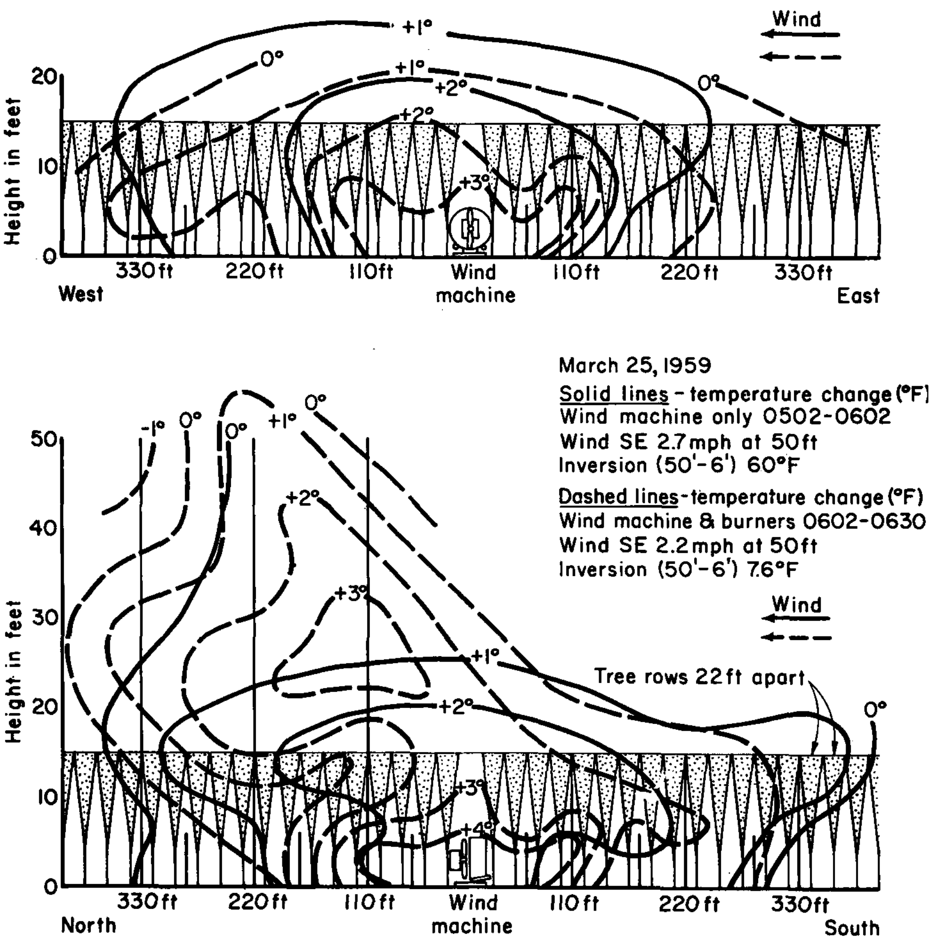
Wind machine-orchard heater system for Frost Protection in deciduous orchards

The following article is the twelfth annual report of progress in studies on orchard frost protection published in California Agriculture.

Development of an orchard frost protection system, utilizing the good features of wind machines and orchard heaters while minimizing their disadvantages, is the objective of current research.

Orchard heaters, when evenly distributed, are the most positive means of frost protection. Common practice is to use 25 to 50 heaters per acre, but labor to place, fill, and light the heaters is expensive and sometimes unavailable.

Tower mounted wind machines which mix the warmer air above the trees with the colder orchard air are relatively successful in citrus orchards in southern California. In those citrus areas the winter temperature inversions—air temperature at 50′ above ground minus that at 6′—are 10°F to 14°F. Tower mounted wind machines are not so successful in the deciduous orchards of the Sacramento Valley. The deciduous tree branches form a canopy which acts as a barrier to the air jet, and spring temperature inversions are only about half as great as in southern California.



Vertical cross-section showing the temperature changes (°F) on March 25, 1959. Note the schematically presented trees and the solid heavy vertical lines which indicate the masts for the temperature sensing instruments.

An under-tree wind machine, with its air jet originating in the relatively open space under the branch canopy, is an improvement over the tower mounted machine, but the weak temperature inversions of the Sacramento Valley do not permit a temperature rise sufficient for adequate protection.

The least expensive way to increase the temperature rise in an orchard—from the standpoint of labor—is to add heat at the wind machine for distribution by the air jet. Increased protection close to the wind machine has been observed but the warm air jet, with its added buoyancy, quickly rises out of the orchard.

Adding heat to a wind machine protected orchard with a few distributed orchard heaters has given good results.

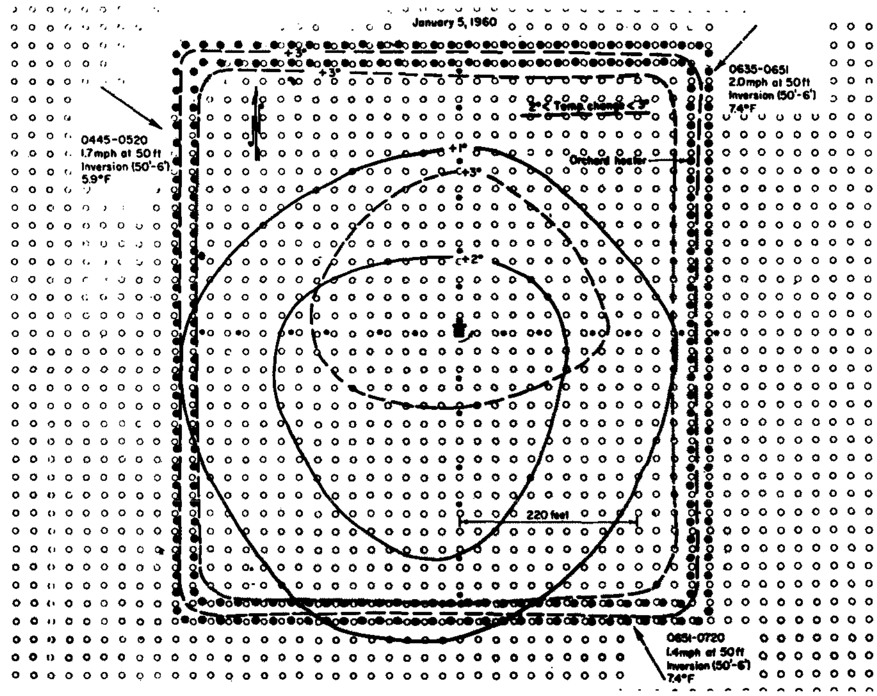
All tests with wind machines alone indicate a definite area of protection near the wind machine but an indefinite pattern of protection farther out. An advantage of orchard heaters is their flexibility in placement to efficiently provide protection over an area of almost any size or shape.

In February 1959, instruments were installed in a cling peach orchard near Rio Oso, to study the use of an under-tree wind machine for frost protection.

The addition of 4,000,000 Btu per hour, from each of two propane burners to the air jet at the wind machine, did increase the protection within 100′ of the machine but decreased the area of 1°F protection because the added buoyancy of the warm air lifted the jet out of the orchard. A vertical cross section—profile—of the temperature responses shows that a large share of the heat from the burners was wasted above the trees. The wind machine temperature response lines are symmetric around the machine, with a higher temperature overhead caused by warmer air being drawn down to the machine. The north-south cross-section shows the warm air bulge slightly displaced to the north by the southeast wind. The 3°F temperature response lines show the patterns of added warming under the tree foliage within 100′ of the machine and above the trees because of the addition of heat at the wind machine. The northward displacement of the maximum temperature response is due to the southeast wind. Temperature responses of that magnitude above the trees indicate inefficient use of heat for protecting the orchard against frost damage.

Any time an orchard is warmed for frost protection, the air in the area being protected becomes buoyant relative to the surrounding air and tends to rise. Cold air is then drawn into the orchard from the edges. Utilizing the orchard heater's flexibility in placement to aid the wind machine in protecting the normally square-shaped orchard, a border of heaters around the orchard was the pattern chosen for study. The border pattern also defines the area being protected. Variable winds in the Sacramento Valley change the area protected by a wind machine alone from night to night. The heaters were placed in the tree rows to permit rapid lighting with a jeep- or tractor-mounted automatic lighting torch and for easier refueling.

The first heater pattern studied enclosed eight acres with a 2-row square border of heaters around the wind machine. A total of 200 heaters—one in every tree space—was used. The results from two nights' tests in December, 1959, were encouraging, so the border was moved out farther from the machine. For the next tests, 11 acres were enclosed with a 2-row border of 240 heaters. Two nights' tests were conducted with the enlarged pattern. All of the 1959 and 1960 test results are summarized in the accompanying table.



Six foot temperature changes (°F) on January 5, 1960, due to the wind machine (solid lines) and the wind machine plus 240 orchard heaters (dashed lines).

The type of protection pattern obtained is illustrated by horizontal and vertical presentations of the data for January 5, 1960. An upward bulge in the temperature response lines over the wind machine—displaced southward by the natural wind—was the result of the

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Results of 1959–60 Frost Protection Tests

Date	Inversion (50′–6′) °F	Wind at 50 ft mph	Min. 6 ft temp. °F	Wind machine thrust lbs	Heat added at wind machine Btu/hr	No. of orchard heaters at ½ gal. per hour	Acres enclosed by outer row of heaters	Temp. rise °F	Temp. rise % of the inversion	Acres over which rise occurred
Mar. 20, 1959	*7.4*	NW 2.0	35.1	320	0	0	0	1	13.5	2.7
								2	27.0	0.6
	8.2	NW 1.7		320	8 million	0	0	1	12.2	2.1
								2	24.4	0.6
								3	36.6	0.1
Mar. 25, 1959	6.1	SE 2.7	33.9	320	0	0	0	1	16.4	3.8
								2	32.8	1.1
	7.6	SE 2.2		320	8 million	0	0	1	13.2	4.2
								2	26.4	1.1
								3	39.4	0.2
Dec. 8, 1959	8.6	N 3.3	23.0	Approx. 250	0	0	0	1	11.6	3.8
								2	23.3	1.6
								3	34.9	0.6
Dec. 11, 1959	3.1	N 5.9	28.0	395	0	200	8	1	32.2	7.1
								2	64.5	1.7
Dec. 16, 1959	6.5	N 3.6	24.0	390	0	200	8	1	15.4	>8.0
								2	30.8	>8.0
								3	46.2	8.0
								4	61.5	1.5
Dec. 22, 1959	4.9	NW 3.0	32.0	400	0	240	11	1	20.4	9.8
								2	40.8	5.8
								3	61.2	0.3
Jan. 5, 1960	5.9	WNW 1.7	21.0	390	0	0	0	1	17.0	7.3
								2	34.0	2.4
	6.8	NE 2.0 SSE 1.4		390	0	240	11	1	14.7	>11.0
								2	29.4	11.0
								3	44.1	4.6
April 15, 1960	4.0	NW to E 2.7	36.0	Approx. 470	0	0	0	0.5	12.5	1.0
								1	25.0	0.01
	6.0	NW 2.5		Approx. 470	0	204	11	1	16.7	10.6
								2	33.3	5.6

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warmer overhead air being pulled downward into the wind machine. A warming of the air out in the orchard 150′–250′ from the wind machine was due to the colder orchard air being mixed with the warmer overhead air. The cold orchard air had a cooling effect on the temperature at 25′–40′ above the ground. With the border orchard heaters burning, the area of protection was better defined, with the best temperature responses in the heater row and near the wind machine. The protection pattern was symmetric around the wind machine, probably due, in part, to the natural wind changing from northeast to south southeast during the middle of the test run. A test of the same pattern on December 22, 1959, had indicated better temperature responses downwind than upwind. The vertical cross-section of the January 5 temperature responses shows that the overhead temperatures were not cooled as much by the mixing action of the wind machine when the heaters were burning. An area of smaller temperature responses between the heater row and the wind machine indicated that the heater row was probably as far out from the wind machine as is practical for adequate protection under the conditions of the test.

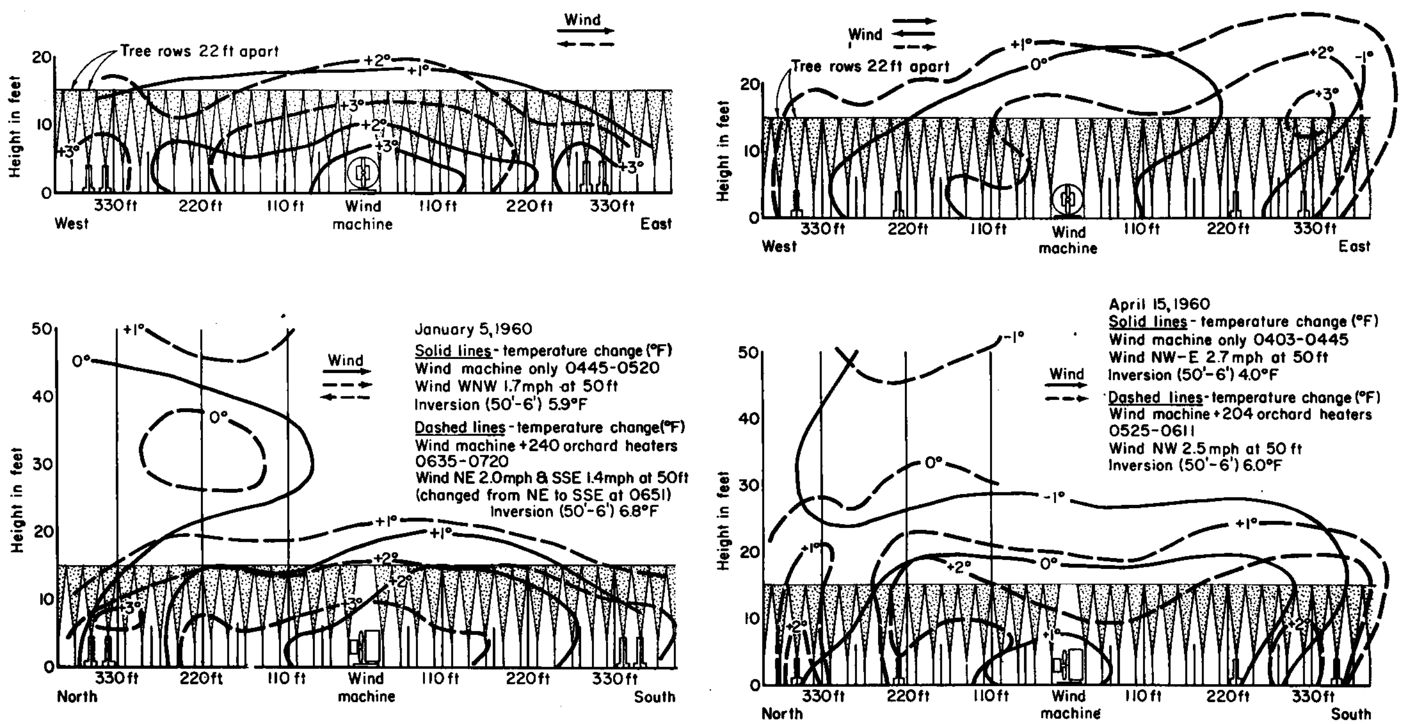
Another test was designed to use just the outer border of heaters around the 11 acres and one additional row in a square pattern 220′—10 tree rows—from the wind machine. This design approaches a distributed heater system but on a much simpler pattern from the standpoint of lighting and refueling. The wind machine air blast was strongly felt at the 220′ distance—it was not noticeable at the outer border of heaters—and should be effective in distributing the heat from the inner row of heaters. This pattern reduced the total number of heaters needed for the 11 acres to 204. A test of this system was made on April 15, 1960, and the results are given in the table.

An unusual feature of the wind machine temperature response lines on the vertical cross-sections was the amount of cooling which took place, probably due to the natural wind changing from northwest, at three to four miles per hour at the beginning of the test run, to east and then almost calm for the last half of the run. The initial surge of air from the east was evidently colder than the orchard air and counteracted the warming effect of the wind machine. Also, as the natural wind dropped off during the test period, the temperatures in the orchard tended to get colder due to less natural mixing. Without natural wind to help along the air turbulence created by the wind machine, the machine could not be so effective. In previous tests the wind was more constant during the control station correlation run and the test run. Also, there was more tree foliage but the cover crop had been disked under before the April test.

During the test run with the machine and 204 heaters, there was a northwest wind. The temperature responses were not so great upwind as downwind of the machine due to the air jet being restricted or helped by the natural wind. To the north, the weak temperature response between the two rows of heaters indicated that the wind machine was not effectively distributing the heat from the inner row of heaters. A spot check indicated that when the wind machine faced north, a slight ripple of leaves was detectable only 240′ north of the machine. Under similar conditions, with less air jet thrust, the first part of March, the ripple of leaves was detectable 280′ north. The effect of increased foliage on the travel of the air jet from the machine was shown to be important.

Comparing the tests of December 22, January 5, and April 15, it appears that the pattern used on April 15 with 204 heaters on 11 acres was justified. However, for adequate protection late in the spring, each row of heaters probably should be moved one tree row closer to the wind machine.

Exact comparisons of the effectiveness of an under-tree wind machine with a tower mounted wind machine for frost protection in deciduous orchards are impossible because the two types of wind machine have not been studied under



***Left*—Vertical cross-sections showing the temperature changes (°F) on January 5, 1960. *Right*—Vertical cross-sections showing the temperature changes (°F) on April 15, 1960.**

G. N. DAVIS

Breeding Potatoes for disease resistance

All new potato varieties and a large number of advanced generation experimental lines from many sources have been tested for disease resistance and adaptability to California growing conditions. A true breeding program with the production and evaluation of large numbers of F_1—first generation hybrid—seedlings was initiated in the spring of 1958.

The objectives of the program are to develop varieties similar in appearance to those being grown in California, but with higher quality and resistance to disease—particularly to common scab and Verticillium wilt, and resistance to a predisposition to black spot.

Desirable materials to be used as parental lines in the various crosses are collected from many sources. Crosses must be made in the winter and early spring, when air temperatures do not exceed 70°F. Since potatoes require long days to initiate flowering, the natural daylight must be supplemented by artificial light during this time of the year. This is usually accomplished by a three-hour night time period of illumination with ordinary incandescent light.

At the time the crosses are made the plants used as females are cut from the roots and immersed in bottles of weak nutrient solution, where they remain for five weeks until the seed matures. If this procedure is not followed, many or all of the seed balls may drop from the plant.

The seeds are germinated in flats, and the small seedlings are transplanted to 4″ pots so that the small tubers from each plant may be kept separate at harvest. One year after the original crosses are made, the small tubers from the pots are planted in the field for evaluation and selection. Most of the seedlings are discarded for one reason or another. The small percentage selected is saved for further testing.

Inheritance is very complex in the potato. This necessitates the growing of large populations. For example, to obtain certain expected ratios in such plants as peas or corn, a population of at least 64 plants would be necessary. To obtain the same expected ratio in the potato, a population of 46,656 plants would be required.

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identical conditions. However, results from previous work do come close to being comparable with the test results of the last two years.

Tests were made in 1955 with two electric wind machines mounted 42′ above the ground in a large almond orchard near Chico. Before foliage development and with a 5°F inversion, the 280-pound thrust machine could not produce a 1°F temperature rise anywhere in the orchard. With a 4.5°F inversion the 340-pound thrust machine produced a 1°F rise over 1.8 acres. Although those tests were in an almond orchard, cling peach trees are similar in shape and the thrust of the electric tower machines was about the same as the under-tree wind machine. As the almond leaves increased in size, the response from the tower machines decreased. By the middle of March, 1955, it was difficult to follow the air jet—twig and leaf movement in the tree tops—beyond 150′ from the machine, and the jet was not reaching the ground anywhere. In contrast, in March 1959 and in April 1960, the under-tree wind machine had a detectable effect on the leaves to 240′ from the machine.

The tower machines generate turbulent air mixing, in the path of their air jets above the trees, which does not necessarily extend into the tree zone except where the jet itself strikes the tree tops. Here the air jet velocity is relatively high and the energy loss from forcing the air jet through the leaf and twig canopy at an oblique angle is great. In contrast, the under-tree wind machine works in the relatively open space under the tree canopy. Cover crops, tree trunks, and foliage offer some frictional resistance, but the jet does not have to penetrate a tree canopy at high speed. As the jet rotates under the trees, it sends out a slowly expanding wall of air which sweeps the cold air ahead of it. The warm air is drawn down from above, behind the slowly expanding wall of air. Occasionally the wall of air breaks through the tree canopy to be caught in the overhead wind and mixed with that warmer air over the orchard.

The under-tree wind machine generates air turbulence in the tree zone, which is then linked to the overhead wind and strengthened. The tower wind machines generate turbulence above the trees, which is then carried along by the wind except where the air jet is able to penetrate the tree canopy.

The combination of an under-tree wind machine with border heating gave fairly uniform temperature rises over a 10-acre area, which probably is about the maximum sized area for any under-tree wind machine. A larger thrust machine would require a larger propeller, and a 6′ diameter propeller seems to be about the maximum practical size. To increase the thrust of the air jet by speeding up the machine would cause wind damage to the trees.

In orchards of more than 10 acres, requiring more than one wind machine, the machines should be spaced close enough together so that heating is not necessary between them. The whole area to be protected should be outlined with a border row of heaters with a second row of heaters several tree rows inside. Under these conditions, the number of heaters per acre should be less than necessary with a single wind machine.

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Rodney Vertrees provided the test peach orchards and the under-tree wind machine, and assisted in the tests.

Fred Lory and Richard Miller, Department of Agricultural Engineering, University of California, Davis, assisted in these studies, as did George Post, Dave Chaney, and Dave Ramos, Farm Advisors, University of California, Sutter County.

Joe Ganser and Tom Beecroft, United States Weather Bureau, also assisted with forecasts and participation in the spring tests.

The return stack orchard heaters used in the experiment were loaned by National-Riverside Company and Scheu Products Company.

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