Frost Protection for Citrus

combined use of wind machines and distributed orchard heaters provides extra frost protection

F. A. Brooks, D. G. Rhoades and H. B. Schultz

Orchard temperature responses— measured at the Citrus Experiment Station at Riverside—showed a gain of 20% to 30% above the sum of the separate responses—verifying reports of growers that the combination increased frost protection.

Continuing frost protection studies started in 1937 the University installed a 75 horsepower single-motor electric wind machine to cover about 10 acres in the lower part of field No. 1 of the Citrus Experiment Station. Special apparatus was built into the machine to permit measuring the delivered jet momentum by weighing the thrust reaction. The thrust measurement when blowing with the drift decreased only 2% for a change of air drift velocity from 2.3 to 3.5 mph. Four 40-foot poles which carry thermocouples and anemometers for measuring temperature profiles and air velocities were erected extending down drift to 600 feet. Other thermocouples were distributed in trees and throughout 20 acres, 63 points being connected to four electronic potentiometers for continuous recording. A pitot tube was installed directly facing the propeller to measure the initial jet velocity pattern.

Intensive study of air jets was made covering three powers: 50, 90 and 130 brake-horsepower; and three sweep speeds: 180° in 55 seconds; in 2½ minutes; and in five minutes. The 90 b.h.p. fast sweep failed to carry more than 400 feet but in oscillating 200° it seemed to create a continuous turbulence at 150 and 250 feet. Further tests are necessary to verify this indication.

The two nights of temperature tests with wind machine and distributed heaters are not sufficient for broad generalization. The tentative conclusions indicated, however, are in line with the findings of other experienced orchard operators who, this year, lit eight to 12 distributed heaters per acre and received a substantial boost in temperature response with the wind machine running as usual.

The usual firing of eight to 12 heaters per acre without wind machine would afford unsatisfactory protection because of the dark trees for such sparse distribution, but field experiences of other growers show that with wind machines this inequality is well counteracted. This combination could be expected to give good results because ordinarily the stack convection heat—which is greater than the radiant fraction—usually spreads above the trees and is useful mainly in strengthening the overhead temperature. When, however, these heater updrafts are inside the area disturbed by wind machines much of the stack gas heat is made directly available to the trees. It seems quite clear at least that the forced horizontal distribution by wind machine tends to equalize the protection of the dark trees with those close to heaters.

In a survey in June 1950, it was found that almost all of the growers interviewed were agreed that an installation of wind machines plus 25 heaters per acre provide a satisfactory frost protection system—as good as can be justified in an economic sense. The growers would light all the heaters only in case of machine failure or extreme frost condition, and most expect the wind machine alone to afford sufficient protection at least half the frost nights. There was general concurrence that after a night with damaging temperatures the machines should be kept running several hours after sunrise, at least until the fruit was dry.

The natural air drift at the Citrus Experiment Station is much faster than at Oxnard where studies were made in 1948. The two Riverside tests were run late in the season, on February 24 and February 25, and in maritime Polar air mass persisting for four days previously. The nights always had clear skies, but occasionally light ground fog, with an average extension to a height of 25 feet. The inversion and the nocturnal radiation con-

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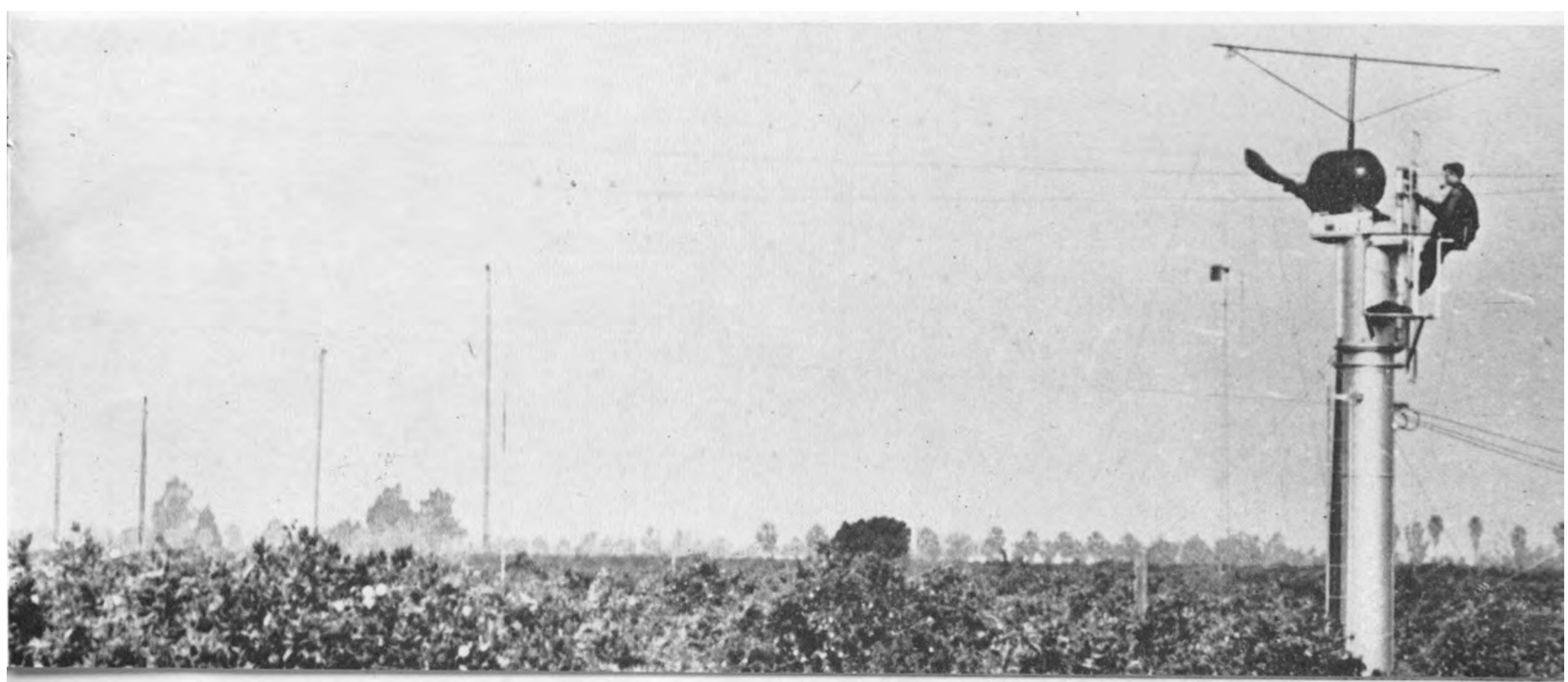
View of test wind machine showing the thrust weighing operation and the four-pole installation for measuring velocity and temperature profiles at the Citrus Experiment Station, Riverside.



ditions were all typical for a light, moist, radiation frost night. Only the temperature level was not typical being considerably above freezing, so the findings should be useful as long as interpretation is limited to the changes of temperature produced by the various systems.

On the night of February 25–26, 1950 the wind machine propeller was set for 90 bhp and was oscillating 200°—± 100° from the average down-drift direction. The time for a complete sweep cycle was five minutes. The machine was first run alone starting at 9:05 p.m. and 25 minutes allowed for conditions to stabilize before the readings were averaged in the next 1½ hours to obtain the 2.1° F response tabulated in the first line of the above table. It was then shut down for two hours. At 1:00 a.m. it was started after 15 Return-Stack heaters per acre were lit—one heater every other tree row, two and four rows apart crosswise—delivering about 1,500,000 Btu per acre hour.

Allowing 20 minutes for stabilizing, the average orchard response for 10½ acres—down-drift—by wind machine plus heaters was 5.0° F in an air drift of 1.9 miles per hour. The temperature inversion—40 feet to seven feet—averaged 7.4° F. Judging by the 1.8° F response the previous night with heaters alone the expected contribution by heaters alone would be about 1.7° F because inversion and drift velocity are slightly worse. However, adding the separate responses of 2.1° and 1.7° a total of 3.8° F should have been expected. Actually the combined response averaged 5.0° F showing an excess of about 1.2° F namely 32% over the sum of separate heater and wind machine effects.

Another test was run February 24–25, 1950 first with heaters only, and later heaters and wind machine in combination. The average orchard response to heaters only was 1.8° F in a 7.8° F inversion and a slow drift six feet above tree tops of 1.3 mph. Later with wind machine also running the combined response averaged 4.8° F. The estimated response of wind machine alone would have been about 2.1° F because the conditions were practically the same as for the wind machine February 26, 1950. Here again the sum of the two separate protections would be about 3.9° F, while the observed combined response averaged 4.8° F showing a gain of 0.9° F—namely 23%.

It must be borne in mind that the gain from distributed supplemental heat is not possible from heated air jets. Well-de-

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Temperature Response in Citrus Orchard of Wind Machines with Distributed Heaters

(Tests of two nights only at Citrus Experiment Station, Riverside)

Date, time, test	Ave. 80" temp. 150' from wind machine	Ave. 80" temp. 250' from wind machine	Ave. 80" temp. 400' from wind machine	Ave. 80" temp 600' from wind machine	Weighted orchard averaged (area)	Ave. 80" temp. outside station	Orchard response	Orchard response due to wind machine	Orchard response due to heaters	Orchard response extra gain due to combination		Average inversion 80"–40'	Air drift average direction	Air drift ave. vel. 80" above surface
2/25/50 9:30–11:00 p.m. wind machine alone	46.9° F	47.6°	47.8°	47.2°	47.4°	45.3°	2.1°	2.1°	....	...	...	7.9°[1]	East	1.6 mph
2/26/50 1:20–2:45 a.m. wind machine and heaters	46.3°	47.8°	46.4°	45.2°	46.0	41.0	5.0°	(2.1°)[2]	(1.7°)[3]	1.2	32%	7.4	Southeast	1.9
2/24/50 10:05–11:25 p.m. heaters alone	44.0	44.2	44.5	44.9	44.4[4]	43.6	1.8°	....	1.8°	...	...	7.8°	East	1.3
2/25/50 2:35–4:00 a.m. wind machine and heaters	45.2	45.7	44.6	43.2	44.1	39.3	4.8°	(2.1°)[2]	(1.8°)[2]	0.9	23%	8.6	Northeast	1.7
Relative areas for weighting	1.00	2.19	4.81	8.00										

[1] Preceding half hour inversion average = 10.9°. [2] Taken from date of 2/25/50 the outside conditions being similar. [3] Estimated from data of previous night. [4] Arithmetic average as all areas equally affected by heaters.

View of the range of protection afforded by wind machines in an orchard exposed to cold-air drift—from the right—near East Highlands, California.

Growth Results of Chicks Fed a Diet Containing 44% Cottonseed Meal Plus Amino Acid Supplements.

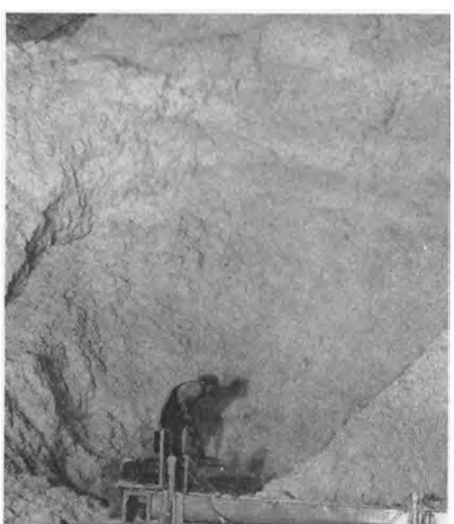
Diet	Level of supplemental L-lysine monohydrochloride, %	Average gains in grams with these DL-methionine supplements, (%) 0	0.05	0.10
Cottonseed meal mash	0	157	152	150
	0.05	164	160	151
	0.10	163	132	148
	0.20	159	148	155
Chick starter mash . . .	0	162		
Connecticut broiler mash . . .	0	176		

When high levels of cottonseed meal were fed, more riboflavin was needed in the diets than was expected, based upon published analyses of cottonseed meal for this vitamin. Until more definite information is available on this point, it is suggested that cottonseed meal not be depended upon to contain more than two milligrams of riboflavin per pound.

Because animal products supply vitamin B_{12} and probably some unidentified vitamins, it is recommended that 3% of fish meal be kept in the diet. A source of additional vitamin B_{12} may well be added to the diet.

Conclusion

Expeller-type cottonseed meal can be used extensively for chick-starting, broiler-fryer, and growing rations for chicks to provide the principal source of protein. Such rations should not be fed to laying hens, however, because of their adverse effect upon interior egg quality, particularly after storage. Under practical conditions, diets containing cottonseed meal probably need no amino acid supplements.



Cottonseed storage awaiting treatment in expeller.

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signed blowers drawing air through oil-fired furnaces were installed several years ago near Whittier and it was found in general, that drawing cold air, the jet carried about 500 feet as would be expected from conventional wind machines. With heated air, however, the carry was only about 300 feet because the buoyancy lifted the air blast out of the orchard.

Portable wind machines blowing under the trees with small open-flame burners are probably not so subject to the buoyancy fault as overhead, furnace-heated jets, but their effective reach down the tree rows is more limited. Only one test was possible this season. A 37-horsepower rig was tried having two fans blowing at right angles to both sides of the line of travel. The air conditions were unfavorable for the test, there being only a 4.4° F inversion, a light fog, and the considerable air drift of two mph, above tree tops.

A square route was followed in the citrus orchard enclosing 2.9 acres, repeating every six minutes. Running with one burner only, which delivered about 1,000,000 Btu per hour toward the inside, the combined response in the three acres was approximately 1° F. This indicates that forced delivery is advantageous because this response is at least three times what should be expected from small distributed heaters delivering the same amount of heat, and very little temperature gain could be expected from the blower in such poor inversion. Further tests are essential before substantial conclusions can be drawn.

The early freeze of December 13, 1949 caused a lot of frost damage, which in some cases clearly revealed the limitations of wind machine protection.

The illustration shown on page 12 was taken from a bluff on the east of an orchard in East Highlands. Areas protected by wind machines appear dark, but damaged spots show the light brown color of the frozen leaves. In this picture three of the five wind machines can be seen surrounded by undamaged circles up to a distance of about 400 feet. A small orchard to the northeast in a cold spot—to the right outside the picture—was completely damaged not being equipped with any kind of frost protection. A small frost spot is seen close to the nearest wind machine where the air is relatively quiet.

A significant frost area is to be noted extending from the northeast corner of the whole area—righthand side—in a wedge between the near machine and the two farther wind machines—in the west orchard. Here the frost border approaches within 200 feet of the wind machine. The main reason for this damage is probably that the cold canyon air drift received an extra low-level chilling in the meadow and the unprotected orchard to the northeast. Then the extra stability of this cold strata would be more difficult to penetrate by the wind machine jets, and stagnant air is virtually self-chilling. However, other reasons such as growth susceptibility might be the explanation for a considerable part of the frosted area.

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The survey of citrus growers, in June 1950, which resulted in the decision to install additional wind machines was conducted by Dr. L. D. Batchelor, Director of the Citrus Experiment Station, R. H. Gray, Superintendent of Cultivations, Citrus Experiment Station, with Dr. F. A. Brooks.

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NEWCASTLE

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tained from the Poultry Husbandry Division at Berkeley. These were kept in isolation for 30 days and representative samples tested at intervals for pneumoencephalitis antihemagglutinins. At the end of the 30 days these chickens were taken to the ranches and distributed in the various bird pens. These birds were inspected at three- to five-day intervals during the following 30 days. Any sick or dead birds were examined at the University to determine the presence or absence of Newcastle disease. At the end of the 30-day interval, the quarantines on the various farms were lifted, and the owners were told that it was considered safe for them to restock their aviaries.

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