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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conditions 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 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 10 1/2 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. 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

| Date, time, test | Ave. 80°F temp. from 150' to 250' wind machine | Ave. 80°F temp. from 250' to 400' wind machine | Ave. 80°F temp. from 400' to 600' wind machine | Ave. 80°F temp. outside station | Weighted orchard temp. averaged (area) | Ave. 80°F temp. orchard response due to wind machine | Ave. 80°F temp. orchard response due to heaters | Orchards 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°F | 47.8°F | 47.2°F | 47.4°F | 45.3°F | 2.1°F | 2.1°F | 7.9°F East | 1.6 mph |
| 2/26/50 1:20–2:45 a.m., wind machine and heaters | 46.3°F | 47.8°F | 46.4°F | 45.2°F | 46.0°F | 41.0°F | 5.0°F | (2.1°F) (1.7°F) | 1.2 32% 7.4 SouthEast 1.9 |
| 2/24/50 10:05–11:25 p.m., heaters alone | 44.0°F | 44.2°F | 44.5°F | 44.9°F | 44.4°F | 43.6°F | 1.8°F | 1.8°F | 7.8°F East | 1.3 |
| 2/25/50 2:35–4:00 a.m., wind machine and heaters | 45.2°F | 45.7°F | 44.6°F | 43.2°F | 44.1°F | 39.3°F | 4.8°F | (2.1°F) (1.8°F) | 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°F. 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.

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 1 1/2 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 F. Judging by the 1.8°F response the previous night with heaters alone the expected contribution by heaters alone would have been about 1.7°F because inversion and drift velocity are slightly worse. However, adding the separate responses of 2.1°F and 1.7°F 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-

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.

<table>
<thead>
<tr>
<th>Level of supplemental L-lysine monohydrochloride, %</th>
<th>Average gains in grams with these DL-methionine supplements, (%)</th>
</tr>
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<tbody>
<tr>
<td>Diet</td>
<td>0</td>
</tr>
<tr>
<td>Cottonseed meal mash 0</td>
<td>157</td>
</tr>
<tr>
<td>0.05</td>
<td>164</td>
</tr>
<tr>
<td>0.10</td>
<td>163</td>
</tr>
<tr>
<td>0.20</td>
<td>159</td>
</tr>
</tbody>
</table>

Chick starter mash 0

Connecticut broiler mash 0

157 164 160 160 163 132 148 159 148 155

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 B₁₂ and probably some unidentified vitamins, it is recommended that 3% of fish meal be kept in the diet. A source of additional vitamin B₁₂ 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.

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The above progress report is based on Research Project No. 6670E.

NEWCASTLE

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When the frost damage is most serious, the cold canyon 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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