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A GROWER'S OBSERVATIONS OF FROST PROTECTION BY USE OF A BLOWER

E. DOMINGO HARDISON

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In the fall of 1936, Hardison Ranch Company installed a large blower of the so-called double-header type. This machine was powered by two 320 h.p., airplane type engines placed on a 40 ft. tower, and was of such size and power as to theoretically have protected a 40 acre grove. It was used on a block of citrus comprising 35 acres, 25 of lemons and 10 of Valencia oranges. The grove is roughly rectangular and approximately two and one-half times as long north and south as it is wide east and west. The ground slopes in a rolling manner from north to south, being approximately 100 ft. higher on the north end. A small draw, or swale, runs from west to east near the north end. The west border of this orchard rises about 100 ft. in a quarter of a mile, rising toward other orchards. The north border is a range of hills, rising to higher mountains, and the east a mesa, planted to more citrus, this mesa being slightly higher and sloping toward a barranca, which separates the two. As a matter of fact, the grove resembles in shape a half of an elongated gravy boat.

In the past, the coldest spots in the lemons have been found to be in this upper draw, and again in a low area approximately eight rows above the intersection of the oranges and lemons. Temperatures in the lemons gradually lowered from the upper, or north side of the grove, to the south, being lowest at the two points above mentioned, and even lower in the Valencias on the extreme south side.

The blower was placed eight rows from the south side of the lemon planting. The greatest distance from the machine to the northeast and northwest corners was 1,100 feet; to the southeast and southwest corners 850 feet. All orchard heaters were removed from both lemons and oranges. Past experience in firing this grove had seemed to indicate that the so-called "ceiling" was usually low. We had no data.

Therefore, being curious regarding upper air temperatures and what constituted a "low ceiling," we had designed and built for us two ingenious machines for the taking of upper air temperatures. This was done by Dr. Irving P. Krick of the California Institute of Technology, and they were built under his direction. The name given this instrument was "Telethermoscope," which was derived from the Greek "tele," operating at a distance; "thermo," temperature, and "skopein," to view. The instrument was equipped with a parachute and carried aloft by a small hydrogen-inflated balloon. The temperature was computed by timing the interval between the flashes of a white light and a red one. These lights could be plainly seen at any height to which we sent the

instrument.

The first few nights of operation were short and enabled us to work out a few kinks in the operation of both the blower and the telethermoscope. It was soon discovered that to follow accurately the results of the blower we would require more thermometers in the orchard than we had. Accordingly, we placed a line of eight of them running north and south through its entire length, this line also passing under the blower. These were placed in the tree-row and approximately 250 feet apart. There were others placed in the corners of the grove. We had a man read this line of thermometers every hour after the danger point was reached and during the actual operation of the blower. A thermometer was also placed on the tower just under the revolving platform. There it would properly record the air temperature, being thoroughly shielded from any radiant heat or warm air stream from the motors. One of the line thermometers, #4, was within 100 feet of the base of the tower, and this thermometer, as well as the one on the tower, was always read before starting the blower. This was done when the temperature reached 32° on wet nights, and 30° or lower on dry nights.

On dry nights there was invariably a considerable temperature difference between the ground and 40 ft. above. With a reading of 30° on the ground, the tower would show 40° or above, usually 42° to 45°. One night in particular, the lower thermometer read 27°, the upper 45°. This change of temperature seemed to take place most frequently from four to six feet above the tree tops—a fact often observed by myself and the other men who assisted in the operation of this equipment. On wet nights the temperature inversion was not so great. Rarely, however, was the temperature on the tower below 37°.

It was not to be expected that the temperature readings would gradually diminish in a uniform rate, progressively away from the blower. One reason is that the ground is rolling, and a thermometer placed in one of the dips or depressions, would not be as greatly affected by the blower as one placed on a slight elevation. Another is that there seemed to be quite a strong northeast drift in the air above the tree tops. In locating the blower not sufficient importance was attached to this drift, for later it was found that it very noticeably affected the air-stream from the blower. Thermometer readings indicated that each one of these depressions was at least partially protected from wind from the blower, or else that between revolutions there was sufficient time for a little greater settling of cold air. The draw mentioned above was deep enough so that when the drift was quite strong no observable air mixing was obtained.

Now—a typical night's operation; night of December 31, 1936, 10:00 p.m. to 8:a.m., January 1, 1937. The operator was called at 9:45 p.m. The heaters for heating the crank case oil were turned on at 10:00, the motors started on "idle" at 10:15. At 10:35 they were on full throttle. Temperature at 10:15, 30.6° at #4 on the ground, 37° on the tower. At 11:00 p.m., 37½° on the tower, and at #1, on the extreme south, 33.7°, #2-34°, #3-34°, #4-34.9°, #5-34.6°, #6-32.6°, #7-32.6°, #8-33.8°. At 2:00 a.m., thermometer readings beginning at #1 and reading north to #8 were: 30.5°, 32.3°, 33.1°, 32.8°, 31.8°, 31.6°, 31.4°, and 31°. Tower—36.7°. At 6:00 a.m., readings: 30.1°, 31.2°, 31.8°, 30.7° 30.5°, 29.2°, 29.8°, 30.2°. Tower—35.3°.

You will note the effect of the northeast drift holding the temperature lower on the higher

ground to the north than on the lower ground to the south.

This was one of the coldest nights of that series. Now for a really cold one—the night of January 7-8, 1937. With blower operating, thermometer readings at 2:00 a.m.—#1 to #8: 31.9°, 30.7°, 31.9°, 32.6°, 29.9°, 29.8°. At 4:00 a.m.—30.6°, 29.9°, 31.0°, 32.8°, 28.5°, 28.7°, 29.0°, 31.2°. Tower—38°. A uniform drop of about 1° at all stations. At 6:00 a.m.—29.5°, 29.8°, 30.8°, 30.1°, 29.2°, 27.9°, 27.9°, 29.9°. Tower—35.6°. A uniform drop of about .8°.

Of course, a considerable amount of fruit was lost at this time.

Since we were getting no observable air movement at thermometers #6 and #7, each reading at 27.9°, and knowing that most of the fruit was frozen anyway, we decided to temporarily idle the motors to see if there would be a temperature change at those stations. The operator did so, walked to the two stations, and in 15 minutes from the time of idling, the temperature had dropped at each one to 24.5°. By putting the motors on full throttle again, the temperature was brought to 27.9° in 10 to 15 minutes and the performance repeated—to be certain that there had not been a change in the northeast drift which had given us the temperature change. Immediately, the temperature dropped to 24.5°, and again returned to 27.9°, under the influence of the blower.

Due to the terrain and the fact that groves to the west, southwest, and east were heated, outside temperatures were impossible to obtain that would be of any value in interpreting results. However, my residence is on the easterly edge of this grove. The tower was placed between rows 7 and 8. These rows came out at the driveway on the upper side of my home. The minimum temperature recorded on a thermometer sheltered on the north side of the house and partially protected from the influence of the blower recorded 22° on the morning of January 7, 1937. The temperature differential between this thermometer and the ground thermometer at the tower is usually 2 to 3 degrees, the grove being the colder. This would indicate that the grove might have gone to 20° without protection of any kind.

These last figures I give you for what they are worth, and do not place a great deal of value upon their extreme accuracy, because of the irregularity of the terrain and the influence of wind-breaks located not far distant. I do believe, however, that it is safe to assume that there was at least an 8 degree temperature raise at the tower, since the minimum recorded there was 30.1° as against 22° at my home.

Considerable use was made of the telethermoscope during some of those cold nights. Although the great demand upon our labor and supervision at the peak of the freeze precluded its continuous use, observations were made on some quite representative nights. For example—the night of 12-29-36 - 12-30-36, observations were made above the grove with the blower operating. From 11:40 p.m. to 1:00 a.m. readings were taken at each thermometer to a minimum distance of 50 feet. A total of 31 observations was made and recorded that night.

	Ground	20′	30′	40′	50′	60′	70′	80′	90′	100′
#1 Temperatures	30.3°	36.5°	36.3°	40°	39.5°	39.5°				
#2 Temperatures	32.5°	38°	34.5°	37.5°	36.5°	34.5°	37.5°	36°	37.5°	37.5°
#6 Temperatures	30°	37°	—	38°	39°	41.5°	41°			
#7 Temperatures	30°	40°	—	39°	39°	—	—			

These figures indicate what I would call a "low ceiling" night. Safe temperatures are indicated from 20 ft. up. Certainly a blower of high efficiency should thoroughly mix the air strata and give excellent results.

Being desirous of obtaining the information as to just what our upper air temperatures are on cold nights, we decided to make observations in other sections of our property, even while burning orchard heaters, feeling that while this would not be entirely accurate, it would be partially indicative of those conditions. Consequently, some 65 observations were made and recorded on the night of 12-31-36 - 1-1-37, from 12:00 p.m. to 7:00 a.m. A typical series of observations is given for one station in section 1, 12:00 p.m., heaters burning; ground, 31.3°; 10 ft. 35.7°; 20 ft. 34.3°; 30 ft. 34.3°; 40 ft. 34.3°; 50 ft. 35.3°; 60 ft. 35.3°; 70 ft. 36.3°; 80 ft. 36.3°; 90 ft. 36.3°; 100 ft. 37.3°; 150 ft. 36.3°; 225 ft. 37.3°; note that the temperature at 10 ft. is 35.7°. Since this is typical of the series of observations made above heaters, undoubtedly the lower readings at 10 and 20 feet, and possibly even those up to 40 feet were influenced by the fires from the heaters. I question whether there was much influence above 50 feet. The trend of our observations indicates the ceiling at somewhere between 60 and 70 ft. I would call a night of this character one of high ceiling. Another reading over Valencias #3, the section under the blower, taken at 5:45 a.m. 1-1-37; ground, 30.1°; 10 ft. 31.6°; 20 ft. 31.4°; 30 ft. 31.4°; 40 ft. 31.4°; 50 ft. 33.6°; 60 ft. 32.1°; 70 ft. 31.6°; 80 ft. 32.1°; 90 ft. 32.6° ; 100 ft. 31.6° ; 225 ft. 35.1°. Apparently the blower was effective in raising the temperature to tree height, even though the upper .air to a height of 100 ft. was very cold.

An attempt was made to compare the frost damage in this grove with that in a grove on higher ground which was unprotected, and which had not been protected since its planting in 1914. Fruit was cut from each fourth tree in every tenth row; 50 fruits of all sizes were cut from each tree, the trees first having been divided into quarters, and an equal number cut from each quarter. Fruit was selected from top, sides, bottom, and from within the tree. Any frost damage that could be detected in a fruit caused that fruit to be classified as frozen, regardless of how extensive the damage might be. Much of the fruit, of course, recovered and was later marketed. An examination of this kind revealed an average loss of 46% in the grove protected by the blower and 59% in the unprotected grove. Examining the record of fruit cut from various quarters of the tree indicated much less damage on that side of the tree exposed to the blower. The north side of trees north of the blower showed a much higher loss than the south side of the same trees. The same relation held true in any quarter of the grove. A similar examination of the records on the unprotected grove indicated a much higher percentage of loss on the northeast and southeast portions of the trees. Again, these comparative figures are not an indication of what might have happened in the protected grove had it been unprotected. The unprotected grove is much better exposed to light breezes, has always been several degrees warmer, and has a natural air drainage

away from it and into the grove protected by the blower. However, it was the only comparison we could make. It is my opinion that the fruit loss in the unprotected grove would have been extremely low had a blower been used. The Valencias showed no frost damage, except a slight marking of the rind occasionally on exposed fruit.

Many mechanical difficulties were encountered in the blower operation. Magneto trouble and burned valves were common occurrences. The motor block on one bank of cylinders cracked during one night's operation. On another occasion the gasoline primer feed line to one motor broke, pouring gasoline into the propeller; it was fortunate that no fire resulted. Drive chains on the fans would occasionally fail.

Typical daily report sheets—December 5, 1936—"one motor stopped at 7:35 a.m.; safety plugs shorted; water low and leaking into cylinder head; magnetos dirty." December 8, 1936—"broken fan braces; tower not set at correct angle; one distributor cap loose; fan chain on #75 does not run smoothly." Remarks on the care and repair of the blower, same date—"clean magneto distributors; install one new magneto brush; fasten distributor cap." December 12, 1936—"make and install new distributor cap clamps; tighten cam shaft drive housing; clean distributor caps; repair broken temperature gauge and loose distributor cap on #74. Repair oil leak in cam shaft drive housing and broken fan bracket braces on *#75;* remove, weld, and replace fan bracket braces."

On February 8, 1937, the blower had operated a total of 157 hours. A total of *7½* hours had been spent in service and adjustments, and 43¾ hours spent in repair, a combined total of 116¼ hours, and for 9 hours the equipment had been operated while not in good condition At all times the manufacturer gave good and courteous service. Never at any time was the equipment not ready to go when called upon. A telephone call brought mechanics with all parts needed for repairs, and they were promptly installed.

At the end of the season we concluded that airplane type motors were not sufficiently rugged to stand that kind of service. In the fall of 1937 the single tower was removed and in the same grove two towers of slightly less height were installed, and double header blowers, powered by smaller V-type 8-cylinder motors, made by the manufacturer of a popular priced automobile, were installed. Since these motors are of a much higher speed than required by the propeller, reduction in speed is accomplished by the use of a transmission, driving the propeller in second gear. No figures are available on the efficiency of this equipment since its use was not required during the winter of 1937-1938.

Electric power would be an ideal kind of power for this work. There are some serious drawbacks, primarily the fact that no power company is prepared to bring into a citrus district sufficient power to operate blowers in that district if many growers install them. Economically, the grower cannot afford to pay the "standby" charge plus the cost of power consumed, especially in those years when his equipment would not be used. Occasionally, a grower has a well and pump of sufficient size located in a place suitable for a blower. By having both pieces of equipment operated through the same meter and on a double throw switch, so that just one piece of equipment may operate at a time, he can reduce his power bill on his combined equipment by using an electric blower.

To sum up the matter of blowers, it is my opinion that they are in an early stage of

development. Better control of the air stream is needed, also greater flexibility in the horizontal direction of the air stream. Some blower manufacturers standardize on about 8½ horse power per acre. That figure, in my judgment, should be carefully scrutinized, and possibly revised. Our records and observations indicate that blower efficiency drops very rapidly with distance. There is a big field, and a great deal of use can be made of blowers alone or in combination with orchard heaters. A number of growers have stated that if a blower will take care of their groves on the average cold night when only a raise of from two to four degrees is required and will take care of the local radiation frosts in the spring, they could pay for one in from three to five years over and above the cost of smudging. In many instances they would plan to maintain their orchard heating equipment to be used in case of the blizzard type of freeze, such as prevailed in 1913 and 1936-1937.