PROTECTING THE CALIFORNIA ORANGE CROP FROM FROST.

By A. G. McADIE.

The following table from the California Fruit Grower, December 30, 1911 (annual review number), shows the shipments of citrus fruit from California for the past 17 years:

Season.	Carload.	Season.	Carload.	Season.	Carload.
1894-95	7,575	1900-1901	24,900	1906-7	29,820
1895-96	6,915	1901-2	19,180	1907-8	32,729
1896-97	7,350	1902-3	23,875	1908-9	40,516
1897-98	15,400	1903-4	29,399	1909-10	33,099
1898-99	10,875	1904-5	31,422	1910-11	46,394
1899-1900	18,400	1905-6	27,610		

The orange is commercially grown in different parts of the United States, the best known districts being Florida, a narrow strip of the central Gulf coast, and in California. The extent of the industry in the last-named State is shown by the above table. Unlike the other sections, latitude in California does not control thermal conditions, and oranges mature in the northern foothills of that State in latitude nearly that of New Jersey or Pennsylvania, and are ready for shipment by the end of November, while farther south in the great citrus belt of California, i. e., the San Gabriel Valley, only slightly farther north than Florida and Louisiana, the fruit is not thoroughly ripe until January. Oranges are grown commercially in the following counties of California, going from north to south: Tehama, latitude 40° N., Glenn, Butte, Yuba, Sutter, Placer, Yolo, Sacramento, Napa, Sonoma, Merced, Fresno, Tulare, Kern, Ventura, Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Imperial. The two latter counties are in latitude 33° N.

As shown by the above table, the crop, including lemons, of the whole State last season exceeded 45,000 carloads. Estimates for the crop of 1911-12 range from 45,000 to 55,000 carloads. Of this, 70 per cent is grown in southern California. These estimates, however, were made previous to the cold weather during the last week of the year. Estimates of the damage done by the frosts of December 26 and 27, 1911, vary from 2 per cent to 20 per cent. It is difficult to properly estimate frost loss, inasmuch as the injury is in a way progressive. As has been pointed out in various papers upon frost fighting, the injury depends in large measure upon the thawing out and exposure of the fruit subsequent to the freezing of the water in the cells.

Frost fighting in its present form may be said to have originated in the orange belts of southern California beginning with the experiments of the Riverside Horticultural Club in cooperation with the Weather Bureau in 1895. It is therefore a matter of considerable interest to review the conditions prevailing during the frost period of December, 1911, and compare the results with those of previous years.

The chief seat of the orange industry on the Pacific coast is in the San Gabriel Valley, the coast line running from Point Conception, on the west, to San Diego Harbor, extreme east. The San Gabriel Valley, sometimes known as the Great Valley of Southern California, runs practically east and west a distance of about 60 miles, from Pasadena to Redlands. It is bounded on the north by the San Gabriel Mountains, with an eastern extension known as the San Bernardino Range. The land is gently rolling for the most part and particularly well suited for citrus fruit growing. There is now invested in this district approximately $200,000,000, and there is every likelihood that the industry will continue to develop and that in a few years the output of citrus fruit from this section will be doubled. In the Monthly Weather Review for December, 1910, the writer gave a detailed description of the valley and the general air circulation. A short extract covering the general conditions may be of interest here:

> The topography favors a drainage of the air from the mountains seaward at certain hours and a return flood, or movement of the surface air from the sea inland at certain other hours. In other words, the conditions are extremely favorable for the development of air streams which reverse their direction at least twice in each 24-hour period.
>
> In general the lower air flows to the southwest during the night and early morning hours and to the northeast during the afternoon hours. During the winter months when areas of high pressure pass over the Great Basin, the surface air apparently moves south, crossing the northern flank of the Sierra Madre and descending with some momentum into the Great Valley. The wind movement is particularly marked in the vicinity of the mountain passes, a good illustration being near Cajon Pass, 3,823 feet. During these so-called "northers," also locally known as Santa Anas, the temperature rises and the humidity falls. The existence of a low pressure area south of the Valley of the Colorado seems to intensify the condition. Heavy frosts occur as a rule after a period of boisterous north wind; and they are undoubtedly traceable to the displacement of the warm air of the valley by air that is not quite so warm, but remarkably dry and comparatively free from dust. During the stillness of the morning hours and before the return flow of air from the sea can be effective, the soil, which in places consists principally of river wash, coarse sand, and gravel, or else a light sandy loam, loses heat rapidly by radiation through the dust-free dry air; and it is not unusual on January mornings to have temperatures of about 26° F. in the orange orchards. At many points, especially in the lower lands, care must be taken to protect oranges and lemons from both the fall in temperature during the night and the rather rapid rise which occurs about 7.30 o'clock in the morning.

Most of the orchards have an unobstructed exposure to the east and south.

A study of the thermograph records shows that the temperature rises rapidly after sunrise. It is not unusual to have a rise of 14° or more in two hours. Even these figures do not adequately tell of the change to which the orange is exposed, as it is probable that the temperature on that portion of the skin of the orange exposed to the sun's heat is much higher than the temperature indicated by a thermometer in the air. That portion of the orange which is in shade probably has a temperature somewhat below that of the air.

The hygrograph records show that the relative humidity continues to increase after sunset and begins to diminish rapidly after sunrise. It must, however, be admitted that our hygrographs in their present form are of doubtful service, as they tell nothing of the actual amount of water vapor present.

Regarding the valley as a whole, the following general data were obtained:

Minimum temperatures.

Place.	December, 1911.		January, 1910.	December, 1909.
	26th.	27th.	6th.	19th.
	°	°	°	°
Azusa	32	28	27	27
Beaumont	26	35	24	31
Chino	23	27	30	33
Claremont	27	27	28	30
Colton	22	32	30	30
Duarte	27	32	28	40
Escondido	17	20	26	23
El Cajon	25	25	26	27
Elsinore	17	20	20	24
Los Angeles	39	42	37	39
Monrovia	28	32	.....	.....
Orange	26	28	.....	.....
Pasadena	29	30	28	30
Redlands	24	31	25	27
Riverside	21	24	27	26
San Bernardino	19	22	23	23
San Diego	36	38	34	36

For purposes of comparison the minimum temperatures of the last severe frost periods are also given. Data for Lakeside and San Diego are included, although not in the valley. The records at Los Angeles and San Diego are made at the top of tall city buildings and therefore do not truly represent conditions in the orchards. The readings are probably 10° higher than if made in the fields.

It is evident that temperatures were fully as low as during the frost period of December 19, 1909. The damage, however, was much less.

In the following extracts of letters received at this office, unequivocal evidence of the value of the protective devices may be found. It should be explained that the Limoneira Ranch is located on the northern side of the range and that the general air drainage is different from that of the San Gabriel Valley. A report from the official in charge of the local office of the Weather Bureau at Fresno is also given; but a detailed discussion of the conditions in the Porterville section and also in the northern citrus fruit belt must be omitted.

Mr. Edwin R. Sorver, special meteorological observer, Pasadena, Cal., states:

There was very little damage done in the vicinity of Pasadena, except to flowers and tender plants, by the frost. The new growth of citrus trees was nipped in quite a few instances and in some places ice formed one-half inch thick; but on the whole the damage done, especially to the citrus fruit, was a very, very small per cent.

Mr. A. F. Call, Corona, Cal., states:

The frost warning sent me about 4 p. m. December 25 enabled me to get ready in some orchards not then prepared and enabled me to save crops worth at least $10,000. Where smudging was properly done it was a complete success; but poor work or inefficient preparation has led many to believe it does no good.

I find a great difference in readings, which I think is largely due to the locations of the thermometers, difference in height from the ground, or to slight elevations or depressions from normal contours, or some protection from buildings or trees.

The mornings of the 24th and 25th were not cold here; about 32° in exposed places. All day of the 25th it stood about 50°. By 10.30 p. m. the temperature dropped to 28° and at 1 a. m. of the 26th it had dropped to 22° and by 4 a. m. to 20°, remaining at that until 7 a. m. The temperature was almost uniform over the slope, the 1,000-foot level showing as cold as the 600-foot level.

The cold wave came in from the southeast, down the Temescal Canyon, and moved westward across the mesa at the rate of a mile an hour. Smudging was only done by a few large growers, covering about 200 acres and when thorough work was done was very effective, saving practically all the young lemons.

The smoke from smudged orchards saved a great area of oranges in the neighborhood of each orchard smudged, but was not sufficient to protect lemons to any great extent except in the immediate vicinity of the fires.

A thermometer on the ground read 5° to 6° colder than one 2 feet above the ground.

The only effective smudging here was in the use of slop distillate in 2-gallon pots, set one to the tree, lighting the first half early and the second half toward morning. It is better and much safer to have double the number in alternate rows, so that one to the tree can be used in the morning.

With 80 pots to the acre, burning free—i. e., without soot collectors or covers—the temperature can be raised on a still night 8° or 9° in an orchard of large trees.

Mr. W. E. Bonnett, local forecaster, Fresno, states:

Although temperature conditions in the floor of the San Joaquin Valley were extreme during December, there has been no great damage in the foothill section. At Fresno oranges and lemons were repeatedly frozen on the trees beginning with December 18; but these fruits are not commercially grown and the monetary loss is small. These trees are now turning quite brown and many of the leaves will drop off. This cold period was the most prolonged and most severe since December, 1897.

Mr. C. C. Teague, manager of the Limoneira Co., states:

On the night of December 24 the temperature on our ranch dropped as low as 23°. We immediately fired all of our oil pots and raised the temperature to 34° * * *. Our experience during the last cold spell convinced us more than ever of the necessity and efficiency of adequate frost protection equipment. The cold portions of our property are equipped with 112 coal baskets and 56 2-gallon Bolton heaters to the acre. We have come to believe that it is very important that one begin firing early in the night before the heat held by the ground and trees has been entirely lost; and our practice has been to begin firing at the first indication of ice on the trees in the most exposed portions of the grove. We feel convinced that we can handle successfully a temperature of 20° or lower for many hours.

It is our belief that if the orange districts where the damage was so great had been as thoroughly equipped as we are and had this equipment been intelligently handled there would have been practically no damage.

Other portions of Mr. Teague's letter, are covered in the report of Mr. Clarence H. Matson, in the following extract from the Pacific Rural Press of January 13:

EXTRACT FROM THE PACIFIC RURAL PRESS, JANUARY 13.

By CLARENCE H. MATSON.

Although the temperature fell dangerously near to the 20° point, C. C. Teague, manager of the great Limoneria Ranch, near Santa Paula, absolutely saved his lemon orchards from damage by frost all through the recent cold spell. Mr. Teague says that not only the fruit, but also the young, tender growth on the trees, show no effects of the frost. Mr. Teague is among the most successful lemon growers in California. He makes a specialty of this branch of the citrus industry and has probably made a more thorough study of lemon growing in all its phases than any other man in the world. His opinions are usually the last word on lemons. In the cold spell, which included holiday week, he proved beyond a doubt the advantages of smudging as a means of frost prevention. He smudged the 225 acres of lemons on the Limoneria Ranch 12 nights out of 14, bringing the fruit through without damage, while groves that were not smudged were badly frosted.

On 200 acres of these groves which are the more liable to frost Mr. Teague had 112 ordinary wire coal baskets and 56 2-gallon distillate burners to each acre. The remaining 25 acres were higher, and on them he used less equipment. The coal baskets are part of old equipment for frost protection, but the distillate burners are comparatively new. They proved very effective, however, and Mr. Teague thinks that if the burners were used exclusively, 100 to an acre would be sufficient, or approximately one to every tree.

On the coldest night of the cold spell the temperature got down to 23° before the smudges were started, yet the burners immediately raised it above freezing point, and it was maintained there. This made a rise of about 11°, as thermometers in the surrounding region kept falling, indicating that the higher temperature in the Limoneria groves was due to the smudging. In some places the mercury went down to 19°.

In the 12 nights that the smudge pots were kept burning nearly 21,000 coal-basket lightings were made, and 50,500 oil-burner lightings at a total cost for fuel and labor amounting to $4,700. This was about $1.75 per acre for each night, or less than 2 cents per tree.

The fuel used in the oil burners was slop distillate of from 23 to 28 gravity, and costing from 85 cents to $1 a barrel. An oil pot will burn about nine hours.

In order to be ready to smudge on short notice, Mr. Teague has a cement reservoir for distillate, holding 100,000 gallons. The oil is pumped into tank wagons with a small centrifugal pump capable of filling a wagon in three minutes. The wagons hold 430 gallons each.

There are no hard and fast rules by which a grower can be guided as to when smudging is necessary, Mr. Teague says, as conditions of moisture and air currents have much to do with it. Sometimes ice will begin to form on the fruit when the temperature is only down to 30°, while at other times the mercury will fall to 26° before causing ice. Mr. Teague's instructions to his men are to watch the lowest place in the groves, and as soon as ice begins to appear on the trees, to start the smudge pots.

It is much better to start them before the temperature gets low, rather than to wait until the freeze begins and then thaw the fruit. Not only is more heat necessary to raise the temperature after it once goes down