INFLUENCE OF EXPOSURE ON TEMPERATURE OBSERVATIONS.

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SYNOPSIS.

Although the daily temperature observations of the Weather Bureau are designed to indicate as nearly as possible the temperature of the free air surrounding the thermometers, it is not practicable to accomplish this exactly, on account of the influence of the character of the exposure of the thermometers on the readings. Both maximum and minimum temperatures are affected.

The fruit-region instrument shelter, designed to allow a freer circulation of air and lessen the disturbing effects of exposure, is described in this paper and compared with the cotton-region shelter in general use.

Data are given to show differences between current temperatures inside the fruit-region shelter and current readings of the dry bulb of the whirled psychrometer outside the shelter, at different locations and at different hours. After sundown radiation of heat from the roof and sides of the shelter reduces the temperature of the air in its interior below that of the outside air. Within certain limits, the stronger the radiation and the more quiescent the surrounding air, the greater will be the depression of the temperature inside the shelter below that outside.

Minimum temperatures recorded in different portions of the foliage of two lemon trees did not differ materially from those recorded inside a fruit-region instrument shelter, located between the two trees, all the thermometers being at the same height above the ground.

It is well known that a thermometer freely exposed to a clear sky at night will show a lower temperature than a similar thermometer located at the same height above the ground inside a standard Weather Bureau instrument shelter. The depression of the unsheltered thermometer is due principally to loss of heat by radiation to the sky, the thermometer, especially such parts as radiate heat readily, i. e., dull-surfaced metal, becoming colder than the air. Evaporation of moisture from the bulb of the exposed thermometer sometimes increases the difference between the sheltered and exposed thermometers, but as a general rule this factor is of little importance.

The difficulties in the way of obtaining accurate free-air temperatures are generally understood. It has recently been shown [1] that there may be considerable difference between extreme temperatures registered in two standard Weather Bureau shelters when one shelter is shaded from the open sky by a tree and the other stands in the open.

In making minimum temperature forecasts for a certain location it is evident that their verification will depend to a considerable extent on the exposure of the thermometer with which the temperatures are recorded. When minimum temperature forecasting was first begun by the Weather Bureau in the Rogue River Valley fruit district, orchardists were in a habit of checking up the official forecast for their district by comparing it with the temperature registered by their own thermometers, which were generally very poorly exposed, often without any shelter whatever. As a result, the forecasts were often criticised unjustly.

FRUIT-REGION SHELTER.

When special fruit-frost investigational work was begun in 1917 a new instrument shelter, patterned after the French type, was designed by Mr. B. C. Kadel, Chief of the Instrument Division, with a view to obtaining a freer circulation of the air and making it possible to obtain temperature readings that would more nearly approximate actual free-air temperatures. This shelter is shown in figure 1. The door, to face toward the north, is entirely open except for a covering of large mesh heavy wire screen. The bottom is open except for two narrow horizontal wooden strips to carry a thermograph and hygrograph. The bottom is also screened to prevent interference with the instruments. A small vertical wooden arm, attached to the front horizontal strip, carries the Townsend support and the maximum and minimum thermometers. Direct sunlight is excluded from the interior of the shelter on the back and sides by wide, overlapping boards, far enough apart to allow free movement of the air.

In order to determine how this shelter compares with the cotton region shelter of the Weather Bureau, a series of comparative maximum and minimum temperature readings were obtained at Pomona, Calif., during the winter of 1917–18. These are shown in Table 1.

The shelters were placed about 50 feet apart on level ground, in as nearly identical a position with regard to surrounding trees as possible. Both shelters were completely surrounded by orange and olive trees and were shaded from the sun during most of the day (see fig. 2).

Maximum temperatures registered in the fruit-region shelter were generally lower than those registered in the cotton-region shelter, especially on warm days. This would appear to be a result of better ventilation in the fruit-region shelter. There was very little difference between the daily minimum temperatures registered in the two shelters, especially on clear nights.

During the spring frost seasons of 1919 and 1920 a cotton region and a fruit region shelter were placed side by side in an open, unshaded space over grass-covered ground in the city of Medford, Oreg. Minimum temperatures registered in these shelters on clear nights are shown in Table 2. Differences never amounted to more than 0.9° F.

From an examination of Tables 1 and 2 it appears that for registering minimum temperatures the new type of shelter is only a slight improvement over the regular cotton-belt type in general use at cooperative stations.

COMPARISONS OF TEMPERATURES INSIDE AND OUTSIDE INSTRUMENT SHELTER.

During the progress of the fruit-frost investigational work at Pomona, Calif., and Medford, Oreg., a great many simultaneous readings of the minimum thermometer inside the shelter and the whirled sling psychrometer outside the shelter were made, mostly during the night. The fruit-region shelter was used in every case.

The Medford observations are shown in Table 3 and those taken at Pomona in Table 4. The earlier afternoon observations at Medford were made before the sun had set. At Pomona observations were never begun until after sunset.

As a general rule, the shelter temperature was somewhat higher, or nearly the same as the outside air temperature before sunset, and considerably lower than the outside temperature after 8 or 9 p. m. Differences between the shelter and outside temperatures were usually near the maximum at the time the minimum temperature was registered inside the shelter. Differences were greatest when the sky was clear, although high cirro-stratus clouds failed to affect the readings either inside or outside the shelter. These statements

[1] Flora, S. D.: Shading Instrument Shelters. MONTHLY WEATHER REVIEW, May, 1920, 48: 271-272.

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FIG. 1.—Fruit region instrument shelter in a pear orchard near Medford, Oreg.

FIG. 2.—Cotton region (on left) and fruit region (right) instrument shelters used in making comparative readings of maximum and minimum temperature.

would not be true if a stationary thermometer exposed in the open was substituted for the whirled dry bulb, for, as explained in the first paragraph of the article, the thermometer so exposed will usually be colder than the air at night.

With a rising temperature the natural lag of the alcohol minimum thermometer behind the dry bulb mercurial thermometer of the psychrometer would tend to cause the shelter temperature to appear lower than it actually was, but with a falling temperature, as was the case when most of the readings in Tables 3 and 4 were taken, the lag of the minimum thermometer would serve to lessen the difference between the temperature inside and outside the shelter.

Radiation of heat from the roof and sides of the shelter reduces the temperature of the air in its interior considerably below the temperature of the outside air, even when the bottom is practically open. Within certain limits, the stronger the radiation and the more quiescent the surrounding air, the greater the depression of the temperature inside the shelter below that outside. A current of air sufficient to cause a steady movement of air through the shelter may cause the minimum temperature to read one or two degrees higher than it would if the air were still. This being the case, it is rather surprising that minimum temperature fore-

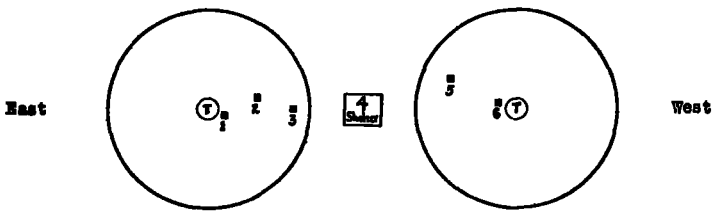

FIG. 3.—Relative positions of two lemon trees and fruit region instrument shelter. Locations of minimum thermometer stations in foliage of trees shown by numbered black square. T=trunks of trees.

casts are accurate within one degree as often as they are.

To produce a flow of air through the shelter sufficient to bring the inside and outside temperatures into agreement, a sustained wind velocity of several miles per hour is required. Sudden temporary rises in temperature during the night of 3° F. or less, caused by a slight wind, are often not recorded either by the thermograph or the minimum thermometer in the shelter; both these instruments may show a stationary temperature at such a time. The observations between 10:08 p. m. and 11:39 p. m. on December 23, shown in Table 4, will serve to illustrate this.

TREE AND INSTRUMENT SHELTER TEMPERATURES COMPARED.

During the winter of 1917-18 minimum temperature readings were obtained in various portions of two heavily foliaged lemon trees and in a fruit region instrument shelter set between these trees, in order to determine how accurately the minimum temperature in the shelter represented the minimum inside the foliage. This experiment was initiated by Mr. William. G. Reed. Figure 3 shows the relative positions of the instruments in the trees and the instrument shelter. Minimum temperature observations from each station are given in Table 5.

To carry the minimum thermometers in the trees, Townsend supports were attached to small vertical boards fastened to the top of iron rods which were driven into the soft ground under the trees. Small horizontal boards partially sheltered the thermometers above, although the heavy foliage effectively screened them from the sky. The instrument shelter, set exactly between the two trees, was cut off from about a third of the sky, but as the trees were only about 12 feet high the roof was sheltered but little.

The extreme difference in average minimum temperature was 1° between stations 2 and 6. Contrary to expectation, the lowest average minimum was not found in the shelter, but at station 2. The temperature inside the shelter was undoubtedly depressed below the temperature of the outside air through radiation, but the dark leaves of the trees probably radiated sufficient heat to cool the air in the interior of the foliage to about the same extent.

The distribution of the average minimum temperatures at the different stations is probably due to the effect of the early morning sun. The eastern half of the tree receives the benefit of the sunlight first, and it is probable the small amount of radiant heat received while the sun is near the horizon is sufficient to prevent a further fall in temperature there, while the temperature in the portion of the tree facing toward the west may continue to fall for some little time afterwards.

CONCLUSION.

In view of the results described above, thermometers which are exposed in the open evidently will give better indications of actual air temperature if they are fastened to the trunk of a fruit tree within the foliage.

For verifying minimum temperature forecasts for a number of stations in the same section it is necessary to have as nearly uniform exposure for the minimum thermometers as possible at all stations.

For registering maximum temperatures the fruit-region instrument shelter probably is superior to the cotton-belt type, owing to better ventilation, but for registering minimum temperatures the new shelter does not appear to be much of an improvement.

Temperatures inside the fruit-region shelter are the same as, or higher than, the outside air temperature before sunset and lower than outside temperatures during the latter part of the night. At the time of the occurrence of the minimum temperature the depression of the shelter temperature is generally near the maximum for the night. The influence of exposure on minimum temperatures at least partially accounts for the lack of constancy in the difference between minimum temperatures at near-by stations on level ground.

TABLE 1.—*Daily maximum and minimum temperatures in cotton region and fruit region instrument shelters at Pomona, Calif.*

Date.	Maximum.		Departure.	Minimum.		Departure.
	Cotton region.	Fruit region.		Cotton region.	Fruit region.	
1918.	°F.	°F.	°F.	°F.	°F.	°F.
Jan. 3	72.3	70.3	−2.0	38.0	38.0	0.0
6	76.2	74.2	−2.0	[1]31.0	[1]31.0	0.0
7	70.2	69.0	−1.2	44.8	44.1	−0.7
8	62.9	62.8	−0.1	47.1	48.0	−0.9
9	61.9	60.9	−1.0	41.0	41.1	−0.1
10	65.3	65.3	0.0	[1]30.0	[1]30.0	0.0
12	63.7	63.3	−0.4	[1]28.1	[1]28.1	0.0
13	60.7	61.0	−0.3	37.8	37.9	−0.1
14	62.1	63.0	−0.9	33.0	33.0	0.0
15	59.8	59.7	−0.1	37.8	37.9	−0.1
Feb. 7	68.7	68.6	−0.1	48.2	48.1	−0.1
8	65.9	65.0	−0.9	[1]33.0	[1]33.0	0.0
9	78.4	77.2	−1.2	[1]29.9	[1]29.4	−0.5
18	58.3	58.1	−0.2	39.5	39.6	−0.1
20	58.7	57.2	−0.5	42.8	42.0	−0.8
21	64.1	65.0	−0.9	46.0	46.0	0.0
22	62.7	63.6	−0.9	50.0	50.0	0.0
23	68.0	67.9	−0.1	45.4	45.4	0.0

[1] Clear nights.

TABLE 2.—*Minimum temperatures on clear nights in cotton region and fruit region instrument shelters at Medford, Oreg.*

Date.	Cotton region.	Fruit region.	Departure.
1919.	°F.	°F.	°F.
April 7	28.4	29.0	+0.6
8	27.4	28.0	+0.6
11	28.0	28.9	+0.9
12	31.7	32.1	+0.4
14	26.6	27.0	+0.4
20	30.8	31.1	+0.3
26	31.9	32.1	+0.2
May 4	32.9	33.1	+0.2
5	32.0	32.7	+0.7
10	32.5	33.2	+0.7
13	33.0	33.6	+0.6
1920.			
April 11	31.8	31.8	0.0
14	34.9	34.9	0.0
16	35.0	35.0	0.0
17	33.6	33.7	+0.1
18	27.0	26.9	−0.1
20	32.0	32.0	0.0
22	28.4	28.1	−0.3
23	26.0	26.1	+0.1
24	29.5	30.0	+0.5
25	31.6	32.0	+0.4
29	34.0	34.0	0.0
May 2	32.5	32.8	+0.3
3	31.0	31.4	+0.4
4	31.1	31.4	+0.3

TABLE 3.—*Simultaneous current-temperature observations inside and outside fruit region instrument shelter at Medford, Oreg.*

Date and time.	Shelter temperature.	Air temperature.	Departure.	Clouds. Amount.	Clouds. Kind.	Dew-point.
1919.	° F.	° F.	° F.	0–10.		
Apr. 6–7:						
3:43 p. m.	56.0	56.0	0.0	6	Cu.	32
4:48 p. m.	52.2	52.1	−0.1	6	Cu.	32
6:46 p. m.	47.7	48.5	+0.8	6	Cu.	35
7:20 p. m.	46.4	46.7	+0.3	7	Cu.	32
8:25 p. m.	42.8	44.1	+1.3	4	Cu.	33
8:58 p. m.	42.1	43.0	+0.9	3	Cu.	33
9:28 p. m.	41.0	42.1	+1.1	1	St. Cu.	33
9:59 p. m.	40.0	40.0	0.0	Few.	Cu.	33
12:42 a. m.	33.9	35.3	+1.4	0	0.	31
5:55 a. m.	32.9	33.3	+0.4	5	St.	31
Apr. 7–8:						
4:51 p. m.	57.2	57.3	+0.1	8	Ci. St.	31
5:33 p. m.	54.1	54.2	+0.1	2	Cu.	30
7:25 p. m.	46.6	46.6	0.0	0	0.	30
12:05 a. m.	34.9	35.8	+0.9	0	0.	29
12:31 a. m.	34.0	35.0	+1.0	0	0.	29
12:59 a. m.	33.2	34.1	+0.9	0	0.	29
1:30 a. m.	32.5	33.8	+1.3	0	0.	29
2:02 a. m.	32.1	33.0	+0.9	0	0.	31
5:57 a. m.	28.2	29.7	+1.5	3	St.	27
Apr. 10–11:						
4:45 p. m.	57.5	57.9	+0.4	6	Cu.	32
5:50 p. m.	55.0	54.7	−0.3	5	Cu.	28
6:40 p. m.	52.2	52.0	−0.2	4	Cu.	27
7:38 p. m.	47.4	47.5	+0.1	3	Cu.	27
8:01 p. m.	45.9	46.0	+0.1	3	Cu.	27
11:30 p. m.	36.4	38.0	+1.6	3	Ci. St.	28
12:29 a. m.	34.8	35.4	+0.6	2	Ci. St.	28
1:04 a. m.	33.9	34.7	+0.8	Few.	Ci. St.	28
6:29 a. m.	29.9	32.0	+2.1	0	0.	30
Apr. 11–12:						
4:44 p. m.	63.0	62.2	−0.8	10	Ci. St.	31
5:47 p. m.	61.1	61.0	−0.1	3	Ci. St.	27
7:06 p. m.	53.0	52.0	−1.0	3	Ci. St.	35
7:38 p. m.	49.1	49.8	+0.7	3	Ci. St.	35
8:08 p. m.	48.0	48.9	+0.9	4	Ci. St.	34
8:50 p. m.	46.0	47.2	+1.2	5	Ci. St.	34
2:07 a. m.	37.0	38.0	+1.0	6	Ci. St.	32
2:58 a. m.	35.0	35.8	+0.8	1	Ci. St.	31
3:30 a. m.	34.0	35.8	+1.8	0	0.	31
Apr. 19–20:						
3:43 p. m.	53.8	54.2	+0.4	9	St. Cu.	40
4:47 p. m.	54.1	54.0	−0.1	9	St. Cu.	39
5:51 p. m.	52.6	53.0	+0.4	6	St. Cu.	39
7:23 p. m.	49.9	50.2	+0.3	3	St. Cu.	40
8:34 p. m.	45.0	45.4	+0.4	1	Cu.	41
9:00 p. m.	44.1	45.0	+0.9	Few.	St. Cu.	39
9:28 p. m.	42.8	44.1	+1.3	Few.	St. Cu.	39
9:59 p. m.	41.3	42.2	+0.9	Few.	St. Cu.	38
10:27 p. m.	41.6	43.0	+1.4	0	0.	38
11:03 p. m.	40.2	41.2	+1.0	0	0.	38
3:31 a. m.	33.7	34.3	+0.6	0	0.	32
5:44 a. m.	31.1	32.5	+1.4	3	St. Cu.	32
May 4–5:						
3:38 p. m.	78.0	74.8	−3.2	0	0.	37
4:38 p. m.	75.9	75.8	−0.1	0	0.	37
5:29 p. m.	73.8	73.0	−0.8	0	0.	31
6:32 p. m.	67.6	67.0	−0.6	0	0.	31
8:31 p. m.	56.0	55.4	−0.6	0	0.	31
8:57 p. m.	53.0	53.0	0.0	0	0.	32
2:43 a. m.	36.8	38.3	+1.5	0	0.	28
6:45 a. m.	41.0	42.2	+1.2	0	0.	32

Shelter temperature is current reading of minimum thermometer inside instrument shelter. Air temperature is reading of dry-bulb thermometer of sling psychrometer after whirling.

TABLE 4.—*Simultaneous current-temperature observations inside and outside fruit region instrument shelter at Pomona, Calif.*

Date and time.	Shelter temperature.	Air temperature.	Departure.	Clouds. Amount.	Clouds. Kind.	Dew point.
1918.	° F.	° F.	° F.	0–10.		
Dec. 23–24:						
7:10 p. m.	35.0	36.0	+1.0	0	0	34
7:40 p. m.	35.0	35.6	+0.6	0	0	34
8:12 p. m.	33.4	34.3	+0.9	0	0	32
8:41 p. m.	32.2	32.7	+0.5	0	0	31
9:07 p. m.	31.4	32.2	+0.8	0	0	31
9:39 p. m.	31.9	32.5	+0.6	0	0	31
10:08 p. m.	30.2	30.6	+0.4	0	0	29
10:38 p. m.	31.9	35.0	+3.1	0	0	32
11:07 p. m.	30.9	30.9	0.0	0	0	29
11:39 p. m.	30.1	30.8	+0.7	0	0	29
12:07 a. m.	30.0	30.2	+0.2	0	0	30
12:42 a. m.	29.7	30.0	+0.3	1	A. St.	30
1:10 a. m.	29.1	30.1	+1.0	1	A. St.	30
1:37 a. m.	28.8	29.2	+0.4	0	0	29
2:10 a. m.	29.3	31.9	+2.6	0	0	29
2:37 a. m.	29.1	30.0	+0.9	0	0	27
3:06 a. m.	28.7	29.8	+1.1	0	0	27
3:35 a. m.	28.6	29.7	+1.1	0	0	27
4:06 a. m.	27.5	28.5	+1.0	0	0	27
4:35 a. m.	26.7	27.9	+1.2	0	0	26
5:05 a. m.	26.8	27.2	+0.4	0	0	26
5:37 a. m.	26.0	26.8	+0.8	0	0	25
6:07 a. m.	25.9	26.7	+0.8	0	0	25
6:38 a. m.	25.8	27.1	+1.3	0	0	24
7:06 a. m.	25.4	26.6	+1.2	0	0	25
1919.						
Nov. 27–28:						
6:43 p. m.	37.5	37.6	+0.1	5	St.	24
7:36 p. m.	35.0	35.4	+0.4	0	0	25
8:27 p. m.	35.4	37.1	+1.7	0	0	23
8:57 p. m.	33.4	33.7	+0.3	0	0	25
9:27 p. m.	31.8	31.7	−0.1	0	0	26
10:26 p. m.	29.5	31.0	+1.5	0	0	26
11:27 p. m.	29.9	31.0	+1.1	0	0	23
4:43 a. m.	26.2	27.6	+1.4	0	0	25
Dec. 13–14:						
6:30 p. m.	40.1	42.1	+2.0	0	0	30
6:56 p. m.	39.7	40.7	+1.0	1	Cl.	29
7:27 p. m.	39.0	41.0	+2.0	0	0	24
7:57 p. m.	37.9	38.8	+0.9	0	0	27
8:27 p. m.	35.4	36.2	+0.8	0	0	28
8:58 p. m.	34.2	35.6	+1.4	0	0	29
1:27 a. m.	32.8	34.1	+1.3	1	Cl.	20
1:54 a. m.	32.1	33.6	+1.5	2	Cl. St.	21
4:26 a. m.	32.3	34.1	+1.8	9	Cl. St.	20

Shelter temperature is current reading of minimum thermometer inside instrument shelter. Air temperature is reading of dry-bulb thermometer of sling psychrometer after whirling.

TABLE 5.—*Minimum temperatures in various locations in lemon trees and in fruit-region shelter.*

Date.	Station numbers.[1] 1	2	3	4	5	6
1917.	°F.	°F.	°F.	°F (shelter.)	°F.	°F.
Dec. 18	37.0	36.9	37.0	37.0	37.0	37.0
19	38.5	38.0	38.1	38.1	38.5	38.9
20	34.5	34.0	34.2	34.2	34.6	35.0
21	36.9	36.6	36.9	36.9	37.0	37.8
22	32.5	32.0	32.6	32.6	32.8	33.0
23	37.9	37.5	38.0	37.9	38.0	38.0
24	42.9	42.2	42.9	42.5	42.9	43.5
25	36.0	35.2	35.6	35.4	35.9	36.0
26	34.9	34.0	34.1	34.8	34.5	35.1
27	33.9	33.1	33.6	34.0	34.0	33.9
28	37.6	37.0	37.1	37.1	37.8	38.0
29	35.0	35.5	35.5	35.5	35.9	36.0
30	37.0	36.8	37.2	37.0	37.5	38.9
31	34.9	34.3	34.9	33.8	35.0	35.0
1918.						
Jan. 1	34.0	33.8	34.0	34.5	34.1	35.0
2	31.0	30.3	30.8	31.0	31.2	31.9
Average	35.9	35.4	35.8	35.8	36.0	36.4

[1] *See* fig. 3.

DIFFERENCES BETWEEN THE READINGS OF SHELTERED AND UNSHELTERED THERMOMETERS IN FIELD WORK.

By H. J. Cox.

[Presented before the American Meteorological Society at Chicago, Dec. 29, 1920.]

(Author's abstract.)

The subject of the exposure of thermometers in the field should always be given careful consideration, and