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A STUDY OF THE EFFECTS OF FREEZES ON CITRUS IN CALIFORNIA

BY
H. J. WEBBER AND OTHERS

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A STUDY OF THE EFFECTS OF FREEZES ON CITRUS IN CALIFORNIA*

By H. J. WEBBER AND OTHERS

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* Paper No. 55, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, Cal.

INTRODUCTION

The recent injury to the citrus industry caused by the severe cold weather of the first week in January, 1919, has again emphasized the importance of having available for the use of growers data on the effects of such freezes as a guide in handling injured fruit and trees. Following the great freeze of January 5 to 7, 1913, a frost damage survey was organized by the College of Agriculture under the direction of the Citrus Experiment Station and much valuable material was collected. This information has been summarized and is published in this bulletin with the belief that it will be of service to growers in handling the problems connected with this winter's freeze.

Much of the data presented and the methods suggested are applicable to any freeze, but some of the matter presented has historical value only. The section on "Protection by Artificial Heating" will be recognized as not being up to date. Even this section of the bulletin, however, is believed to be of value, as it is a record of achievement in the "big freezes" with what would now be considered very inferior equipment. If growers succeeded so well with inferior equipment it would seem certain that a grove, with modern equipment, could be perfectly protected in another freeze of equal severity. To delay the publication until such sections could be brought thoroughly up to date would make its publication too late to be of any serivce in the present freeze.

This bulletin, then, is really a record of the freeze of 1913. While there had been freezes in preceding years, in which citrus fruits and various subtropical plants were somewhat injured, nothing so severe and disastrous as this freeze had occurred in the state since the citrus industry was started.

Aside from the general field studies and observations, special studies were made on the chemical and physical changes that took place in the deterioration of frozen fruits. It is the purpose of this bulletin to discuss such of the studies as it is thought will be of interest and value to growers, in case of future freezes. No attempt will be made to compare the relative degree of damage done to groves in various sections, as it is thought that the conditions shown in this freeze might be reversed or much changed in another freeze, and such comparisons might thus be misleading.

Messrs. A. D. Shamel, L. B. Scott, and C. S. Pomeroy, of the U. S. Department of Agriculture, coöperated with the Experiment Station in making certain observations on the effectiveness of artificial heating, and their findings are reported in a special article in this bulletin.

Many growers in various parts of the state, too numerous to mention individually, have also greatly assisted our investigators and have given freely of their time and experience. To these and to all who have aided in the preparation of this report I wish to express the thanks of the institution.

H. J. WEBBER,
Director, Citrus Experiment Station.

Fig. 1.—Badly frozen Eureka lemon grove. Leaves still hanging but drying out. Photographed by Smith, March 7, 1913. (See same grove later in fig. 2.)

A STUDY OF THE FREEZE OF 1913 IN CALIFORNIA

By C. S. MILLIKEN, A. R. TYLOR, W. W. BONNS, and H. J. WEBBER

METHODS OF INVESTIGATION

In gathering the data for this report a large number of the citrus groves in different districts of southern California were visited.

In making the observations several trips were necessitated to various sections in order to determine the final effects of different methods of treatment. Wherever an interesting case or experiment was found, the observer continued to follow the recovery of the trees until the full effect of the treatment became apparent. One of the writers of this article made similar extended observations following the great freeze of 1894–95 in Florida* and in this article frequently a comparison of the conditions and methods of treatment has been made.

The conclusions which have been drawn are based upon numerous observations, and these have been made in a number of different districts by many different observers. While it is possible to find exceptions to most rules, the value of the rules is not destroyed by the exceptions, and so in this summary of the effects of the freeze, an attempt has been made to state those things which as a rule were found to prevail, believing that the clearest record of conditions can be given in this way.

GENERAL AND METEOROLOGICAL OBSERVATIONS

The freeze began Sunday, January 5, 1913. Unlike visitations from frost in previous years, the Sunday cold was accompanied by a strong wind. Somewhat different conditions prevailed in different places. The following are the conditions as noted at the Citrus Experiment Station. Sunday, January 5, was a cold day throughout. Ice three-sixteenths of an inch thick was observed in the street about noon, toward evening the wind went down, and between 7 P.M. and 11:30 P.M., the coldest period, there was scarcely any movement of air. The temperature during this period, at a point about 300 feet to the east of the grove, remained between 15° and 18° F. (Compare Chart I).

* Webber, H. J., The Two Freezes of 1894–95 in Florida, and What They Teach, Yearbook, U. S. Dept. Agr., 1895, pp. 159–174.

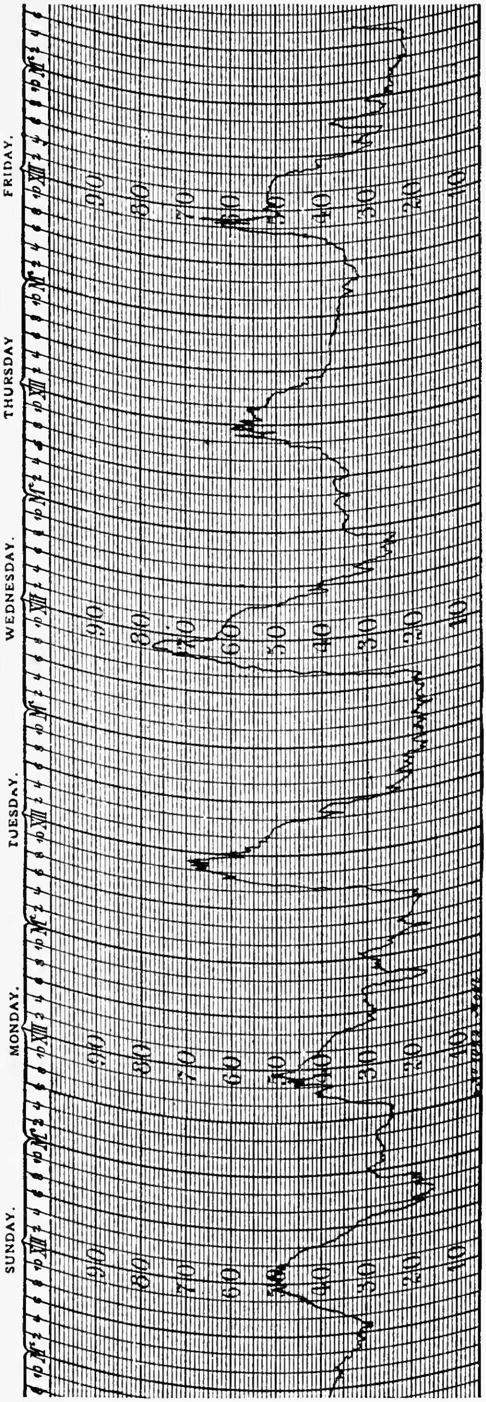

Chart I.—Thermograph record at the Citrus Experiment Station, Riverside, Cal., for the period from Sunday, January 5, 1913, to 6 A.M. Saturday, January 11, 1913.

In general throughout the citrus belt the Sunday night cold was accompanied by a strong wind that blew throughout the night. By Monday night, January 6, the wind had died down, but the cold was unabated; and on Monday night and Tuesday morning the temperature went lower than it had gone the night before. Tuesday night and Wednesday morning were also cold, sufficiently so in most of the citrus districts to freeze fruit. After this, the temperature became more moderate, although for several days the skies were cloudy and the weather stayed cool. On the 9th and 10th, there were light rains in most sections and heavier rains about the middle of the month. The month of January as a whole was the coldest January for fifteen years; while the cold spell from the 5th to the 8th was the coldest weather ever experienced by citrus growers in southern California.

Heretofore cold spells have usually occurred on still, cloudless nights. On such nights the air becomes stratified, the colder strata resting on the ground. A breeze improves the temperatures at such times by mixing the strata of warm air with those of colder air. The freeze of 1913, however, was very different from previous periods of cold. It was preceded by strong winds which came from the northwest and north. Mr. A. G. McAdie, of the United States Weather Bureau, has called attention to the fact that the winds preceding frosts in California usually come from the northeast. He points out that this year the cold wind came from the north and northwest, moving directly over the Sierra Madre Mountains, with their elevation of six thousand feet, instead of taking the customary course through the El Cajon Pass.

The temperature records reported from various places are in general so inaccurate that little dependence can be placed upon them. The Weather Bureau records are thus the best ones that can be taken for comparison. True, these records do not represent grove records, but they are at least comparative for different places. The following table supplied by Dr. Ford A. Carpenter, in charge of the Los Angeles Observatory, U. S. Department of Agriculture, Weather Bureau, gives the maximum and minimum records for the period of the freeze for various points in California.

The minimum temperatures reported from the different parts of southern California show a range from 25° F. to —2° F. The accuracy of these extremes may well be questioned. It may safely be concluded that most citrus districts reached a temperature as low as 18° F. Several places have reliable records as low as 15° F., and a few places show apparently reliable records as low as 12° F. In many sections the temperature remained at or below freezing for sixty hours.

TABLE 1.—MINIMUM AND MAXIMUM TEMPERATURES, JANUARY 5–7, 1913, IN VARIOUS PARTS OF CALIFORNIA

Stations	Minimum temperature			Maximum temperature		
	5th	6th	7th	5th	6th	7th
Azusa	25	22	20	48	49	54
Bakersfield	28	16	14	52	49	40
*Beaumont	20	16	24	25	32	38
*Chino	30	28	16	44	42	44
Claremont	27	25	19	47	42	49
*Colton	28	27	19	42	35	47
*Duarte	....	28	28	....	45	46
El Cajon	30	20	21	52	46	54
Escondido	32	15	13	56	42	45
*Exeter	17	17	19	54	52	51
Fresno	24	17	20	39	39	44
Lemon Cove	22	18	20	65	52	56
Los Angeles	36	30	28	49	47	50
Monrovia	28	24	18	50	45	50
Pasadena	31	25	21	47	43	50
Pomona	25	21	18	48	43	51
Porterville	22	20	18	41	46	48
Redlands	31	22	18	42	36	50
Riverside	30	21	22	48	41	55
San Bernardino	31	26	18	46	35	53
San Diego	36	28	25	47	45	49
Three Rivers	28	17	16	40	39	44
Ojai Valley	28	13	13	49	50	55
Santa Barbara	28	27	30	52	44	58
*Tustin (Irvine Ranch)	48	32	34	70	50	56

At stations marked (*) the minimum temperatures were taken at 7 A.M., and are probably not so low as the true minimum. The maximum records of these stations were taken at 2 P.M., and are probably lower than the true maximum.

Frosts during the winter months are not uncommon in southern California, and it often happens that a certain amount of loss of fruit results from low temperatures, especially in low places where the citrus area has been extended out beyond its adaptable sphere. Abbot Kinney in his book on Eucalyptus refers to an unprecedented frost in 1893. In 1898 in certain sections, severe damage was experienced, and again in December, 1912, a very heavy frost occurred, but the freeze of January, 1913, was probably more severe and widespread than any ever experienced here within the memory of white man.

Maximum and minimum thermometers, although of much greater value and satisfaction than the ordinary instruments, are in themselves of little real value, unless it is possible to compare these recorded temperatures with the story as pictured by thermograph records taken in the same vicinity, for the actual minimum temperature means but little in regard to the resulting effects upon plant life, unless the duration of the low temperature, as well as the actual minimum, is also known. Lemon trees subjected to a temperature of 20° to 22°, but of very short duration, were not injured; while the much more hardy orange trees, experiencing a similar low temperature that continued for nine or ten hours on three successive nights, were entirely defoliated.

Fig. 2.—Badly frozen Eureka lemon grove two months after the freeze. The same trees as those shown in fig. 1, but three months later. Photo by Smith, June 24, 1913.

The elevation of groves above sea-level does not indicate their liability to frost injury. Citrus fruits in southern California are grown at elevations ranging from sea-level to twenty-seven hundred feet or more; and while in some sections trees at sea-level suffered severely from the January freeze, and groves at 1400 and 1500 feet were unharmed, in other sections the reverse conditions occurred.

Fig. 3.—Frozen Valencia oranges showing characteristic spots on surface and the breaking down of the interior, accompanied by thickening of the skin. Photo by Smith.

THE EFFECTS OF THE FREEZE ON CITRUS TREES AND FRUITS

Effect on Citrus Trees.—One of the first noticeable effects of the cold weather upon citrus trees was the formation of ice in the fruits. The ice formed earlier in lemons than in oranges, and at the same temperature lemon fruits were frozen much firmer than oranges. At

Fig. 4.—Lemons showing characteristic external spotting of fruit and breaking down of tissues caused by freezing. Photo by Smith.

temperatures at which lemons were frozen so that they were solid, juiceless and brittle, oranges could be pressed out of their natural shape and some juice could be extracted.

Another effect of the low temperature which made a conspicuous change in the appearance of the trees was the curling of the leaves of the orange trees during the cold. This curling of the leaves, which did not occur on the lemon trees, gave to the orange trees a sort of deathly aspect. It was commonly remarked by growers that the orange trees seemed to be affected worse than the lemons, and many growers were prepared to believe that another of the unusual things so usual in California had happened and that lemon trees had been less injured than orange trees by the cold. In a few days, however, the leaves of the lemon trees began to droop and turn brown; while the orange leaves, where the temperature did not go too low, unrolled and assumed their normal functions. Due to the slow physiological changes in both fruit, foliage and wood following the freeze, it was some time before accurate indications of the extent of damage became visible.

Effect on External Appearance of Fruit.—The orange and lemon fruits, while still frozen, often showed in the skin clear, icy areas adjoining other areas which were not icy. A few days after the freeze these fruits became spotted (figs. 3 and 4), caused by a shrinking of the tissue between the oil-bearing cells and a consequent drawing together of these more deeply-colored, oily portions of the skin. Soon after the freeze lemons which were frozen very hard were covered with white watery patches, which gave them a loathsome appearance. A black mold frequently established itself on these fruits and they shriveled and dried up on the trees.

The degree to which fruit becomes spotted gives a good, early indication of the severity with which it is damaged, especially with oranges. If none of the oranges in a grove are spotted, the fruit may have been injured, but usually there still will be fruit of value in the grove. Where the freezing has been harder, spotted fruit will show on the north side of the tree, and to some extent, there will be spotting on the north side of fruit on the south side of the tree. The stem end seems to be most easily spotted. In groves where north side spotting is general, there is little fruit which will not show signs of deterioration by the time three months have passed. The fruit which is spotted is valueless, for though it may retain juice for some time, it deteriorates so rapidly that it does not pay to ship it. Where the fruit in all parts of the tree is spotted, but little value can be attached to the crop.

All citrus fruits are not subject in the same degree to this frost spotting. The tangerine apparently is not subject to it and the Valencia, while sometimes found badly marked, is much less susceptible than either the navel or the Ruby Blood. Both the pomelo and lemon are readily marked with these frost spots, the former fruit, when exposed, being especially susceptible. The frost spots of both the pomelo and lemon in time turn brown and become far more conspicuous on the yellow background of these fruits than the yellow spots of the orange on the orange-colored background of that fruit.

Effect on Internal Condition of Frozen Fruit.—One of the earliest internal indications of frost damage in citrus fruits is the formation in the membranes or pulp of small white spots or crystals of hesperidin. In oranges, lemons and grapt fruit these are found on the membranes between the segments (fig. 5). In tangerines where they are very conspicuous they are scattered throughout the pulp. These white spots

Fig. 5.—White spots, hesperidin crystals formed in the membranes of the Washington Navel orange as a result of freezing. One of the most characteristic symptoms of cold injury. Photo by Smith, February 8, 1913. (Somewhat enlarged.)

can be found in from five to ten days after the freezing and can best be seen by cutting the fruit transversely and tearing the segments apart.

When frozen oranges are cut transversely they often show a pale area part way between the center of the fruit and the skin. Frozen lemons are somewhat more opaque than uninjured fruit. In all varieties the pulp cells of frosted fruit tear apart more easily when cut across than is the case with unfrozen fruit.

When a month or so has elapsed after the freezing, the segments of fruit begin to pull apart because of the drying of the frozen tissue (figs. 3 and 4). This condition is best seen in cross-section. It shows first in fruit which was exposed to the morning sun where it may appear within ten days after the freezing. Sometimes, especially with fruit inside the tree, this breaking down may not begin for three months.

How to Determine the Extent of Fruit Injury.—It is frequently of importance soon after a freeze to be able to determine the extent of the fruit injury. The external and internal character shown by frozen fruit are given in the preceding sections.

Another method of recognizing fairly quickly the good from the frozen fruit was found in the changes in specific gravity that took place in fruits that were picked and stored. Good fruit increases in specific gravity by the drying out of the skin causing a decrease in volume without much loss of the interior juices. Frozen fruit, however, rapidly decreases in specific gravity as the interior juices pass out into the skin readily, and are evaporated without producing much change in volume.

In an investigation conducted by Professor John S. Burd and Mr. W. H. Dore of the College of Agriculture it was found that these changes could be greatly hastened by picking and storing the fruit in a warm atmosphere. The following statements prepared by them will show the possibilities of this method.

The following typical data illustrate the relative changes in specific gravity of unfrozen and frozen fruit over several time intervals when stored in a cool room. The figures in every case represent the average of a number of individuals.

FRUIT STORED IN COOL ROOM

	Initial	After 4 days	After 8 days	After 16 days		
Unfrozen oranges	0.857	0.865	0.876	0.894	Maximum 50 days	0.951
Frozen oranges	0.838	0.836	0.828	0.787	After 40 days	0.689
Unfrozen lemons	0.942	0.955	0.967	0.981	Maximum 50 days	1.023
Frozen lemons	0.806	0.747	0.615			

When sound and frozen fruit are stored in a room at a temperature of 95° F., the specific gravity changes are similar in character to those observed in the cold room fruit, but the rate of change is about three times as great in the warm room as in the cold, as shown in the following data.

Fruit Stored in Warm Room

	Initial	After 4 days	After 8 days	After 16 days
Unfrozen oranges	0.848	0.874	0.920	0.926 (Maximum)
Frozen oranges	0.842	0.842	0.816	0.729
Unfrozen lemons	0.943	0.979	1.006 (Maximum)	
Frozen lemons	0.811	0.691		

The absence of change in the first interval in the case of the frozen oranges is due to the fact that a gain in specific gravity in some individuals counterbalanced a corresponding loss in others. After the first four days nearly all individuals showed a decrease.

By picking separately a quantity of fruit from different parts of an injured grove and different parts of certain trees, and storing it in a warm dry room at a temperature of from 85° to 100° F. within six to ten days the changes have become marked and an examination will enable an accurate estimate to be made of the damage.

Effect on Quality and Uses of the Fruit.—Oranges that were frozen sometimes developed a bitter taste after the freeze. This, however, was by no means universal, and later this bitterness disappeared. Even when no bitterness was produced the flavor was affected, becoming gradually less rich. No harmful ingredients developed, however, and the oranges were very generally eaten so long as they remained juicy and palatable. So much was said immediately after the freeze regarding the possible injury to health that might result from the eating of frozen fruit that this point should be strongly emphasized. In California and Florida and indeed in practically every orange country, frozen fruits have from time to time been used in large quantities without injury. The evidence on this matter is so extensive that we may conclude, without fear of contradiction, that under all ordinary conditions frozen fruit may be eaten with the same impunity as normal, unfrozen fruit. So long as the frozen oranges remain juicy and palatable they may be considered as a wholesome article of food.

Effect on Foliage.—The fruit of citrus trees is more tender than other parts of the trees with the exception of the tender young growth (fig. 6). Next to the fruit in tenderness are the leaves and then the wood. There were areas during this freeze where all of the fruit on lemon trees was frozen and the trees still retained 50 per cent or more of their foliage. Many acres of orange groves had all of the fruit frozen without any loss of matured foliage.

Effect on Wood.—Young trees, of course, suffered more than older trees, and young parts of trees more than older parts (fig. 6). The parts of the bearing trees that had been of faster growth were injured much more readily than the parts of the trees that had attained their size more slowly. This is probably the explanation of some of the freakishness noticed in trees where one branch of the tree was killed and the rest of the tree remained undamaged.

A case illustrating this point may be cited, where a navel orange tree showed no signs of injury except on one branch, and this branch was killed. On careful inquiry, it was found that a year or two before

Fig. 6.—Valencia orange tree in foreground on which the young rapidly growing branches were all killed. The mature foliage on the older trees in the background was but slightly injured. The fruit on trees showing such injury is certain to be a total loss. Photo by Smith, January 24, 1913.

a branch on this side of the tree, which was particularly heavy with fruit, was twisted and broken during a strong wind, so that it had to be cut out, leaving a large hole in the side of the tree. A new sprout grew out near the base of the cut branch, and it was this rapidly-grown branch that was frozen.

Effect on Bark.—After the freeze, many of the trees showed a splitting and loosening of the bark. This was especially common on lemon trees, but occurred also on orange and grapefruit trees, where the temperature went sufficiently low. Sometimes the bark split even when the foliage was not damaged, and cases were reported where the bark on limbs had been split, and the fruit on these limbs had not been noticeably injured.

The loosening of the bark in most cases signified the killing of the cambium layer, but this was not always the case, because several months after the freeze, it was common to find bark, which had loosened along one edge but which had continued to live and grow, forming a new layer of wood (fig. 11). One tree was found where a strip of bark had completely separated from the tree, forming a bridge. The bark was alive and had developed a layer of wood and a new bark had formed next to the tree.

The most surprising feature in connection with the severe bark splitting on the trunks has been, in many cases, the comparatively slight injury to the tops and foliage. Often there was bark splitting when there was but little frost damage to either fruit or foliage.

Some lemon groves of large old trees were observed that showed much cracking and checking on the limbs and trunks, where similar, adjoining groves, apparently as severely injured, showed almost no checking.

While it is true that in most cases where the bark was split and loosened from the tree it was killed, it does not follow that when the bark was killed it always loosened. Instances were common where trees were girdled with frozen bark and the bark remained perfectly tight. Sometimes these girdled trees showed no foliage damage and there would be no suspicion that they had been injured until suddenly, perhaps four months after the freeze, the leaves would droop and the tree would die.

In Florida the area of bark immediately around the bud-union is very susceptible to injury by freezing, being more tender than the bark on other portions of the trunk. This greater tenderness of the bud-union was not noticeable in California, the bark on the other portions of the trunk being injured just as readily as around the bud-union. In California the point most susceptible to injury seems to be in the crotches of the limbs.

RELATIVE HARDINESS OF DIFFERENT VARIETIES AND SPECIES OF CITRUS FRUITS

Relative Hardiness of Trees.—The freeze brought out marked differences in the hardiness of the several varieties of citrus trees grown in California. It also demonstrated that the relative hardiness of the trees of a variety is not the same as the relative hardiness of the fruits of that variety, and this fact must be borne in mind in order to avoid confusion.

Orange trees, of course, proved themselves much hardier than lemon trees. It was common to see lemon trees entirely defoliated, and among them orange trees which had lost few or none of their leaves. There were other places where the lemon trees were partly defoliated and had split bark in the limbs, while the orange trees showed no damage except in the fruit, and even here the damage was so limited that the grower received good returns for his crop.

In most places there seemed little difference in hardiness between Washington navel trees and Valencias, this being especially true of the bearing trees.

In one locality, where there was not much damage to the bearing orange trees, a careful comparison was made between the condition of 250 young Valencias and the same number of navels. These trees were all of the same age, two years and a half old at the time of the freeze, and offered an opportunity for a perfectly fair comparison. Fourteen per cent of the navels and 3 per cent of the Valencias had the limbs killed; 64 per cent of the navels and 93 per cent of the Valencias were largely defoliated without having the limbs killed; 22 per cent of the navels and 4 per cent of the Valencias were only partially defoliated. In this case the navels were not less hardy than the Valencias, but the amount of variation was greater in the navels. More navels than Valencias were badly frozen, but there were also more navels than Valencias among the trees which were only slightly injured.

The conflicting degrees of injury exhibited by these varieties in different places indicate that they are naturally of about the same degree of hardiness and that the differences observed in different places were due to the varying condition of the trees at the time of the freeze.

There was a marked difference in the hardiness of the two principal varieties of lemons, the Lisbons showing themselves decidedly more resistant than the Eurekas. Temperatures low enough to cause Eureka trees to drop three-fourths of their leaves were withstood by Lisbons with practically no foliage damage and with some uninjured fruit. Villafranca lemons proved somewhat hardier than Eurekas, but not so hardy as Lisbons. In one nursery two-year-old Eureka and Villafranca trees on sweet stock were found side by side. The former trees were frozen nearly to the buds, whereas only the upper half of the Villafranca tops were killed.

The grapefruit trees proved more hardy than lemon trees. The fruit of the pomelo is never so easily frozen as the orange fruit, but the trees usually showed themselves somewhat more tender than orange trees.

Among the other varieties of citrus trees the tangerines and the Satsuma oranges were more hardy than the navels and Valencias. The tangerine tree is very resistant, and many cases were found where this tree retained its foliage alongside of orange trees that had been entirely defoliated. Only two groves were found containing King orange trees, and in both of these instances they were more seriously injured than near-by navel orange trees.

Lime trees were more tender than lemons, the Tahite lime being more hardy than the Mexican. The citron was slightly more tender than the lime. Several instances were observed where lime and citron trees were growing in lemon orchards; and in such cases they were entirely defoliated and a portion of the brush or tops killed alongside of lemon trees that merely lost the outer layer of foliage.

When one considers that the citrus tree is a native of the tropics, it is surprising to find it capable of standing the temperatures of the 1913 freeze. In one place young navel orange trees, that were subjected to a minimum temperature of 5° F. above zero, came through with trunks alive, notwithstanding that the navel orange was brought to the United States from a place only 12 degrees south of the equator.

Relative Hardiness of Fruit.—The fruit of the pomelo was less injured by the cold than any other of the citrus fruits. Even when the skin was spotted as a result of the freezing the inside pulp often showed no breaking and remained juicy. In this respect the pomelo was quite different from the orange, because there was always a noticeable injury to the pulp of oranges which had spotted skin.

The comparative injury of navel and Valencia fruits varied with the locality. In many sections there seemed to be little difference in the condition of the two kinds of fruit, but where there was a difference, it was more common to find the injury greater in the Valencias. As the Valencia is the later variety, the fruit was less mature at the time of the freeze than were the fruits of the navels. In Whittier, and in the Sespe Cañon in Ventura County, the Valencia proved to be more hardy than the Washington navel. The Thompson Improved navel proved more tender than the Washington navel or the Valencia. Blood oranges ranged about the same as Washington navels.

Although the tangerine trees are so hardy, their fruit is more easily frozen than the fruits of the navel and Valencia.

Lemon fruit is injured at a temperature several degrees higher than that which injures oranges, and of course the young, small-sized lemons are more tender than those which are large enough to be picked.

It has been supposed that lemons can withstand a temperature of 28° F. without injury, but whether the crop of small fruit can be exposed to this temperature without loss has never been determined with sufficient accuracy to be convincing. The tendency among the best orchardists is to regard any temperature below 32° F. as dangerous.*

Lisbon fruit was less easily damaged than that of Eurekas. The difference did not seem to be due entirely, at any rate, to the heavier foliage of the Lisbons, because the fruit of the heavy foliage type of Eureka was injured more than the Lisbon fruit.

Yellow or tree-ripe lemons were more sensitive to frost injury than either the large-sized silver or green fruit. The packing-house reports from one young grove showed practically no loss of the large-sized green fruit, and only 15 per cent frozen fruit in the silver; while the tree-ripes were a total loss. This comparative resistance between the yellow or tree-ripe and the green fruit was found to be quite general.

NATURAL FACTORS INFLUENCING THE TEMPERATURE

Elevation.—Comparative elevation is a very important element in influencing temperature. It was common to hear people remark, soon after the freeze, that it was colder this year on the higher levels than it was on the lower ground; but this was not generally so. Investigation showed that as usual the lower portions of most districts were colder than the higher land of those districts. There were many places where this advantage of the higher ground was clearly illustrated in a single grove. In such groves a gradual transition could be seen from the uninjured fruit and foliage of the higher portions to entirely defoliated trees below.

It must be understood that it is, in all cases, the relative elevation that is important, not the actual elevation above sea-level. An adjoining low area, valley, or arroyo that afforded opportunity for the cold air to drain off was in this freeze, as in other freezes, of decided advantage.

There were some places, nevertheless, where, contrary to the relations existing in most years, the damage on the higher ground was greater than farther down the slope. In Upland this was shown by the condition of the street trees, the pepper trees at the top of the hill being defoliated and those lower down showing only slight damage.

* Compare article on "Recent Investigations in Orchard Heating," by I. G. McBeth and J. R. Allison, The California Citrograph, January, 1919, p. 51.

Protective Hills.—The damage done by freezing was closely correlated with the injury done to the trees by the severe wind.

It was probably on this account that plantings which were sheltered on the north by hills passed through the cold wave in much better condition than areas that received the unintercepted blast from the north. It looked in many cases as if the hills were so located that a body of warm air had been locked in around the trees, and that the cold north wind had slipped over these pocketed areas.

Again, the presence of a mountain range along the south side of certain sections apparently accounts for the little injury to fruit, probably due to a more gradual thawing of the fruit so situated. In still other sections there appeared to be no frost high-line, and the higher orchards, located along a north slope, appeared to be as severely injured as the lower orchards.

Influence of Cañons.—In previous years the territory about the mouths of cañons has usually been favored during cold weather. The current of air coming down the cañon has kept the air well mixed and prevented the stratification which takes place when the air stagnates. This year it seems that the whole mass of air, which moved down over the mountains, was below the freezing temperature, and cold air in motion is much more damaging than quiet air of the same temperature, so that many of the cañons this year changed their nature. This was not universally true, for there were some cañons which gave no evidence of being sources of streams of cold air. The groves nearest to the San Gabriel Cañon, for instance, were not damaged so much as groves farther out in the valley. The San Antonio Cañon, on the other hand, was very cold, judging by the appearance of the groves near its mouth. The San Antonio Cañon takes the same general north and south direction as that of the wind which ushered in the cold, while the San Gabriel Cañon runs northeast and southwest in its lower portion and nearly east and west in its upper forks.

Water Protection.—The protection afforded by nearness to bodies of water of considerable size, which was shown to be of very great importance in Florida, where there are many lakes and inland bays, was of very little importance in California. In a general way the less injury to trees near the coast may in a measure be due to the modifying influence on the cold, exercised by the nearness of the ocean. Doubtless nearness to the ocean failed to give any very marked indication of water protection, primarily because the wind accompanying the freeze was from the landward side.

Protection Afforded Fruit by Location on Tree.—The location of fruit on the tree frequently exercised an influence on the damage produced. When fruit happened to rest upon the ground it usually remained uninjured, even when all of the rest of the fruit of the tree was frozen so that it soon became juiceless. Because fruit which touched the ground was so protected it does not follow that fruit which was near the ground was less damaged than fruit higher in the tree. The reverse was usually the case.

While there was no advantage to the fruit in being near the ground, it did receive some protection when tucked in among the leaves of the tree. One of the most promising sections of an orange tree on which to find fruit good to eat was in the foliage on the south side of the tree. Fruit in this position on the tree very likely passed through more gradual changes in temperature both in freezing and in thawing than fruit in more open situations.

ARTIFICIAL METHODS OF PROTECTING GROVES

Along with the natural modifying agents of the temperature, such as elevation, hills, and cañons, there were a number of artificial causes which modified the cold. The most important of these was the heating which was done in so many groves. Windbreaks, running water, wrapping of the trees, and lath covering are things which must also be considered.

Windbreaks.—The question of windbreaks, their benefit, and detriment, and the comparative value of different trees for such purposes, has been for many years a constant source of discussion. The ideal windbreak seems to be the Monterey cypress and the blue-gum planted alternately in one row, the trees set five to six feet apart. In such windbreaks the cypress forms a tight base and the Eucalyptus gives the desired height.

The tendency during the past few years in many sections has been to remove windbreaks, for they have served in some places to prevent air drainage, and increase the damage from frosts, where their need as wind shields was not important. There are other sections which are annually visited by strong winds where they are rightly regarded as indispensable.

In most groves the three or four rows on the leeward side of the windbreak were less injured by the freeze than those in other parts of the orchard, but it was rare to find any frost protection more than five rows away from the hedge. It is not clear that all of this protection was due to the modifying of the temperature by the windbreak, as the orchard rows next to the windbreak are frequently much drier than the other trees of the grove, as is made evident by the lighter crops on these rows, and this puts these trees in a different condition to resist cold. It has been found that trees that were dry, provided they were not actually suffering and weakened because of drought, were less easily damaged by the cold than trees which had a more plentiful supply of sap or were in more active growth.

A few groves were found where the rows next to the windbreak had been kept in practically as good condition as the other trees of the grove by giving them extra water and fertilizer. In some of these groves it was also possible this year to notice a slightly better condition of the rows next to the windbreak.

It seems certain from all of the evidence collected that windbreaks did exercise a distinctly modifying effect in this freeze on the damage caused to the trees for a short distance to the leeward of them; but this advantage was slight, and, in view of the rareness of the occurrence of such severe freezes accompanied by wind, it would not, as a whole, seem wise to advocate the use of windbreaks for frost protection only. They take up much valuable space and when the temperature is that of a "frost" rather than a freeze the protection that the windbreak gives to the leeward side is likely to be offset by the increase in damage on the windward side.

Effect of Running Water or Irrigation During Freeze.—One of the first methods of protection to suggest itself to growers was to run water through the grove. The water would have to give up much heat in being cooled, and if water freezes a large amount of heat is released.

When conditions were such that all the factors were the same except for the presence of running water, the groves that were under water sometimes looked better than those which were not.

In one grove only 5 per cent of the fruit (navels) from that portion of the orchard which was irrigated during the cold was rejected at time of shipping, whereas 100 per cent of the fruit from the non-irrigated portion was frozen. Other conditions were apparently similar. The fruit was picked some time previous to March 28.

In three citrus nurseries well defined benefit from running water during the freeze was apparent, and one small orchard of 500 one-year-old Valencia trees was found where one-half of the trees had been irrigated during the entire cold spell from Sunday afternoon until Wednesday morning. Ten per cent of the non-irrigated trees were killed and the outer layer of growth on the remaining 90 per cent was badly injured, while the irrigated trees showed practically no frost injury.

While the above instances would indicate that considerable protection might be obtained from running water through a grove during a freeze, it should be stated that, in very many instances, little difference could be seen between the groves that were under water and those that were dry, and in but few cases did the trees under water show any greater vigor in putting out new growth.

In general it seems that one should not rely upon the use of running water to protect the fruit from freezing. In case of emergency no harm will come from running it, and if the temperature does not go too low a slight benefit may result.

Effect of Spraying Water on Trees.—In a few places, and on a few trees only, water was sprayed upon trees in order to keep them from freezing. This soon gave the trees a heavy coating of ice, and spraying was stopped so that the ice would not become thick enough to break the limbs. In the few cases which were found where this spraying had been done the practice seemed to have little value.

In the case of seed-beds or small nursery stock that would not be injured by a heavy coating of ice this method of protection might be very effective. In a freeze, such as that under consideration in California, it may be questioned whether the injury that would be caused by such a protective treatment would not in general be as great as the damage resulting from the frost injury. Again, it will never be possible for all groves to have a sufficient supply of water for such protection at the same time, unless a reserve water supply is retained in special reservoirs for each grove.

Effect of wrapping Trees.—The difficulty of artificially heating a young grove is greater than with older groves, where the trees are larger and the hot air is more easily retained. The results obtained by wrapping the trunks of young trees are therefore of much practical importance, for if there are ways of protecting young trees which are cheaper than heating the best of these ways should be known.

The principal substances used during the freeze for trunk wrappers were cornstalks, tule, newspapers, and tar paper. Many young trees had protectors about their trunks made of yucca, tar paper, or perforated paraffined paper. These protectors are rectangular pieces, which had been bent around the trunks, forming hollow cylinders, there being an air space between the trunk and the protector. They had been put around the trees during the summer to prevent the sunburning of the bark or its mechanical injury, and were not generally regarded as frost protectors.

Cornstalks afforded a good measure of protection when enough of them were used, and when they were bound firmly enough to keep them in place and to press them together, so that the free movement of the air between them was prevented. In some cases earth was thrown up around the base of the trees, so as to cover the lower ends of the stalks a foot or so deep. There were young groves of two-year-old trees wrapped in this way that received little injury except to the exposed foliage of the last season's growth, while near-by groves which were carelessly wrapped or which were left unwrapped were badly frozen.

One of the most marked cases of benefit from paper wraps was observed in a four-year-old lemon grove, the trunks of which had been scored during the summer preceding the freeze. All the trunks in the lower half of this orchard were well wrapped with paper, but in the upper half (the grove being on a gentle slope with south exposure) no frost injury was expected, and this precaution of wrapping was not taken. In the latter case severe bark-splitting occurred, it being necessary to renew some trees from sprouts; but in the lower and colder portion of the property there was no such injury beneath the paper wraps. The degree of frost injury to the foliage and tops, however, was in indirect proportion to the elevation. It is very essential in wrapping the trunks to get the wrap well down to the ground, and there is no reason why the entire trunk, instead of only the lower half or three-quarters, cannot be protected if wraps of sufficient length are obtained.

The protectors made of yucca, paraffined paper, tar paper, and the like, open at the top, furnished some protection, but are not equal to good newspaper or cornstalk wrapping. The only serious objection which has been raised to the use of protectors is that, under certain conditions, they favor the development of gum disease.

When young trees are tightly wrapped as a protection against frost, it is important to remove the wrapping before hot weather, as otherwise serious injury may result.

Protection by Lath-houses, Burlap, or Cloth Coverings.—Lath-houses, burlap, or canvas coverings afforded good protection to seed-bed stock up to a few degrees of frost.

Lath-houses kept the temperatures within them warmer than the temperatures outside. In one instance the temperature near the middle of a large lath-house was 4 degrees higher than the outside temperature. It was found in this case that it was a degree or so warmer at the center of the house than nearer the sides. Even where there was a covering of lath without any sides, the plants beneath the lath were affected much less than those without any covering. Part of the protection of the lath-house is due, doubtless, to the shading which it furnishes, causing a more gradual warming of the plants after the frost. At night the lath probably reflects back some of the heat radiated from the ground, and it also shuts in a pocket of warm air.

PROTECTION BY ARTIFICIAL HEATING

The cold weather of January, 1913, demonstrated to the citrus growers of Southern California that the only successful way thus far devised for fighting cold weather is the use of orchard heaters. To be sure, success was not universal with those who tried to heat their groves, but there were enough successes to show that where the equipment and supplies are adequate and the work well done orchard heating is effective.

So much doubt has existed in the minds of many growers as to whether artificial heating is effective and pays that special observations on selected plots of heated and unheated areas were made by several investigators. A report on some of these observations will be given as a separate article in another part of this bulletin. General statements only will be given here.

Acreage and General Results.—In all there were several thousand acres in California that had been equipped with orchard heaters for the winter of 1912–13. In a part of this acreage the equipment was entirely inadequate and allowed only a weak and ineffective effort to be made when the cold weather came. In general, however, those who tried to heat their groves obtained results which satisfied them that it had paid. There were many heated groves where the entire crop was saved and where the trees showed no effects of the cold, while neighboring groves which were unheated lost their crop of fruit and suffered such tree damage that it was two years or more before they began to pay expenses. In some lemon groves where successful heating was done the fruit from the first pick, which was made after the freeze, brought enough to pay the entire cost of heating, including the cost of the equipment, and then paid the grower a good profit besides. In addition to saving the fruit which brought in these returns, the young fruit and bloom of these trees was not frozen and there was no injury to the fruiting wood. Results were not always so satisfactory as this, but failure could always be traced to improper equipment, a shortage of fuel, or a lack of vigilance. Failures were seldom complete, however, and the condition of the trees usually showed benefit from the heating, even when the crop was lost.

Equipment and Material.—Most of the heating was done with pots burning oil, many kinds of which were in use in different groves. In

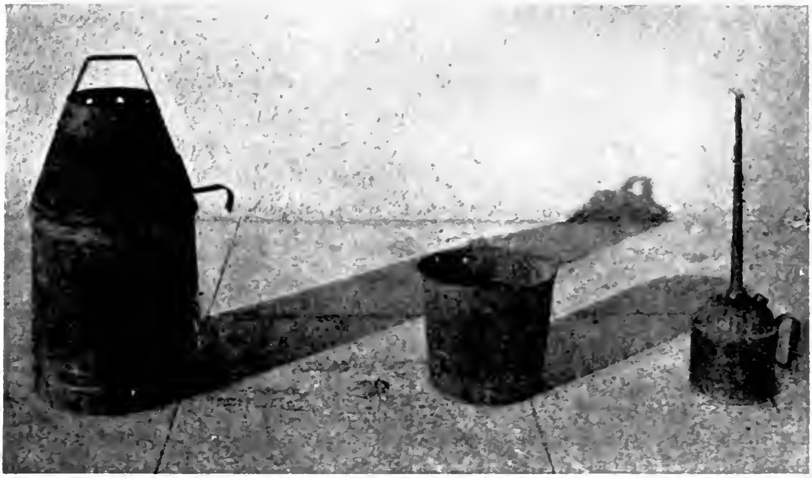

Fig. 7.—On left an orchard coal heater. This is merely an open firebox with grate at bottom. In center, the simplest type of orchard oil heater, being merely an open pail-like structure with holes at top for air draft. on right, a type of torch used in lighting heaters, supplied with asbestos wick and burning distillate or kerosene. Photo by Barrett.

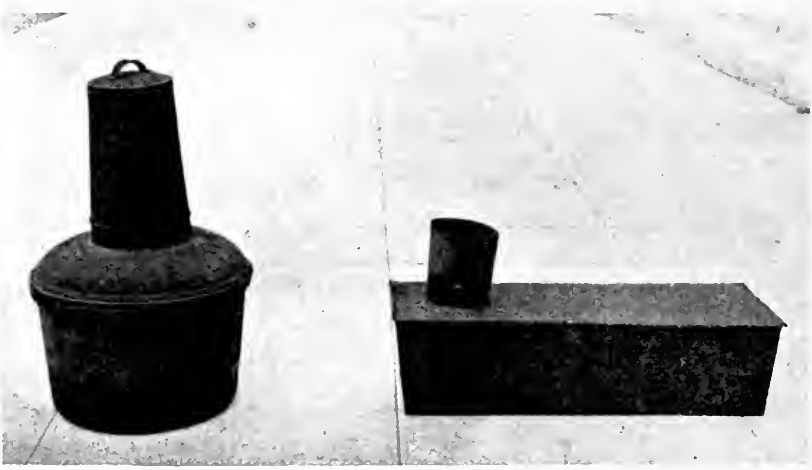

Fig. 8.—On right one of the types of orchard oil heaters very commonly used at the time of the 1913 freeze, having a sliding top and with openings on the side for air draft. On left one of the best orchard heaters that has been perfected since 1913. The smoke stack and drafts are hidden by the cover which is lifted off when heater is lighted. Photo by Barrett.

a few groves baskets and stoves burning coal were used, but in general these did not give as satisfactory results as the oil heaters (fig. 7). Oiled shavings burned in the grove gave little help, and is a method that cannot be depended upon.

The oil pots used varied in capacity from one to four gallons. Some of them were open pots, the shape of flower-pots, some were rectangular with sliding tops, and others were either oblong or round and provided with stacks (fig. 8). The pots which had stacks had the tops covered, but had drafts which could be opened to let in the air. The oil used was a low grade crude oil with asphaltum base, and cost, when put down in the grove, about 3 cents a gallon.

The lighting was commonly done by means of torches that held a gallon of fuel, and had a long spout, inclosing an asbestos wick. Engine distillate, gasoline, or kerosene was used as fuel, and when the torch was tipped some of the burning liquid fell into the pot (fig. 7).

In some cases where new heaters were being used considerable delay was occasioned by the difficulty in lighting the pots, several visits with the torch being necessary. After pots had been burned for some time and had become thoroughly sooted the lighting was accomplished fairly easily. In order to avoid such interruption at a critical period, it seems desirable, either to place a bundle of excelsior in the chimney of each heater, or to light and burn each heater for a half-hour or more before they are required to be lighted during a freeze (fig. 9).

The pots were filled from tank-wagons. Sometimes the oil was drawn from the tank-wagon into buckets and poured into the pots and sometimes a hose was attached to the tank and the oil run directly into the pots. The tank-wagons were filled from storage tanks which were made of steel or of concrete.

These varied in capacity according to the acreage and estimated needs, and many growers found that their estimates had been too low. When twenty or twenty-five cold nights may be expected it is well to have a storage capacity of about 1000 to 1500 gallons per acre in addition to full pots.

As a result of the difficulties experienced in this freeze the tendency hereafter will be to use larger pots of seven to ten gallons capacity and thus avoid the necessity of refilling in the night. The night filling is expensive, because of the higher wage paid the men and the smaller amount of work which they do in the night than in the day, and is responsible for much of the spilling of oil which occurs during the filling of the pots. The oil kills the roots with which it comes in contact, besides rendering the soil unfit for use. Some growers spent as high as 50 cents a tree in removing this oiled soil from their groves after the freeze.

One conclusion very definitely reached by growers, largely from the results obtained in this freeze, is that in the heating of an orchard it is stoves radiating actual heat that is needed, and not those producing a smudge. The smoke given off by the oil heaters collects to some extent on the fruit and is difficult to remove.

Fig. 9.—Lighting a good recent type of orchard heater by means of a torch containing distillate. The fire being applied to a small amount of excelsior placed in the tube of the down draft. The cover on the right when placed on the heater, extinguishes the fire and excludes rain. Photo by Barrett.

Methods.—The groves in which the best work was done were equipped with one pot to the tree. These burned approximately 100 gallons an hour per acre, when they were all going full blast. At these times the temperature of the grove was often from 8 to 12 degrees higher than the temperatures in neighboring unheated groves. Of course it was only during the coldest weather that it was necessary to have all the pots burning at full capacity. Usually only one-fourth or one-half of the pots were lighted, and after these had burned a time they were extinguished and another portion lighted, so that enough oil was retained in the former to allow for relighting them in case of a sudden drop in temperature.

It was found difficult by many growers to get the right kind of labor and to get the help when needed. The use of larger pots will reduce the amount of night labor needed, and the small ranch of ten acres ought to be handled successfully by two men, if they are vigilant and if their methods are correct.

Temperature at Which to Fire.—The experiences of the past have shown that one of the most necessary precautions to take is to begin heating soon enough. There is general agreement that it is easier to hold a temperature than to raise it after it has gone too low. For this reason some of those who have had most experience in heating are planning to begin lighting for lemons at 31 degrees. With oranges a degree or two lower than this may be risked before beginning operations.*

It has also proved of advantage to bank extra pots outside of the grove along the windward side. Not only is this necessary in order to protect the outside rows but it makes it much easier to hold the temperature within the orchard.

Value of Combined Effort.—Where large blocks of groves were heated the task of heating was easier than when the heated areas were small and isolated. The effects from the heating on a large acreage were often noticeable at a considerable distance from the groves where the firing was being done. In one section the heating of one hundred acres produced a rise in temperature of from 2 to 3 degrees in groves a mile distant as soon as the smoke reached these groves. The co-operation of growers in the vicinity of Pomona forms a notable example of the benefit of such combined effort. The co-operation can profitably extend to the employment of special observers, maintenance of special danger calls, employment of labor, purchase and storage of supplies, and the like.

Causes of Failure.—The principal causes of failure in the heating done in 1913 may be briefly stated as follows:

1. The use of pots which were too small. These burned out quickly and were difficult to refill.
2. Insufficient number of pots per acre.
3. Shortage of fuel.
4. The use of fuel which did not give off enough heat.
5. Allowing temperatures to go too low before lighting.

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* See article by J. G. McBeth and J. R. Allison, California Citrograph, Jan., 1919, p. 51.

6. Accumulation in the pots of a residue of asphaltum, which burned with difficulty.

7. Growers relying upon other people's reports of temperatures in other groves rather than keeping track of the temperatures in different parts of their own groves.

8. Discouragement after partial failure. This sometimes proved disastrous.

9. Insufficient amount of labor.

10. Incapable labor.

Costs of Heating.—The exact cost of firing in most cases has been difficult to ascertain, and, although considerable data has been gathered on this subject, most of it is too incomplete to make it of value for general conditions. From the data given in connection with a twenty-five acre orchard in the San Fernando Valley we find, after figuring 6 per cent interest on the total equipment and 20 per cent depreciation of the latter, besides cost of fuel and labor, the total cost amounted to 5.09 cents per gallon of oil burned. The pots were lighted on nine different nights. A similar estimate from one ranch in Ventura County, which had one hundred acres of orchard protected with heaters, gives 5.78 cents as total cost per gallon of oil burned. In this case the pots were lighted fourteen different nights. Near Santa Ana the heaters on an eight-acre orange grove were lighted three different nights, thus saving the fruit from considerable frost injury. In this case the cost amounted to 6.13 cents per gallon of oil burned. In the *Pacific Rural Press*, May 24, 1913, figures given by Mr. T. R. Woodbridge of Upland show a total cost of 6.5 cents per gallon of oil consumed.

The cost of the heating operations have varied of course with the amount of heating which was done. In table 2 data are given on the cost of heating in twelve groves selected from different parts of Southern California. These groves were more or less successfully heated. One grower, who kept a very accurate account of all of his expenditures, found that his average cost of heating an acre for one hour was $1.24. His grove was one-half lemons and one-half oranges, and the cost of heating the lemons was 64 per cent of the entire cost. The fruit was saved in the oranges and in half of the lemons, but in the other half of the lemons the equipment was inadequate and the fruit was lost.

In the tables the total number of nights fired is given. On some of these nights the heating was required for only a few hours, while at other times it was needed during the entire night. The interest on the investment has been figured at 7 per cent. The amount charged

TABLE II—DATA ON THE COST OF HEATING CITRUS GROVES IN CALIFORNIA DURING THE WINTER OF 1912–13

Orchard No.	Acres	Variety	Number of nights fired	Cost of materials		Cost of labor		Depreciation		Total cost		Cost per acre for one night	Investment in	
				Total	Per acre	Total	Per acre	Total	Per acre	Total	Per acre		Total	Per acre
1	12	Lemons	23	$1039.70*	$86.64	........*	........*	$169.00	$14.08	$1209.00	$100.66	$4.42	$729.33	$60.78
2	10	Lemons	20	379.50	37.95	$475.00	$47.50	115.72	11.57	970.22	97.02	4.85	713.25	71.33
3	20	Lemons	16	565.00	28.25	235.00	11.75	253.37	12.67	1053.37	52.67	3.30	691.00	34.55
4	15	Lemons	7	451.50	30.10	122.00	8.13	217.92	14.53	791.42	52.76	7.54	784.50	52.30
5	14	Lemons	16	437.00	31.21	201.50	14.40	147.12	10.51	785.62	56.11	3.51	573.25	40.95
6	15	Oranges and Lemons	21	528.25	35.22	372.13	24.81	167.00	11.13	1067.38	71.16	3.40	734.00	48.93
7	7	Oranges	22	181.25	25.89	132.00	18.86	65.00	9.29	379.25	54.18	2.46	216.30	30.90
8	22	Oranges	5	211.00	9.59	320.60	14.57	273.51	12.43	804.51	36.50	7.30	987.75	44.90
9	7	Oranges	19	189.50	27.07	93.75	13.39	66.77	9.54	350.02	50.00	2.63	245.00	35.00
10	10	Oranges	9	211.50	21.15	64.00	6.40	106.35	10.64	381.85	38.19	4.24	401.10	40.11
11	20	Oranges	5	435.60	21.78	232.00	11.60	334.63	16.73	1002.23	50.11	10.02	1282.38	64.12
12	20	Oranges and Lemons	17	766.56	38.33	499.05	24.95	398.90	19.95	1664.51	83.23	4.90	1445.17	72.27

* Included with materials.

off to depreciation has varied according to the equipment and the usage that it received. The depreciation on the oil heaters has usually been as high as 25 per cent and that on the other equipment probably about 10 per cent.

The cost in the groves where the best work was done ranged from 5½ to 6½ cents per gallon of oil consumed; or, figured on the acre basis, from $50 to $100 an acre was spent in these groves. With increased experience and improved equipment, it ought to be possible in the future to lower these costs. At present the items of labor and of depreciation contribute too large a percentage to the total cost. The equipment of the future will probably last longer and require less attention during its operation.*

FACTORS INFLUENCING RESISTANCE OF TREES TO COLD INJURY

It has already been noted that there was a marked difference in the resistance that different citrus trees showed toward the cold weather. Trees side by side were often very differently affected. It was evident that these differences were not always due to differences in temperature, and a search was made to discover why certain trees should have withstood the cold so much better than others.

Dormancy of Trees.—Trees that were dormant and inactive were able to stand much more than those which were growing and where the parts of the plant were actively functioning. Orchardists recognize this fact by their expression that trees in a "sappy" condition are more easily damaged than trees which are more "mature."

The treatments that stimulate a tree to growth or to activity, therefore, should be omitted, if possible, when cold weather is to be expected. This applies particularly to young trees. Some growers feel that with lemons, at least, it is more profitable to keep the trees growing through the cold weather and protect them from damage by heating.

Some of the things which influence the dormancy of citrus trees, as recorded by the freeze, are dryness and the time of irrigation, pruning, and, in young trees, the time of planting.

Time of Planting.—Young trees which were planted so late in the fall that they had not started to grow at the time of the freeze were much hardier than trees similarly located that had been planted in the summer or in the spring and were growing. In one young grove, that was set in the spring of 1912, most of the growing trees were

* The California Cultivator, Los Angeles, June 26, 1913, gives some excellent articles on the protection of citrus groves against cold.

The Pacific Rural Press, San Francisco, May 24, 1913, has an excellent statement on cost of heating.

The Monthly Bulletin, State Commission of Horticulture, vol. 3, no. 1, has an article giving costs of heating a large acreage.

killed half way to the ground, while trees that had not started were uninjured. In another grove of two-year-old trees some resets, that had been planted in the fall, mere green sticks, were uninjured, while the two-year-old trees all about them were killed to the ground.

Dryness.—It was very common to find trees which on account of being dry were less injured than those which had received more water. If the trees had become so dry during the summer, however, that they had shown the effects of drought, they were often severely injured by freezing. In a grove of young trees three or four years old, that had received scant irrigation during the summer, the trees farthest from the head ditch had become, before the freeze, yellow-leafed and looked as if they were dying. These trees were frozen to the ground, but nevertheless most of the trees of this grove were less injured than those in near-by groves that had received more water. Of course it would not be desirable to keep a grove dry and dormant all summer in order that it might live through the winter. These cases are referred to merely to show that dormancy in some cases was induced by dryness, and that it is best not to give a young grove too much water in the fall of the year.

Irrigation.—It was found that even when trees had been well supplied with water during the summer the interval that had elapsed between the freeze and the time of the previous irrigation frequently influenced their hardiness. A number of places were found where all of the factors were the same except the time of irrigation and where there were marked differences in the injury which the differently irrigated portions had sustained. In these cases the trees that had been irrigated about two weeks before the freeze were damaged more than trees which were about six weeks from irrigation. Even when it is likely that all of the trees had their conducting vessels well supplied with moisture there was sometimes a difference in condition among these trees corresponding to the differences in the intervals that had elapsed since the previous irrigation. To illustrate, in one grove water was running over the entire grove at the time of the freeze. Most of the grove had not been irrigated before for about six weeks, but a few rows at one side of the grove had been given an extra run of water about two weeks before the freeze. These rows were much more damaged than the rest of the grove.

While the number of conflicting cases observed make it difficult to deduce any general rules, it seems safe to conclude that trees which were suffering from lack of water and trees that contained the maximum quantity of water were more severely injured than trees that contained a medium amount of water.

Pruning.—It has been the practice of many lemon growers to prune in the fall of the year. Groves were found where trees that had been pruned at this time were much more seriously injured than unpruned trees which were under otherwise similar conditions. The most severe damage was to those trees that had started a vigorous growth as a result of the pruning. In one grove of young trees, which had been stimulated into growth by pruning, the bark of the trunks and limbs was badly split. Some adjacent trees of the same age and similarly located, which had not been pruned, were injured but little. The pruning was done the last of September, so that in this case there had been a three months' interval between the pruning and the freeze.

Where the cutting had been done so late that no new growth had started there was, as a rule, no noticeable difference in resistance between the pruned trees and those which had not been pruned. In one young grove, however, a very marked difference was to be seen between some trees which were unpruned and some adjacent rows where the pruning had been discontinued the night before the freeze. The grove consisted of four-year-old Eureka lemon trees and the cutting had been moderate. There was a very marked difference in condition between the section which had been pruned and that which had not been pruned. This difference was not so decided immediately after the freeze as it was when the trees began to grow. At this time the unpruned trees showed much more vigor than the other trees. The pruning of the grove was finished in the spring and all of the trees had been made the same size, so that there was no difference in that respect. Any one in walking through the grove could easily tell to a row where the pruning had been done before the freeze.

A few instances of late pruning were found which resulted in a greater loss of fruit than in trees not pruned. This, of course, is to be expected, for the abundant top growth affords considerable protection to the fruit.

Unhealthy Trees.—Sickly trees were invariably more severly injured than vigorous, healthy trees. This was very noticeable in the case of trees suffering from such diseases as gummosis and scaly bark. Trees that had been badly infested with insect pests were damaged more than trees which were in good health and free from pests. Branches that had been attacked with red spider were completely killed in many trees which suffered only partial defoliation of the other branches.

Sometimes healthy trees had been given some treatment before the freeze that weakened them and augmented the frost damage. For example, young trees which had been scored along the trunks on one or two sides, with the idea that by thus cutting out a narrow strip of bark growth could be hastened, were much oftener found with split and loosened bark after the freeze than trees where the bark had been left intact. The demonstrations of this point were so general that the method of scoring young trees will probably not be practiced in the future.

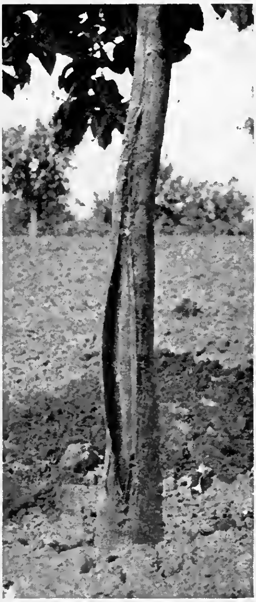

Fig. 10.—Two-year-old Eureka lemon on which bark had been slit longitudinally (scored) with knife before the freeze and which the freeze further seriously injured though the foliage of the tree remained uninjured. Scoring the bark in this way does no good and may cause serious injury. Photo by Tylor, July 5, 1913.

Some ranchers had practiced rubbing neatsfoot oil on the bark of trees which were affected with gum disease. Occasionally a man was found who had put this oil on the bark of healthy trees, reasoning that if neatsfoot oil was good for trees suffering with gum disease, which it is not, it should be a good preventive measure. In some of these places, where large bearing lemon trees that had been in good health but had had the trunks painted with neatsfoot oil as a preventive against gummosis, the oiled trunks had all of the bark killed, while trunks which had not been oiled had their bark unharmed.

Although the observations as to greater frost injury to sick trees were in most cases from a few isolated trees in individual orchards, where the majority of trees were healthy, the same general results have been noted between entire groves in the same section, and under practically the same condition as to elevation and temperature. Although immediately following the freeze there was little difference in appearance between groves in various states of vigor, the greater recuperative powers of the healthy, well cared for, clean orchards than of dirty, sickly, poorly cared for groves has been very marked.

Influence of Trunk-Section of Top-Worked Trees.—A very interesting difference which was brought out by the freeze was that of the resistance offered by trees which had the same kind of tops but different kind of trunks. Of course most of the citrus trees have the top and the trunk the same, as they are budded low. But there are many groves in which the trunk of the tree is lemon and the top orange, the trees having been worked over from lemons to oranges at a time when lemons were not paying. There are also some places where trees with lemon tops have orange trunks.

Several places were found where young trees with lemon tops and orange trunks were set among lemon trees of the same age which had lemon trunks. In one of these places the trees were all of the same age, having been set about one year. Most of the trees had lemon trunks, but there were two rows of trees in the middle of the grove that had Valencia trunks with lemon tops. The trees of the grove were uniform in size, and previous to the freeze there was nothing to draw one's attention to the fact that some of the trees in this young lemon grove had orange trunks. After the freeze, however, any one passing this grove would have noticed that two rows in it differed in some important respect from the rest of the trees. For the trees with orange trunks bore branches covered with green leaves, live lemon branches and lemon leaves, but the other trees in the grove were killed nearly or quite to the ground. Four other places were found where young lemon trees with orange trunks were adjacent to young lemon trees on their own trunks, and in all of these cases the trees with the orange trunks proved much hardier. It might be thought from this that the superior hardiness of the trees with orange trunks is due to the well known greater resistance to freezing which orange wood possesses. It is rather hard to see on this basis, however, why the lemon tops of the trees with the orange trunks should have been so slightly injured. The superior resistance of the trees was not confined to the trunks, for their lemon tops were hardier than the tops of the trees with lemon trunks. It is clear that the trunks of these trees had influenced the tops and had increased their hardiness. This probably means that in some way the trunks of the trees modified the dormancy of the tops.

Not many bearing groves have been worked over from oranges to lemons, so that it has not been possible to find many comparisons between such groves and bearing lemon trees on their own trunks. Some bearing lemon trees with orange trunks were found, and also some bearing lemons which had tangerine trunks, but these trees did not seem to be strikingly hardier than ordinary lemon trees.

It was much easier to find bearing orange groves where the trees in parts of the grove had lemon trunks. Such groves are rather common in southern California because about ten years ago there was such a depression in the lemon market that many growers budded their lemon trees over to oranges.

In some places these orange trees with lemon trunks were injured much more than adjacent orange trees on their own trunks. One grove of navel oranges was found where every other tree in the row had a lemon trunk. In parts of this grove the trees with the lemon trunks had lost two or three times as many leaves as the trees with the orange trunks. Numerous other cases were found where orange trees with lemon trunks were injured more than similarly situated trees with orange trunks, but the reverse of this sometimes occurred, so that no positive rule can be stated. It is, however, pretty clearly evident that it is, in general, poor policy to top work lemons to oranges.

Influence of Roots or Stocks.—It has been claimed that the root-stock on which the tree is budded may affect the resistance of the top. The stocks that have been most used in California are the sweet orange and the sour orange. In general, no difference in the resistance of the trees on these two stocks could be found.

In one rather large nursery, containing both sweet and sour seedlings, all the trees were killed to the ground in January, but on June 12, 1913, a count of several hundred trees of each variety showed that 71.3 per cent of the sweet and 71.2 per cent of the sour trees were recovering, and new sprouts several inches long were growing from the young trunks near the surface of the ground.

Comparative Resistance of Sweet and Sour Stock

	Number trees counted	Number trees producing new sprouts	Per cent trees recovering from freeze
Sweet Orange	882	629	71.3
Sour Orange	795	566	71.2

Pomelo stock has been used by many growers, but no cases were found where the trees on this stock were noticeably different from those on other stocks.

In one young lemon grove the trees on trifoliate orange roots were hardier than the trees on sour orange roots. At least one case was observed in California where navels on trifoliate stock appeared to be distinctly less injured than navels on sweet stock planted at the same time and in the same grove and having the same treatment. In general, it may apparently be concluded that the trifoliate stock has a tendency to render orange budded on it rather more hardy, but that the difference is slight.

In some cases there is apparently a definite influence of the tops upon the stocks. In one case, in the spring of 1912, a nursery of sour seedlings was budded to Eureka lemons. Many of these buds did not take, so that during the freeze of January, 1913, there were in this nursery, at the same elevation and under the same conditions, yearling lemon tops on sour stock (buds had been inserted several inches above the ground) alongside of sour seedlings. While a slight injury to the foliage was the only harm experienced by the latter, the lemon tops were killed, and the frozen wood extended three to four inches down on the sour stock. Similar conditions were found on pomelo stock, while the pomelo seedlings were scarcely touched.

Individuality of Trees.—One of the most pronounced features of the freeze was the greater resistance of some individual trees to frost injury than of other trees, of the same age and kind and growing under the same conditions. This perhaps was more apparent in young orchards than in old ones, and many instances have been seen in which the majority of trees in a young lemon grove have been killed to the bud, while here and there scattered irregularly through the grove were individual trees retaining a certain proportion of green foliage. The same individuality of trees occurs in old groves, but is not always so well defined.

In no case was it possible to determine whether the escape of these trees from injury was due to accidental conditions, rendering such trees more dormant and thus more resistant, or whether due to inherent frost-resistant qualities.

TREATMENT OF FROZEN TREES

Soon after the freeze it became apparent that the citrus groves had been very seriously injured and growers were confronted with many important problems connected with their rejuvenation. No experience was available to serve as a guide, and thus many different methods were tested that appeared to give promise of value. The trees given these different treatments were watched, and it has been possible to reach definite conclusions regarding the value of most of the practices which followed the freeze.

Binding Loose Bark.—In many places where loose bark was bound back to the tree again apparently nothing was gained, for the loosened bark died. Many growers, however, reported that they had trees the bark of which was loose immediately after the freeze but which later reunited with the wood.

Considerable uncertainty exists regarding most of these reports, but it is probable that some of them are true, inasmuch as there were many examples where the bark had split and separated from the tree without being killed. This bark not only remained alive but developed a layer of wood on its inner surface, and a new bark was developed next to the wood of the tree.

Some trees were found which clearly showed that such an occurrence actually took place. The bark on the north side of a three-year-old lemon tree had been longitudinally split and had separated from the wood for an inch and a half or so on each side of the split. At one place it had been tied down to the tree again by a piece of twine, which brought the wood and bark together at this place only. Both above and below the twine the bark had remained separated from the tree. The bark was not killed, and where it had been tied it had reunited firmly with the tree.

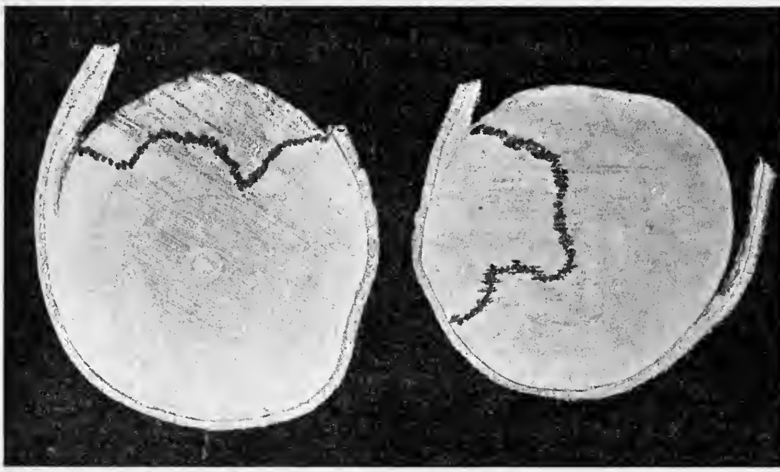

Fig. 11.—Cross section of young lemon trunks on which bark was split by freezing, showing the injury to the wood which is dead back to the inked lines. New wood can be seen forming on the loose ends of the bark which was not killed.

In many cases where split trees were wrapped the process was so thoroughly done that the moisture was held in and molding favored. The best instances of recovery from wrapping were those where cord, like binding twine, or narrow strips of cloth were wrapped around the tree spirally, leaving the greater portion of the bark uncovered and allowing the free access of the air, but holding the loose bark firmly against the wood. Such wrapping to have any effect must be done promptly after a freeze, while the injured surfaces of bark and wood are fresh, otherwise the wrapping naturally could have no beneficial effect. Where bark is split and loosened it is likely to bend outward as it dries and exert a force that will have a tendency to extend the injured area. Binding with cord as indicated will prevent such extension of the injury and favor the bark healing on, while it is not too severely injured. In many cases where no beneficial results were observed from wrapping the treatment was applied too late, or the injury was so severe that no treatment could be effective in saving the injured parts (fig. 12).

Fig. 12.—Four-year-old Eureka lemon, on which the split bark was covered with grafting wax and wrapped with twine. Treatment apparently did no good because of grafting wax. Loosened bark promptly wrapped with twine without other treatment frequently healed on. Photo by Tylor.

Where trees are treated in this way following a freeze they should be given no other treatment, unless the trunks are whitewashed to protect them from sunburning. No further treatment than the wrapping is necessary for several months, or until the new growth is well under way and until bark that was killed has dried out and clearly shows the extent of the damage. As soon as this time arrives, the wrappings should be removed, the dead bark thoroughly cut away, and the injured patches thoroughly cleaned. After this cleaning, probably the best treatment is to first paint the injured area with Bordeaux paste and some weeks later with asphalt dissolved in benzine. The use of Bordeaux paste as a first treatment seems to be very desirable, as it seems necessary to use some sterilizing solution to prevent the development of fungi. Following this treatment with a coating of asphalt paint renders the wound impervious to water and gives a permanent finish to the treatment.

Waxing and Painting Split Bark.—The covering of the splits in the bark with grafting wax was a very common practice. Some growers used white lead instead of wax. Sometimes the bark was wrapped after the waxing, and sometimes the waxing was the only treatment given. Where there was a chance to compare waxed trees with those that had not been treated, there was nothing to show that the waxing had done good. It was practically impossible to get the wax under the loose bark, and so the wax simply sealed up moist chambers which offered most favorable conditions for the growth of fungi. Even where the wax was put on before there was much loosening of the bark, it did little good because the later loosening and curling of the bark cracked it (fig. 12).

White lead, applied by painting the cracks soon after the freeze, proved no more valuable than wax, and no places were found where trees were in any way benefited by having the trunks wrapped in

Fig. 13.—Badly injured Eureka lemon tree, unpruned, five and one-half months after freeze, showing the extent of damage and the new growth that has developed. Trees at the stage shown in this illustration can be pruned to advantage, all of the dead wood being removed at one time. Photo June 24, 1913, by Tylor. (This tree was immediatley beside that shown in fig. 14.)

cow dung. Some cases have been reported, however, where gummosis was started by this treatment.

Pruning Injured Trees.—One of the most important operations necessitated by the freeze was pruning. It was maintained by some that prompt pruning was very necessary in order to prevent a further dying back of the frozen wood. This dying back would be caused, it was claimed, by a backward passage of sour sap. However, difficulty was experienced in telling soon after the freeze where the uninjured portions of wood began. So when it was advised on the special Frost

Train, run by the College of Agriculture of the University that it would be better to wait, whenever the damage had been at all severe, until the extent of the damage became clearly defined, the majority of the growers adopted this policy.

The effect of early and late pruning was easily observed and was tested out by many growers. The following two instances may be cited as definite experiments. In one orchard of old lemon trees a

Fig. 14.—Badly injured Eureka lemon tree, pruned February 1, 1913, and photographed four and one-half months later, showing the dieing back of large limbs after the first pruning. Such early pruned trees as this made no better growth than unpruned trees and required a second pruning. Photo by Tylor June 24, 1913 (compare fig. 13.)

certain portion of the trees were cut back in February, and all wood at that time thought to be dead was cut out. A check row, however, was left, which was not pruned until summer. The cuts made during February were in most places on wood that ultimately died. In this case there was no apparent difference in amount of new growth produced on the trees under the different treatments, but in the case of the early pruning, a second cutting was necessary in order to completely remove all the dead, frozen branches (figs. 13 and 14).

In an experiment, carried out by the Citrus Experiment Station through the kindness of the Arlington Heights Fruit Company, seven-year-old lemon trees that were rather severely injured were pruned in several different ways. About ten trees were treated by each method, the pruning being done about the middle of March, 1913, thus somewhat over two months after the freeze. Row 1 was left entirely unpruned. In row 2 the trees were pruned moderately, limbs being removed as far back as they were thought to be injured. In row 3 without reference to injury, the trees were cut back to the principal branches, thus being very severely pruned. In row 4 the trees were cut off below the crown, leaving thus only the trunks.

No further pruning was given until May, 1914. At this time it was clearly evident that row 1, unpruned, and row 2, lightly pruned, had developed the largest tops and the most fruit, there being no fruit on the other rows. The dead branches on row 1 had up to this time caused no injury and could be easily distinguished and removed. The growth on these trees after pruning seemed to be, as a whole, better, more vigorous, and more fruitful than on any other row, though scarcely any better than row 2. Row 2, however, required a second severe pruning, the treatment thus being much more expensive than the one pruning given row 1. The pruning in rows 3 and 4 had clearly been too severe to give the best results.

The treatment of limbs on which large patches of bark were killed is very perplexing. Where a limb was partially girdled, it was a question how wide a strip of living bark it should have in order to give satisfactory growth. No positive directions can be given regarding such variable cases, as judgment must be used in every case. It is thought, in general, that where a limb is more than half girdled, it would be better to remove it and allow a strong new branch to take its place.

It must be remembered that in pruning frozen trees, it is highly important to treat the large cut surfaces with a fungicide, such as Bordeaux paste or Bordeaux mixture, followed with asphalt paint.

The results obtained in these experiments correspond entirely with the experience of growers all over the state, and demonstrated conclusively that early pruning after a freeze is unnecessary, does no good, and increases the expense, as a second pruning is necessitated. It may do damage to some extent, by causing sunburning. Far the best method is to delay the pruning for from five to six months or longer, until the trees have had time to throw out new growth and plainly delimit the dead portion. All necessary pruning can then be done at one time. The early pruning of lightly frozen trees, in lemons especially, is likely to remove uninjured fruit wood and lessen the following crop.

The early pruned nursery stock was found to be slower in starting growth than unpruned stock, a delay of as much as three weeks being observed in some cases.

Many growers did not attempt to remove the small frozen twigs in lightly injured trees. Leaving this dead brush in the tree was found to increase the amount of fruit spotting, and decay the next year.

Removing Frozen Fruit.—As soon as it was learned that the fruit had been frozen, some growers had it promptly removed. This cost for oranges from five to ten cents per tree on the average, while some lemon growers had to pay as much as twenty cents per tree.

Experience demonstrated that there is no need of haste in removing frozen fruit, unless it is to be used for making by-products. Some of the frozen fruit will drop of its own accord and if wood injury necessitates pruning much of the old fruit will be removed by this operation. What remains can be pulled off later at any convenient period. There was no evidence obtained indicating that the succeeding crop was injured by this frozen fruit remaining on the tree, other than the injury that may result from the spreading of fungus spores from the old fruit, thereby increasing spotting in the next crop.

Whitewashing Exposed Trunks.—Where trees were defoliated, many growers felt that the bark should be protected in some way from the burning action of the sun. The most feasible way to do this was to whitewash the trees, and this was done in many cases. Where the whitewash was put on before any new growth had started, the appearance of the new growth was delayed about three weeks. When the application was not made until after the growth had started, the tender leaves were sometimes injured. The whitewash was always cooled before using it, but there were many examples where after it had cooled over night, it injured tender growth. Where it was allowed to stand a week before being put on, it had no injurious effects.

In case there are but a few trees to be treated, the whitewashing of bare trunks and limbs can be done with a brush, but on the larger ranches, the most economical system is to make a thin wash that will go through a spray nozzle and apply it by means of a power spray pump. (See formula below.*)

The Renewal of Badly-Injured Young Trees.—Young lemon and orange trees suffered various degrees of injury, but were much more generally and severely injured than older trees. Severe cases of sun-

* Formula for California Whitewash: Take 30 pounds of quick lime, 4 pounds of tallow, 5 pounds of salt, and mix together, slake slowly and blend. Dilute with enough water to make mixture flow well.

burning frequently resulted on the south side of defoliated young lemon trees in particular and the whitewashing of the trunks of such trees soon after a freeze is important.

Aside from whitewashing, there seems to be but one fixed rule, and that is to let the trees alone until the new growth is well under way, and the demarcation between dead and living wood has become plainly apparent.

Fig. 15.—The development of a new tree from a sprout springing from base of trunk above the bud, the old trunk being retained for a time as a stake for the new tree. Photo by Tylor, September 6, 1913.

The method of renewal of young trees depends entirely on the degree of injury. If the trees have lost only a portion of their heads, a new head may be shaped after the growth is well under way. With trees that lost their entire crowns but retained sound trunks, as happened in many cases especially where they had been protected by a wrap during the freeze, it proved to be thoroughly practical to train three or four sprouts, properly located and spaced near the top of the trunk, to form the new head.

If the trunk is killed too far down to produce a good-shaped head, but is still living above the bud, the best method of renewal is to select a strong sprout that springs out above the bud and train it into a new tree, retaining the old trunk as a supporting stake until the sprout becomes strong enough to need no support. Remove all other sprouts and throw the full strength of the tree into this one sprout. Many young sprouts that did not even start growing until the middle or latter part of March, trained in this manner and headed before the August growth, in seven or eight months made splendid young trees, better than new trees planted in the spring. Whatever system of renewing young trees is followed, it is important to start below all large areas of dead wood. There is too much at stake to grow a new tree for several years on a rotten foundation. If the main crotch has been badly frozen and the dead bark and wood extends downward from this injury, sacrifice the top and start the new head from healthy tissue (fig. 15).

Grafting or Budding Badly-Injured Trees.—Where trees were frozen down to the bud, one of three things was done: the trees were uprooted and thrown away; or they were allowed to send out new shoots, one of which was budded; or they were cut off and grafted. Grafting was successful in some places, and failed in others. The two methods used were cleft-grafting and crown-grafting. Where the tree was one or two inches in diameter, it was sawed off down to good live wood, was split, and then two wedge-shaped scions were put in by the cleft-graft method, one on each side, so that the cambium of the scion came next to the cambium of the stock. Where the trees were so large that they could not easily be split in this way, a stick of bud-wood with one end cut diagonally was placed between the bark and the wood, with the cut surface next to the wood. The failures were caused mainly by the drying out of the scions before they had united with the stocks, or by the dying back of the stock below the place where the scion was inserted. Grafting, in general, proved unsatisfactory.

The most successful method pursued was to train up a vigorous sprout from the stock which was budded in the summer as soon as it had reached sufficient size.

Irrigation to Aid Recovery of Frozen Fruit.—It was thought by some people that fruit which had been partly frozen would recover if the conditions were favorable, and that frequent irrigation would assist in this recovery. Irrigation was given a fair trial in several cases with Valencias and navels, but the fruit was not benefited, showing no improvement over adjacent groves which were not irrigated. In fact, no places were found where there was any recovery of fruit after February 1 which was of any commercial importance. Some frozen lemons were examined in which it looked as if new pulp cells had formed next to the skin, but this was not general enough nor extensive enough to need consideration commercially. Instead of any recovery taking place in frozen fruit, there was a steady deterioration the older it grew.

Stimulating Growth in Frozen Trees by Fertilization.—Many growers following the 1913 freeze gave their trees extra applications of nitrate of soda and other quick-acting fertilizers, thinking thereby to stimulate more rapid growth and cause the flowers to set more fruit. Little or no benefit was derived from such extra applications, though no harm was done, as has sometimes followed in Florida. The omitting of all fertilization, however, was very clearly a mistake, unless the freezing had been so severe as to kill all or the greater portion of the tops, or in cases where the grove had been highly fertilized a short time preceding the freeze.

Treatment of Wounds on Frozen Trees.—Reference has been made in various places to the necessity of properly treating wounds on frozen trees, both in the case of areas injured by the freeze and of wounds caused in pruning. In several sections of the state, wood rots were spread in the pruning and apparently caused considerable damage. In almost all cases some material was used by growers to cover cut surfaces, such as grafting-wax applied warm, liquid grafting-wax, white lead, or some sort of paint. It was found by Dr. Barrett and Professor Fawcett that these did not stop the infection with the wood rots spread by pruning. These fungi developed under the wax or paint. In the treatment of the wounds, in case of trunk injuries and comparatively large cut surfaces in pruning (limbs one-half inch or more in diameter), the best treatment that can now be suggested is painting these, when freshly cut, with Bordeaux mixture or Bordeaux paste* and a few days later following this by painting the cut surfaces with asphaltum dissolved in benzine, which gives a hard smooth finish that will last for a long period. Asphalt paint dissolved in benzine (use no turpentine) can be purchased at paint stores.

AFTER EFFECTS OF THE FREEZE

For six weeks or so after the freeze, there were no changes in the appearance of the groves, which could be looked upon by the rancher as encouraging signs. During this time the injury done to the bark became more apparent day by day: green bark became dull in color and then dark brown; cracks opened wider; and the leaves kept falling except in some places where the freezing had been most severe. In these places the dead leaves did not drop but remained hanging as if they were frozen on.

Appearance of New Growth.—Toward the latter part of February, however, the buds began to start, and new growth appeared in abundance. This growth was not confined to parts of the tree which showed no injury. Of course, there was much wood upon which no new growth appeared, but new shoots sprang out from many branches and trunks, which were so badly split that the owners were greatly

* Bordeaux paste formula: Dissolve 1 pound of bluestone (copper sulfate) in 1 gallon of water in a wooden or earthen vessel. This can best be done by hanging it in a sack in the top of the water. Slake two pounds of quicklime in about one-half gallon of water. Some variation from these proportions may be made without greatly changing the value of the paste. Stir together when cool, making a light blue mixture about the consistency of whitewash. If the mixture turns to some other color before being applied, it is an indication that something is wrong. Mix up fresh each day or two, as the mixed paste tends to deteriorate with age. It may be applied with a large brush as whitewash.

surprised to see them putting out such an abundant and vigorous growth.

Dying of New Growth.—After this growth had become a few inches long, much of it began to droop and die. A few weeks later many young trees, which had started out with promise, were entirely dead, and other trees kept weakening and dying throughout the summer. Sometimes some of the new growth would droop and die because of overcrowding. Frequently when two or three shoots sprang from the same place, all would continue to grow until six to ten inches long, and then one or two of these would droop, become loose, and fall out, leaving one strong sprout. Where there were these fatal effects of overcrowding, the trees were doubtless in a weakened condition. Orange trees that were merely defoliated sent out a strong and abundant growth along the trunk and the main limbs of the trees. This growth had large leaves of good color and bore strong vigorous flowers. The leaves that came out near the surface of these trees were generally small and often variegated. This variegated color was plentiful in groves which had previously been free from "mottled leaf."

Where the bark was split, the loosened bark usually curled and died, leaving an elliptical patch of uncovered dead wood. The sound bark surrounding this area began to grow in from all sides and cover this bare wood the same as in the healing of any wound.

After two or three months, trees which had been exposed to the lowest temperatures began to show dead patches of bark on some of the big limbs. These patches were not conspicuous, but could be located by scraping off the outer surface of the bark. The scraping revealed the brown areas, surrounded by bark, which was green and alive. It was rare to find bearing trees ten years old or older, even in the districts which suffered most, where the trunks of the trees showed much injury.

Blooming and Fruiting of Injured Trees.—Slightly defoliated orange trees, even though the crop had been a total loss, in many cases set a larger crop than normal. Orange trees that had been entirely defoliated in January produced bloom in March and April, a large portion of which was small and dropped. During this time strong, vigorous growth was developing on the large limbs within the tree and fruit developed on this newly formed growth. The crop of these trees, which had been entirely defoliated and badly injured in January, was found, to the astonishment of many, to equal in many cases 40 to 60 per cent of normal.

Lemon trees that had suffered but slight frost injury to the fruit, in many cases set a heavy new crop. In many instances it was found that lemon trees, entirely defoliated in January, produced considerable bloom in the spring, but a large proportion of this dropped. The amount of fruit on the lemon trees in the fall was proportional to the amount of fruit-wood not killed during January. Where the trees were killed back to the framework or to branches one or two inches in diameter there was no bloom for twelve months after the freeze, although much new growth was produced.

The devastation wrought by the freeze was so severe that growers feared that no crop would be produced the next year. In this they were fortunately mistaken. In the case of orange trees where the injury was not too severe, the check to the vegetative development apparently acted like girdling and stimulated a heavy bloom and set of fruit. It is interesting to note that similar conditions followed the 1886 freeze in Florida, which was about of equal severity with the 1913 freeze in California. The Florida crop of oranges the year following this freeze was larger than the crop of the year preceding the freeze (see table 3).

TABLE 3.—FLORIDA CITRUS FRUIT CROP FROM 1884–85 TO 1888–89

Season	Oranges, boxes
1884–85	600,000
1885–86	900,000
1886–87 (freeze Jan. 12, 1886)	1,260,000
1887–88	1,450,000
1888–89	1,950,000

Nearly the same conditions followed the California freeze, as will be seen from a comparison of the shipments of oranges and lemons for the years preceding and following the crop year of 1912–13 (see table 4).

TABLE 4.—SHIPMENTS OF CITRUS FRUIT FROM CALIFORNIA, 1909–10 TO 1917–18

	Carloads			Boxes (approximate)		
	Orange	Lemon	Total	Orange	Lemon	Total
1909–10	....	....	....	11,300,246	1,516,021	12,876,267
1910–11	39,360	6,721	46,081	15,575,631	2,256,066	17,831,697
1911–12	33,671	6,104	39,775	13,319,002	2,241,990	15,560,992
1912–13	17,432	2,806	20,238	6,908,084	1,117,940	8,026,024
1913–14	42,706	2,848	45,554	16,957,335	1,202,964	18,160,299
1914–15	40,986	6,658	47,644	16,336,433	2,639,296	18,975,729
1915–16	37,336	7,319	44,655	15,169,559	2,945,589	18,115,148
1916–17	45,723	8,107	53,830	19,702,443	3,312,042	23,014,485
1917–18	19,506	5,823	25,329	8,940,820	2,452,481	11,393,301

(Cars of varying capacity.)

Several factors contributed to make the crop of 1913–14 appear larger than it really was in comparison with preceding crops. The crop of 1911–12 was reduced by the loss of considerable fruit through the Christmas freeze of 1911. The crop of 1912–13 was largely destroyed by the great freeze. There had, therefore, been two years without a normal crop. Meanwhile, very extensive areas of young plantings had reached bearing age, and served to greatly increase the crop of 1913–14. There were many acres of old, bearing trees and trees of all ages, where the crop was very greatly reduced by the freeze. The average yields per acre, therefore, were much smaller than in many preceding years, although the total crop was fairly large.

The lemon trees were much more severely injured, the fruit-bearing wood being destroyed in many sections. The crop of the year following the freeze, 1913–14, was thus comparatively small, as will be seen by an examination of table 4, giving the yields for the last nine years.

Planting Frosted Nursery Trees.—During the summer following the freeze, some cases were reported of loss due to the planting of nursery trees that were more or less injured by the freeze in January but that had recovered sufficiently to be sold for planting several months later.

The reason for this is probably due to the fact that the injured tree, in order to produce a new top, or a new top and portion of the trunk, must draw upon its reserve food material stored in roots and trunk for this new tissue, and that the trees had not had sufficient time before the second shock of transplanting to replenish this reduced reserve food, which is necessary in order that the plant may recuperate when set in the orchard.

Thawing and Recovery of Frozen Fruit.—It has long been known that if frozen tissue is suddenly heated or thawed rapidly, it is severely injured, but if gradually thawed, it often escapes injury. There seems but little doubt that, had the freeze of 1918 been followed immediately by warm sunny weather, instead of the continued cool, cloudy weather accompanied by light showers, that devastation would have been far more serious. It may be stated, however, that no cases of the commercial recovery of fruit was found. Individual fruits have been found in most varieties that have shown a development of new pulp cells, but this is not general enough to be of commercial importance. Instead of recovering, frozen fruit steadily deteriorates.

The Sale of Frozen Fruit.—A large proportion of the crop of citrus fruits was badly frozen, but in many cases only a portion of the fruit was seriously injured. Frozen fruit is known to remain palatable and wholesome for a month or two after a freeze if properly handled. Many growers immediately gathered and shipped large quantities of such frozen oranges, but in many cases they arrived in poor condition, and the market being suspicious and overstocked, the returns were in most cases negligible. Indeed it may be stated that in very few, if any cases did the returns justify such shipments, and the loss to the growers as a whole through the injury of the market was far greater than any benefit obtained. The shipment of injured fruit was continued so long that much of it reached the consumers in dried-out, inedible condition and served to render them distrustful of the California product. The results from such shipments following the 1913 freeze were such that it can be unhesitatingly recommended that in the case of such severe freezes, no shipments of fruit should be made following the freeze, until sufficient time has elapsed to allow the separation of the good from the injured fruit.

It was thought by some growers that oranges picked promptly after the freeze and stored in cool places or placed in cold storage, where they would not dry out too rapidly and fermentation would be arrested, would remain in good condition for a much longer period than otherwise. No trial was made of this method that could be called complete and conclusive, although several experiments were made. In two cases one of the writers made an examination of navels that had been picked two or three days after the freeze and stored in a cool place in the packinghouse (not in cold storage). This examination was made in March over two months after the freeze, and the fruits were compared with navels from the same groves that had remained on the trees. In neither case could any marked difference be observed between the stored and the unstored fruits. In both cases they had dried out considerably, and the flavor had become flat and insipid.

The Separation of Good Fruit from Frozen Fruit.—In many groves all over the state, only a portion of the fruit was so severely frozen as to cause its drying out and decay. The good fruit in most cases was mixed on the tree with the frozen fruit and could not be separated from much of the frozen fruit by any external characters. The making of a practical segregation of such fruit became an important problem following the 1913 freeze, as it had been also in many lesser freezes. No method of separation based on the judgment of external appearances proved successful. The difference in specific gravity between frozen and sound fruit had been used as a means of making a segregation. Finally, as a result of drying out sufficient difference in specific gravity comes to exist between injured and uninjured fruits, so that a solution somewhat lighter than water, such as denatured alcohol, guaged to the right specific gravity, will allow the heavy uninjured fruit to sink, while the lighter frozen fruit will float. For some time following the injury, no such segregation can be made. Time must be given for the changes in the fruit to take place. Lemons change more rapidly than oranges, and give a fair segregation within a month following the freeze. The changes are much slower in oranges, however, and it was about two months after the freeze before a practical segregation by this method could be obtained.

A machine had been devised to make this specific gravity segregation mechanically in alcohol, and had the previous year been installed in a few packing-houses. This machine gave fairly good results as long as the alcohol remained at the proper degree of density. Owing to the rapid evaporation of the alcohol and the change in degree of density, considerable difficulty was experienced in using these machines.

It was found that a practical and fairly economical separation could also be made by this alcoholic method, using special tanks or half barrels, into which open mesh-bottomed trays were fitted. By this method the tray filled with fruit was dipped into the alcohol. The light floating oranges could then be removed quickly by use of a sieve dipper, after which the tray could be lifted out and the heavy oranges removed.

In certain experiments, oils, such as kerosene and engine distillate, have been used instead of alcohol in making specific gravity segregations, but even when friuts so segregated have been thoroughly washed with warm water and "gold dust" to remove the oils, injury almost always ensues.

The alcoholic method of segregation was the only successful method known during the first two months following the freeze, and many were preparing to use it, regardless of the great expense for materials and the difficulty of its application. Fortunately just at this time, before much expense had been incurred in the purchase of alcohol or alcohol separators, Mr. Frank Chase of Riverside rendered citrus growers a great and lasting service by patenting a water separator and giving the patent t● them for use, freely, without recompense, except that reward of personal satisfaction for work well done and the honor that comes to one from the performance of notable public service.

The principle of the Chase water separator is based on the difference in the specific gravity of the injured and uninjured fruit the same as in the case of the alcoholic separator. In the Chase separator, however, the fruits are carried in single rows and dropped from a slight elevation, about six inches, into a current of water, moving at a regular speed. The injured, light oranges do not sink very far and come up quickly so that they are only carried a short distance before they come to the surface. The good heavy oranges sink much deeper as they fall and come to the surface more slowly so that they are carried much farther by the current of water. Taking advantage of this principle, a screen, placed horizontally at a certain depth in the water and a certain distance from the points at which the fruit falls, will allow the light, frozen oranges to arise to the surface and be carried off above the screen; while the heavy oranges will not arise until they pass the end of the sereen and thus are carried on below it and into a separate receptacle, or passed directly into the washing machine in case the fruit is to be washed.

Different crops of fruit have different specific gravities, or the same fruit at different times gives a different specific gravity, so that the separating screen requires to be adjusted to the crop that is being run through at a given time. When it is properly adjusted, a very satisfactory segregation can be made, comparing favorably with the best alcoholic segregation.

The practicality of this method of segregation was immediately recognized, and separators were installed in the various packing-houses requiring them, as rapidly as the machines could be constructed. After the first of May, practically all of the fruit that was shipped from the state was run through Chase separators to eliminate injured fruit. The examination of such separated fruit, and the market reports from the separated fruit shipped, testify conclusively to the value and effectiveness of this method of separation.

CHANGES THAT TAKE PLACE IN FROZEN ORANGES AND LEMONS*

By E. E. THOMAS, H. D. YOUNG, AND C. O. SMITH

After the destruction of a large part of the citrus crop by the freeze of January 6th and 7th, 1913, it was thought to be important to make some studies of the physical and chemical changes that take place in frozen oranges and lemons. The work was carried out at the Citrus Experiment Station and was intended to determine as definitely as possible, the nature and rate of changes that take place in frozen fruit. While it is not impossible that the composition of the ash or mineral elements may be affected, it was not considered advisable to attempt to determine such changes in the time at the disposal of the investigators and only the special points which could most reasonably be expected to show variation were considered. The following points were taken up in the investigation:

The specific gravity of the fruits and of the juice.

The average weight per fruit, of good and frozen fruit.

The percentage and total amount of sugar (total sugar, sucrose and reducing sugars) and acid.

Sound fruit and badly frozen fruit of Washington navel oranges and Eureka lemons were picked every four days following the freeze for two and one-half months and these were weighed and analyzed. They were compared with sound fruit and frozen fruit picked immediately after the freeze and stored.

Four different grades of fruit were examined.

(*a*) Fruit known to be unfrozen, picked from trees whose blossoms and small fruits showed no sign of frost injury.

(*b*) Fruit which was apparently unfrozen, judging from external indications and picked from trees slightly injured by the freeze.

(*c*) Fruit supposedly frozen, picked from same tree as sample (*b*).

(*d*) Fruit picked from badly frozen trees about which there could be no question of the frost injury.

The badly frozen lemons were picked from the trees shown in figures 1 and 2. Oranges of this grade were obtained from large navel trees in the same grove.

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* A summary of these investigations was first published by one of the authors, H. D. Young, while he was employed in the Citrus Experiment Station, in a paper entitled "The Composition of Frozen Oranges and Lemons." See Jour. Ind. and Eng. Chem., vol. 7, p. 1038, Dec., 1915. For further data on same subject see article by H. S. Bailey and C. P. Wilson, "The Composition of Sound and Frozen Lemons with Special Reference to the Effect of Slow Thawing on Frozen Lemons." Jour. Ind. and Eng. Chem., vol. 8, p. 902, Oct., 1916.—H. J. Webber.

SPECIFIC GRAVITY OF FRUITS

The work done in previous years had shown that the specific gravity of frozen fruit decreases and that the frost markings on the rind are unreliable as a means of separation (fig. 16). It was found through work done by Mr. D. C. Lefferts of Redlands, California, that frozen fruit was usually lighter in weight than sound fruit and that

Fig. 16.—Frozen and unfrozen Eureka lemons showing specific gravity of each fruit. The fruit with a specific gravity of .81 is free from frost markings and is apparently uninjured. It is, however, badly frozen. Photo by Smith, January 24, 1913.

by immersing a mixture of sound and frozen fruit in a suitable liquid, such as alcohol, the two classes could be separated. As this method of procedure proved to be fairly satisfactory, a machine was constructed for use in packing houses and a patent granted to Mr. D. C. Lefferts of Redlands and to Mr. George D. Parker of Riverside, covering the principle involved. Following the freeze of 1913 another method of separation, based on the specific gravity of frozen and unfrozen fruit was devised by Mr. Frank Chase of Riverside. (See description, page 297.)

In view of the great demand for exact information on this subject and because of its economic importance, a statistical study was made of the behavior of a number of oranges and lemons of varying degrees of injury by the frost.

Definite points on which information was desired were: (1) Do all frozen fruits have a lower specific gravity than any sound fruit? (2) If so, is the difference great enough to make it possible to separate the two classes absolutely? (3) How soon after the freeze is it possible to detect any difference that may occur? (4) What changes occur in the specific gravity of the fruit if it is picked from the tree and stored? (5) What explanation can be given of these changes?

The specific gravity of the individual fruits was found by dropping them in alcohol of varying specific gravity until that of the fruit and the alcohol was the same. Jars were prepared containing alcohol of specific gravity from .82 to .97 varying from each other by .01. The results obtained are summarized in table 5. For the sake of clearness only the figures for the best and worst fruit are presented. The intermediate classes of fruit which were only partially frozen, gave results which were in complete agreement with those presented.

TABLE 5.—*Average Specific Gravity of Fruit.*

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	0.876	0.850	0.876	0.850	0.890	0.860	0.890	0.860
18	0.876	0.840	0.872	0.846	0.907	0.833	0.879	0.834
22	0.884	0.838	0.874	0.834	0.926	0.807	0.889	0.803
26	0.885	0.832	0.870	0.820	0.930	....	0.887	....
30	0.884	0.821	0.864	0.810	0.941	....	0.869	....
2/ 3	0.894	0.812	....	....	0.953	....	....	....
7	0.903	....	0.873	....	0.959	....	0.881	....
11	0.914	....	....	....	0.966	....	....	....
15	0.923	....	0.880	....	0.968	....	.0873	....
19	0.928	....	....	....	....	....	....	....
23	0.936	....	0.871	....	....	....	0.863	....
27	0.936	....	....	....	....	....	....	....
3/ 3	....	....	0.869	....	....	....	0.862	....
11	....	....	0.866	....	....	....	0.865	....

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.

The first two columns in table 5 present the record of the oranges picked on January 13 and kept in storage, the specific gravity of the fruit being determined every four days. The average specific gravity of the stored navel oranges which were unfrozen incerased from .876 on the date of picking, to .936 on February 27. The average specific gravity of the badly frozen oranges in storage decreased from .850 on the date of picking to below .820 on February 3.* The third and

* A specific gravity of .820 was the lowest determined with the jars of alcohol. Where a lower specific gravity is shown in the tables it is of special fruits.

fourth columns give the specific gravities of successive new lots of oranges picked at intervals of four days. The specific gravity of these unfrozen oranges does not change appreciably, varying on both sides of .876. The specific gravity of the badly frozen oranges on the tree, however, decreased very rapidly from .850 on January 13 to below .820 on January 30. Stored lemons show the same changes in specific gravity but to a greater degree than was found in stored navel oranges. The sound lemons increased in specific gravity from .890 on January 14 to .968 on February 15, while the badly frozen lemons decreased from .860 on January 14 to below .820 on January 22. We also find that the fruits picked at different times during the experiment (columns 7 and 8), remain practically the same if unfrozen, but decreased very rapidly in specific gravity if badly frozen. We thus see that the specific gravity of the fruit which is frozen decreases rapidly whether it is picked and stored or remains on the tree and that the fruit which is unfrozen increases in specific gravity when picked from the tree and stored.

Of still more importance than the average specific gravity is that of the specific gravity of the individual fruit. It might be possible for the unfrozen fruit to have a much higher average than the frozen and yet the specific gravity be so variable among the individuals as to make a separation impossible. This is the condition for some time after the freeze. In table 6 is shown the records of individuals. The number of fruit of each density on the date of picking is shown and the number in the same lot of fruit two weeks later. The fruit was

Table 6.—*Number of Navel Oranges Picked on January 13, 1913 which had a Specific Gravity of Above or Below .87, and their Subsequent Changes.*

	Unfrozen		Frozen	
	.87 or above	below .87	.87 or above	below .87
Jan. 14, 1913	29	26	7	25
Jan. 26, 1913	41	14	6	26
Feb. 15, 1913	55	0	6	26

Number of Eureka Lemons Picked on January 13, With a Specific Gravity of Above or Below .89, and their Subsequent Changes.

	Unfrozen		Frozen	
	.89 or above	below .89	.89 or above	below .89
Jan. 13, 1913	61	3	12	32
Jan. 26, 1913	64	0	2	42
Feb. 15, 1913	64	0	1	43

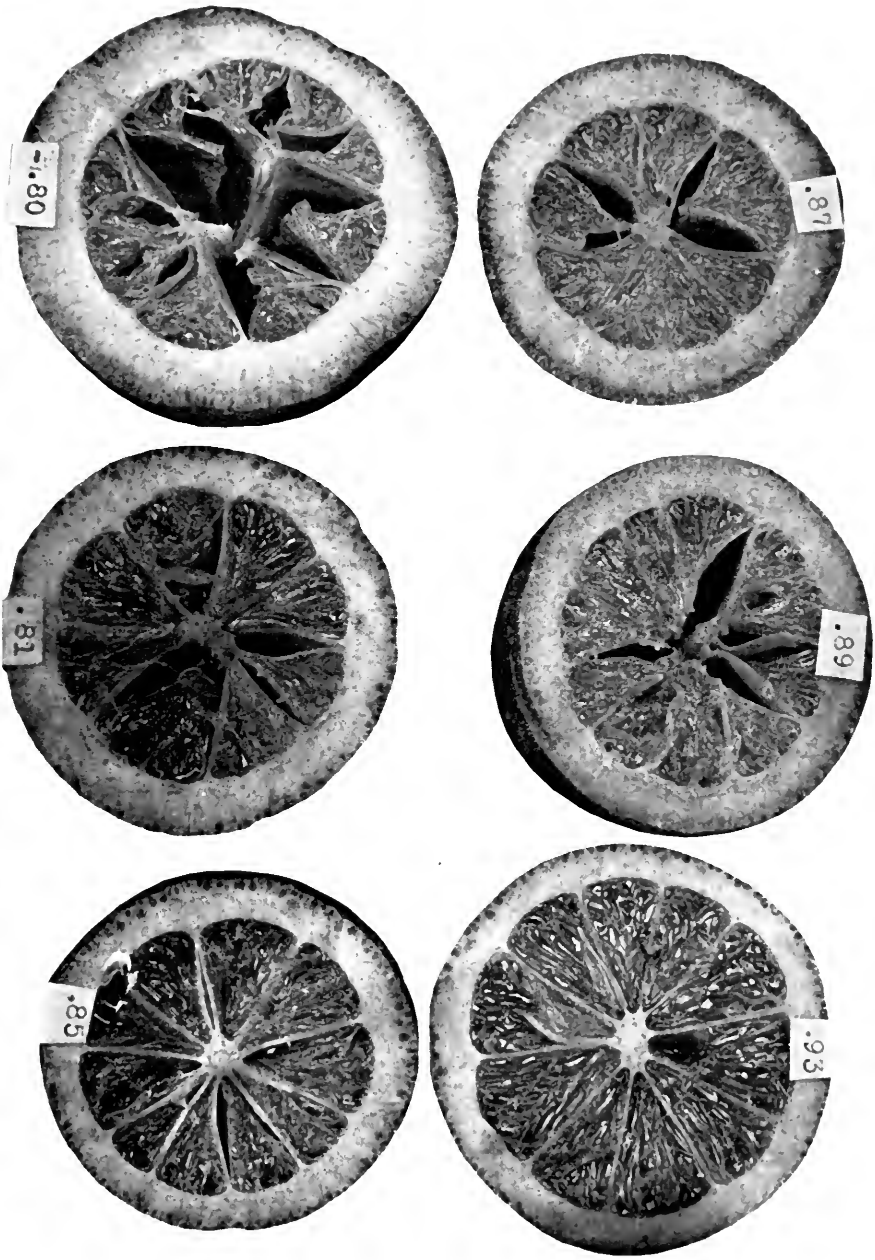

Fig. 17.—Frozen and unfrozen Eureka lemons showing specific gravity of each fruit.

Photo by Smith, January 24, 1913

classed "unfrozen" and "frozen" according to its appearance on being cut.

In the fruit picked on January 13, of the fifty-five sound oranges, twenty-nine had a specific gravity of .87 or more. Of the thirty-two frozen ones, seven were also .87 or more. If, therefore, an attempt had been made to separate the sound from the frozen using .87 as the point of separation, twenty-six good fruits would have gone out with the injured ones and seven frozen ones would have been retained. Two weeks later, however, a similar separation would have recovered forty-one good oranges and six frozen ones. At the end of a month, all of the sound oranges had a specific gravity of .87 or above, while all but six of the frozen fruit were below this point. The effectiveness of holding oranges two weeks or a month after picking, before separation, is, therefore, very clearly demonstrated.

Subsequent picks illustrate the same principle. The most favorable points of separation are not constant throughout, however, nor is the percentage of recovery absolutely uniform. In the fruit picked on January 18 the separation of the oranges would have been made at .88 two weeks after picking, to eliminate all frozen fruit, and thus five sound ones would have been lost. In fruit picked on January 22 the same point, .88, would have eliminated all frozen oranges, but it would also have thrown out twenty-five out of forty-two good ones. Even a separation at .84 would have lost five good ones, while including fourteen frozen ones. In such fruit a single separation becomes inefficient. By making three grades, one below .83, the other between .83 and .87, and the third above .87, very satisfactory results could have been obtained. By January 25 the frozen fruit on the trees had so decreased in specific gravity that it was possible to eliminate it quite completely. Even at this date, however, it was not possible to prevent some loss of good fruit unless the fruit was kept in storage for some time before the separation was made. In fruit picked on January 25, sixteen of the forty-two good oranges were .84 or below, while there were three frozen ones above that figure. Two weeks later there were still seven good oranges below .84 and five frozen ones above that point.

The lemons show a much sharper line of demarcation. On the date of picking, January 13, three of the sixty-four good lemons were below .89 in specific gravity and twelve of the forty-four frozen ones were .89 or above. Two weeks later all of the good lemons had a specific gravity of .89 or above and all but two frozen fruits (one of which is shown in figure 17) were below that mark, so that a very complete separation could have been effected.

Fig. 18.—Frozen and unfrozen Navel oranges, showing difference in thickness of rind. They were the same size, 3$\frac{1}{16}$ inches in diameter when picked, and two months later the unfrozen fruit, the one below, had a diameter of 2¾ inches while the frozen fruit had a diameter of 3 inches. Photo by Smith, March 28, 1913.

In different sections the specific gravity of the good fruit may be higher or lower than that found in the experiments here recorded, but the general conclusion will be the same in the various districts, namely, that the specific gravity of good fruit will increase in storage and that of frozen fruit will decrease.

The explanation of the change in specific gravity of sound and frozen fruit seems to be as follows: Freezing kills the walls of the cells in the fruit and so changes it from a living, semi-permeable membrane to a dead, porous mass, acting like a sponge. In the frozen fruit, therefore, connection is established between the rind and the pulp and the water which is evaporated from the outside of the rind is supplied from the pulp without the fruit suffering much diminution of volume. Losing weight and retaining approximately its original volume, it must, obviously, decrease in specific gravity. The unfrozen fruit on the other hand, loses very little, if any, moisture, except from the rind. This shrinks down very markedly and so decreases the volume of the fruit. As the weight does not decrease proportionately, the specific gravity increases. The difference in the evaporation from the rind is shown very clearly in figure 18. These two oranges were picked on January 13 and stored for two months. They were the same size, 3$\frac{1}{16}$ inches in diameter, on picking. When they were cut the sound fruit had decreased to 2$\frac{3}{4}$ inches while the frozen one had lost only $\frac{1}{16}$ inch, measuring 3 inches in diameter.

SPECIFIC GRAVITY OF JUICE

It was not possible to make a determination of the specific gravity of the juice on all of the samples used on account of their large number; therefore, the data which is presented in table 3 shows a rather irregular appearance. The specific gravity of the juice of unfrozen oranges in storage does not seem to change appreciably but it remains consistently greater than that of the frozen oranges. The juice of the frozen oranges in storage had an average specific gravity of 1.046 throughout a greater part of the experiment and increased quite markedly toward its expiration. The juice of the sound oranges had an average of 1.052 which remained approximately constant. The specific gravity of the juice of frozen oranges picked at different intervals did not increase, as with frozen oranges in storage, but remained constant (see table 7).

The average specific gravity of the juice of the lemons showed about the same differences. The juice of the sound fruit had a higher specific gravity than that of the frozen. There are more irregularities in the tables for lemons, due to the difficulty in getting samples of uniform ripeness. By January 30 the frozen lemons in storage had dried out so completely that it was no longer possible to get enough juice to determine the specific gravity. At this time twenty lemons which were picked on January 13 yielded a total of only thirty-one cubic centimeters of juice.

TABLE 7.—*Average Specific Gravity of Juice.*

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	1.053	....	1.053	....	1.060	....	1.060	....
18	1.052	1.042	1.052	1.044	1.042	1.042	1.048	1.046
22	1.055	1.044	1.056	1.046	1.050	1.041	1.053	1.046
26	1.047	1.046	1.055	1.047	1.045	1.040	1.044	1.041
30	1.050	1.045	1.045	1.040	1.046	1.038	1.046	1.037
2/ 3	1.051	....	1.045	1.043	1.046	....	1.040	....
7	1.056	....	1.045	1.045	1.050	....	1.045	1.038
11	1.053	1.044	1.050	1.048	....	....	1.044	....
15	....	....	1.053	1.048	1.052	....	1.042	1.038
19	1.048	1.050	....	....	1.051	....	1.042	1.038
23	....	....	1.056	1.042	....	....	....	....
27	1.055	1.054	....	....	....	....	....	....
3/ 3	....	....	....	....	....	....	....	....
11 Av.	1.052	1.046	1.051	1.045	1.049	1.040	1.046	1.040

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.

TABLE 8.—*Per Cent Total Sugar in Juice.**

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	10.56	....	10.56	....	3.39	....	3.39	....
18	9.18	6.54	8.92	7.86	2.85	2.47	2.64	3.16
22	8.87	7.08	9.43	7.51	2.88	2.12	3.12	2.89
26	8.07	7.28	9.39	7.44	2.07	2.41	2.94	2.47
30	8.32	7.29	7.50	6.38	2.83	2.33	3.67	2.95
2/ 7	9.11	....	8.09	6.99	2.71	3.14	2.57	1.60
15	9.67	....	7.85	7.01	2.69	....	2.77	2.24
23	9.17	7.17	9.00	8.03	....	....	2.96	2.54
3/ 3	....	....	10.11	8.82	2.79	....	2.57	2.11
7	9.28	7.96	....	....	....	....	....	....
11	....	....	9.41	6.94	....	....	3.30	2.21
15	8.42	8.63	....	....	2.97	....	....	....
Average	9.06	7.42	9.03	7.44	2.79	2.49	2.99	2.46

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.

* The sugars were determined by Bertrand's method.

SUGAR CONTENTS

The unfrozen oranges in storage show a variation in the amount of sugar present, but show no progressive changes, thus indicating that the variation is probably due to the difference in individual samples taken for analysis. The average of the unfrozen lots in storage was 9.06 per cent and the frozen 7.42 per cent throughout the experiment. The average percentage of sugar for the fruit picked at different dates was very close to that of the stored fruits, the difference being within the limits of experimental error. The percentage of sugar in the juice of the lemons shows the same kind of variation as was the case with the oranges (see table 8).

The great change which has been taking place in the fruit is more clearly illustrated when we consider the actual amount of sugar present in the individual fruits (table 9). While the figures for the total

TABLE 9.—*Grams of Sugar per Fruit.*

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	7.2	......	7.2	......	1.3	......	1.3	......
18	5.3	3.6	5.0	4.3	1.0	0.7	0.8	0.9
22	7.9	3.4	6.6	3.6	1.2	0.4	1.1	0.5
26	4.9	2.2	7.3	3.2	0.8	0.3	1.2	0.4
30	6.2	2.9	6.4	3.8	1.0	0.2	1.3	0.3
2/ 7	5.8	......	5.8	2.3	1.0	0.2	0.9	0.1
15	7.9	......	6.3	2.3	0.8	......	1.0	0.08
23	7.6	3.1	8.8	2.0	......	......	1.2	0.08
3/ 3	......	......	8.0	2.1	1.0	......	1.2	0.2
7	7.0	1.9	......	......	......	......	......	......
11	......	......	8.5	1.9	......	......	0.9	0.08
15	5.1	1.8	......	......	0.9	......	......	......

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.

amount of sugar given in grams per fruit is admittedly not exact, because of the difficulty of extracting all of the juice, yet, in view of the fact that the same size oranges, 150's, and lemons of standard ring size were used in all cases, it permits a basis of comparison that is more striking than the percentage composition. It is more important to know, for example, that on February 23rd the sound orange contained 8.8 grams of sugar, while the frozen one contained 2 grams, than it is that the percentage of sugar in the first lot was 9 per cent and in the second was 8.03 per cent. When we consider the average amount of sugar in grams per fruit, we find that in badly frozen oranges in storage it drops to less than 2 grams per fruit against an average of 6.5 grams for an unfrozen fruit. The fruit remaining on the tree showed almost the same difference, the frozen fruit dropping to the same point, while the good fruit showed a slightly greater average than the stored fruit, or 6.9 grams. The lemons again showed the same kind of variation as is found in the oranges, but in a different

TABLE 10.—*Per Cent Invert Sugar in Juice.*

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	4.69	....	4.69	....	2.36	....	2.36	....
18	4.10	3.39	4.13	3.75	2.11	1.53	2.26	2.03
22	4.33	3.60	4.17	3.76	2.24	1.55	2.09	1.85
26	4.06	3.76	4.70	3.88	1.74	1.56	2.30	1.57
30	4.35	3.60	3.66	3.37	1.91	1.48	2.46	1.89
2/ 7	4.60	....	3.49	3.57	2.26	2.09	1.98	1.30
15	5.16	....	3.48	3.73	2.22	....	2.35	1.73
23	4.88	3.56	4.00	3.71	....	....	2.30	1.79
3/ 3	....	....	4.77	3.85	2.25	1.42	1.99	1.50
7	5.18	3.35	....	....	....	....	....	....
11	....	....	4.11	3.45	....	....	2.66	1.74
15	4.87	3.95	....	....	2.42	....	....	....
Average	4.62	3.60	4.12	3.67	2.16	1.60	2.27	1.71

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.

TABLE 11.—*Per Cent Sucrose in Juice.*

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	5.87	....	5.87	....	1.03	....	1.03	....
18	5.08	3.15	4.79	4.11	0.74	0.94	0.38	1.13
22	4.54	3.48	5.26	3.75	0.62	0.50	1.03	1.04
26	4.01	3.52	4.69	3.76	0.33	0.85	0.64	0.90
30	3.97	3.69	3.84	3.01	0.92	0.85	1.21	1.06
2/ 7	4.51	....	4.60	3.42	0.45	1.05	0.59	0.30
15	4.51	....	4.37	3.28	0.43	....	0.42	0.51
23	4.29	3.61	5.00	4.32	....	....	0.66	0.75
3/ 3	....	....	5.34	4.97	0.54	....	0.58	0.61
7	4.10	4.61	....	....	....	....	....	....
11	....	....	5.30	3.49	....	....	0.64	0.47
15	3.55	4.68	....	....	0.55	....	....	....
Average	4.44	3.82	4.90	3.79	0.62	0.84	0.72	0.75

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.

degree. The unfrozen lemons held in storage averaged 1 gram of sugar per fruit, while those that were frozen decreased from .7 to .2 gram per fruit. The fruit which remained on the tree showed about the same amount of variation.

The tables for invert sugar and sucrose present data that is little different from those in the total sugar (see tables 10 and 11). In other words, there seems to be practically no change in the relative amounts of the different classes of sugar present.

ACID CONTENTS

The percentage of acid in the frozen and unfrozen oranges in storage decreased in almost the same degree. The fruit picked at different intervals showed the same change in acidity as the fruit in storage, but had a lower average. Owing to the fact that lemons have a much higher percentage of acid than do the oranges, a much greater variation is found between the unfrozen and frozen fruit. The unfrozen lemons kept in storage averaged 6.98 per cent acid throughout the experiment, while the frozen ones averaged 5.19 per cent. The acid in the fruit picked at different intervals averaged 6.27 per cent in unfrozen lemons and 4.79 per cent in frozen samples (see table 12).

TABLE 12.—*Per Cent Acid in Juice.**

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	1.56	....	1.56	....	5.81	....	5.81	....
18	1.56	1.60	1.45	1.38	5.70	5.01	6.64	4.23
22	1.67	1.62	1.68	1.49	6.96	5.34	7.23	5.02
26	1.47	1.74	1.69	1.83	7.54	4.74	....	4.67
30	1.68	1.88	1.53	1.59	7.67	4.98	6.49	3.66
2/ 7	1.68	....	1.50	1.51	7.00	5.26	6.53	4.72
15	1.59	....	1.31	1.34	6.72	....	6.32	5.18
23	1.40	1.29	1.22	1.37	....	....	5.64	4.72
3/ 3	....	....	1.38	1.15	7.76	5.79	6.19	5.73
7	1.19	1.14	....	....	....	....	....	....
11	....	....	1.20	1.21	....	....	....	5.23
15	1.11	1.20	....	....	7.73	....	5.65	....
Average	1.49	1.49	1.45	1.43	6.98	5.19	6.27	4.79

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.
* The acid was determined by titration, using phenolphthalein as an indicator and was calculated to anhydrous citric acid.

We find again, however, that, as with sugar, the total amount of acid present decreases very markedly in the frozen fruit. The frozen oranges showed .3 of a gram of acid per fruit, in comparison with an average of about 1 gram per fruit in unfrozen oranges. The unfrozen lemons vary to a considerable degree in the amount of acids present, ranging from 2 to 3 grams per fruit, while in the frozen fruit it practically all disappears (see table 13).

TABLE 13.—*Grams Acid Per Fruit.*

	Navel Oranges				Eureka Lemons			
	Stored lots (a)		Different picks (b)		Stored lots (a)		Different picks (b)	
Date	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
1/14	1.1	......	1.1	......	2.3	......	2.3	......
18	0.9	0.9	0.8	0.8	2.0	1.5	2.0	1.2
22	1.3	0.8	1.2	0.7	2.9	1.0	2.4	0.8
26	0.9	0.5	1.3	0.8	2.9	0.7	......	0.7
30	1.2	0.7	1.3	0.9	2.8	0.4	2.3	0.4
2/ 7	1.1	......	1.1	0.5	2.7	0.3	2.2	0.3
15	1.3	......	1.0	0.4	2.0	......	2.3	0.2
23	1.2	0.6	1.2	0.3	....	......	2.3	0.2
3/ 3	......	......	1.1	0.3	2.8	0.1	3.0	0.5
7	0.9	0.3	......	......	.... .	......	1.6	0.2
11	......	......	1.1	0.3	......	......	.....	......
15	0.7	0.3	.....	......	2.4	......	......	......

(a) Fruit picked on January 13th.
(b) Successive new lots picked on date given.

Following any severe freeze growers are confronted with the problem of whether injured fruit should be harvested immediately and used for by-products or whether the picking should be delayed until the extent of the injury becomes apparent. The rapid decrease that takes place in the amount of sugar and acid per fruit in both oranges and lemons as shown by the above tables, indicates that frozen fruit, if it is to be used for by-products should be picked and sold as soon after the freeze as possible.

GROWTH OF FROZEN FRUIT

When fruit is badly frozen the question arises whether the tree would be harmed should the fruit remain upon the branches until it falls naturally. If the frozen fruit did not grow, but remained on the tree in the same condition as when frozen, it would presumably take little nourishment from the tree with the exception of the moisture evaportaed from the rind. In order to determine this point, several hundred Valencia oranges were marked and measured and their growth was noted each month for four months. Groves for this work were chosen where part of the fruit was frozen while the remainder was untouched by the freeze. Different types of fruit were marked and only those with an apparently uninjured stem were selected for the experiment. In one class the fruit was green and normally would have increased in size. In another class the fruit was yellow and almost ripe and would not increase in size like the green fruit. In measuring the fruit the circumference was measured in inches. The same observations were carried on in regard to the growth of frozen lemons, and the results are given in the following table:

TABLE 14.—AVERAGE INCREASE IN CIRCUMFERENCE OF FROZEN AND UNFROZEN VALENCIAS AND LEMONS FROM JANUARY 24 TO JUNE 2, 1913

	Good fruit, full of juice and good flavor	Fruit slightly frozen	Fruit badly frozen
	inches	inches	inches
Valencia, yellow fruit which was very nearly ripe at the time of the freeze	.58	49	.21
Valencia, fruit green; thrifty groves not badly frozen	.71	.56	.41
Valencia, fruit green; grove badly frozen	.48	.34	.18
Valencia, fruit almost ripe and badly frozen	----	.33	.10
Eureka lemons—one-half of the fruit on the trees frozen	.71	.54	.32

From this table we see that the fruits have grown in circumference. In a few instances, however, the stem was found to be injured and the fruit gradually decreased in size. The juice had almost disappeared in the badly frozen fruit, leaving it hollow. In the good fruit the increase in circumference is approximately twice that of the badly frozen fruit. The rind of frozen fruits increases in thickness (fig. 19), thus probably taking nourishment, or at least water, from the tree.*

SUMMARY

1. The specific gravity of frozen citrus fruits, in general, is lower than that of unfrozen ones. This is, however, not an absolute rule.

2. The two classes cannot be absolutely separated, but the division is sufficiently complete to make it commercially practical. Different

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* *Note.*—Observations on various groves in the state lead the authors of the first article in this bulletin to conclude that no noticeable effect was produced by leaving the frozen fruits on the tree. Compare page 289. That the fruit when not too badly frozen increases in size the authors of this paper have proven. Such fruit, however, evidently losses in weight.—H. J. Webber.

machines have been perfected and are used in packing houses to make this separation.

3. Severely frozen fruit will usually show a marked decrease in specific gravity within a week; less severely injured fruit changes more slowly. In lemons the changes in specific gravity are more rapid than in oranges.

4. Holding the fruit for two weeks after picking increases the specific gravity of good fruit very markedly. A month is generally long enough to make a recognizable difference, but better separations can be obtained after six weeks or two mouths.

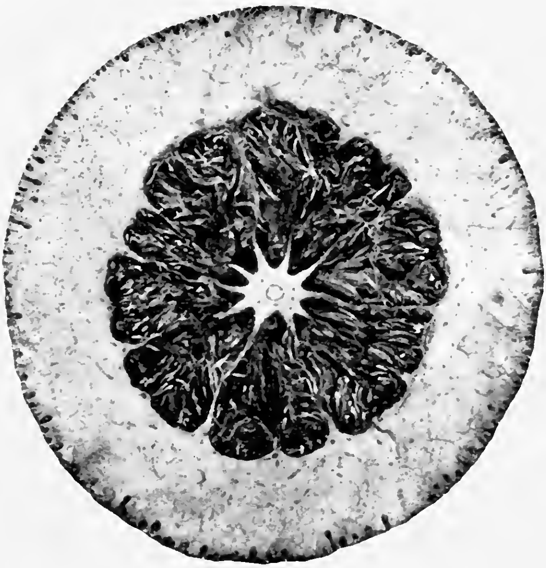

Fig. 19.—Badly frozen orange showing growth of rind when fruit remains on tree. Photo by Smith, March 7, 1913.

5. Frozen fruit decreases in specific gravity whether stored or left on the tree. Sound fruit, however, remains fairly constant on the trees, but gradually increases in density when stored.

6. The excessive loss of moisture in citrus fruits caused by freezing is due to the killing of the walls of the cells in the fruit, thus changing them form semi-permeable membranes to a porous substance that freely allows the liquid to evaporate from the interior without decreasing its volume. This loss in weight and not in volume decreases the specific gravity.

7. The specific gravity of the juice of frozen citrus fruit is somewhat lower than that of the unfrozen.

8. The total amount of sugars decreases in frozen fruit. The average amount in unfrozen oranges of size 150's being 6.5 grams, while in those that are frozen it decreases to less than 2 grams. The same holds true with lemons. Unfrozen lemons of standard ring size have an average of 1 gram per fruit, while those that are frozen decrease from .7 to .2 gram per fruit.

9. No change was found in the relative amounts of the different sugars present.

10. The per cent of acid in the juice of frozen citrus fruits decreases slightly when compared with the unfrozen. The weight of acid per fruit in unfrozen fruit remains nearly constant, while in that which is frozen it continues to decrease until practically none remains.

11. Frosted citrus fruits that remain on the tree continue to increase in size, this development being a thickening of the rind.

A TEST OF THE EFFICIENCY OF ORCHARD HEATING

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The serious damage done by the freeze of 1913 awakened a general interest in ways and means for protecting citrus orchards from this danger. In many sections various means of protection were in use during the freeze, but exact figures were lacking in many cases as to the profitableness of the heating methods used.

The opportunity of securing some practical information in an experimental way on the results that had been obtained seemed too good to lose. Consequently the writers in co-operation with Dr. H. J. Webber of the Citrus Experiment Station of the University of California decided to secure data on this subject in connection with their citrus performance-record work for the improvement of citrus fruits by bud selection.

After consultation it was decided to confine observations to lemon varieties and to orchards located in the Corona district. In this district an unusual number of groves were protected by heaters during the freeze, and in many cases unprotected orchards adjoined the protected ones.

Shortly after the freeze, a committee of Corona lemon growers, Dr. H. J. Webber, and the writers visited most of the lemon groves in the Corona district for the purpose of determining whether or not reliable data on the efficiency of the methods of orchard protection could be obtained. After a careful survey of the situation, it was unanimously decided that such information could be secured under fair and comparable conditions. Therefore, several orchards were selected for study and observation that in the opinion of every one in the party were suitable for this purpose.

The plan of study agreed upon was to keep performance-records of comparable plots of trees in heated and unheated groves, beginning with the first pick after the frost and continuing for at least one year, and if advisable for a longer period of time.

It was soon apparent that lemon varieties differ in their resistance to frost. So it became necessary to compare heated and unheated orchards of the same variety. Not only was this difference very evident, but different types in the same variety apparently differ in resistance to frost, so that it became necessary to compare trees of the same type in heated and unheated groves.

Fig. 20.—The effect of the freeze on unheated Lisbon lemon tree. Compare fig. 21.

In view of the great amount of detailed record-keeping involved for each individual tree, it was found necessary to limit the number of trees for observation. In order to combine reliability of data and limit the number of trees to the smallest possible number, the following plan of plot arrangement was carried out. First, comparable orchards were selected. Then a plot of ten trees in each orchard was arranged on the following basis: Two adjoining trees were marked for observation. Counting these trees as numbers 1 and 2, respectively, the ninth and tenth trees in the same row were also marked. Corresponding trees, ten rows from this row, were then marked, so that the marked trees were the two end trees in a square of one hundred trees. In addition to these eight trees, two trees in the middle of the square were also marked, thus completing the plot.

Fig. 21.—Lisbon lemon tree in grove heated with one stove per tree, crop and tree practically uninjured. Cómpare fig. 20.

This plot arrangement is illustrated by the following diagram:

Record Plot Arrangement

1	2	×	×	×	×	×	×	3	4
×	×	×	×	×	×	×	×	×	×
×	×	×	×	×	×	×	×	×	×
×	×	×	×	×	×	×	×	×	×
×	×	×	×	5	6	×	×	×	×
×	×	×	×	×	×	×	×	×	×
×	×	×	×	×	×	×	×	×	×
×	×	×	×	×	×	×	×	×	×
×	×	×	×	×	×	×	×	×	×
7	8	×	×	×	×	×	×	9	10

The figures in the diagram represent the locations of trees studied.

This arrangement eliminated the personal equation in tree selection, care being taken that the trees of a given variety were of the same general type. Great care was also used to prevent other influences on production than the heating methods used from interfering with the results. Naturally, all observable influences on individual tree-production which might tend to interfere with the results or modify them were considered in locating the plots. From our experience

Fig. 22.—The effect of the freeze on unheated Eureka lemon tree. Such trees have since recovered, but two years' crops were lost.

with these plots since their selection, we feel sure that the results represent fairly the influences of heating as compared with no heating.

The crops from all the trees were picked at regular intervals for one year. After completing one year's data, it was decided that it was unnecessary to continue records in all of the plots for a second year. Two plots, one heated and one not heated, were selected for the second year's data, and records from all of the other plots were discontinued. The difference in production between the heated and unheated plots was found to be considerable the second year.

During the experiment each tree was picked separately. The fruits were sorted into four grades—green, tree-ripe, frozen, and culls.

After sorting, the fruits of each grade were counted and weighed. The percentage of each of these four grades of fruit produced on each plot is given in the following table, and is self-explanatory.

The average cost of heating in the orchards where the plots were located has also been secured from records kept by the growers for this purpose.

TABLE 15

PERCENTAGES OF DIFFERENT GRADES OF FRUIT ON EACH PLOT.
Figures based on *weight* of fruit in the crop of the year.

LISBONS

	Heated Plots		*Unheated Plots*	
	61.4%	Green	19.2%	
	26.5%	Tree Ripe	4.8%	
Plot 4	10.6%	Frozen	74.3%	Plot 1
	1.6%	Culls	1.6%	
	74.4%	Green	31.3%	
	17.1%	Tree Ripe	1.6%	
Plot 6	6.5%	Frozen	66.8%	Plot 8
	2.1%	Culls	0.2%	
	57.2%	Green	10.5%	
	39.4%	Tree Ripe	6.1%	
Plot 9	1.6%	Frozen	83.2%	Plot 10
	1.9%	Culls	0.2%	
		Average of the three series.		
	64.3%	Green	20.4%	
	27.7%	Tree Ripe	4.2%	
	6.2%	Frozen	74.8%	
	1.9%	Culls	0.7%	

EUREKAS

	Plot 7 *Well heated*	Plot 5 *Poorly heated*	Plot 3 *Unheated*
Green	50.7%	39.9%	32.3%
Tree Ripe	43.2%	42.4%	7.3%
Frozen	2.6%	14.1%	58.0%
Culls	3.5%	3.6%	2.4%

UNHEATED EUREKAS VS UNHEATED LISBONS

	Unheated Eurekas		*Unheated Lisbons*	
	32.3%	Green	49.5%	
	7.3%	Tree Ripe	7.8%	
Plot 3	58.0%	Frozen	40.7%	Plot 2
	2.4%	Culls	2.1%	

Both plot 3 and plot 2 were partially protected by heaters in neighboring groves

Table 16

Returns per Acre, F.O.B. Packing House.

Lisbons

Heated Plots	*Unheated Plots*
Plot 4	*Plot 1*
$1759.59	$424.22
Plot 6	*Plot 8*
$888.00	$300.98
Plot 9	*Plot 10*
$2563.46	$128.15
Average of the three series	
$1737.02	$284.45

Eurekas

Plot 7	*Plot 5*	*Plot 3*
Well Heated	*Poorly Heated*	*Unheated*
$1423.06	$768.47	$352.54

Unheated Eurekas vs unheated Lisbons

Plot 3	*Plot 2*
Unheated Eurekas	*Unheated Lisbons*
$352.54	$1126.35

Plots 3 and 2 were partially protected by heaters in neighboring groves.

Table 17

Average Cost of Heating Per Acre on All Heated Plots in the Experiments

Stoves		
Cost	$53.29	
Interest	3.20	
	$56.49	
Depreciation, 33⅓%		$18.78
Reservoir and pipe lines		
Cost	$32.82	
Interest	1.97	
	$34.79	
Depreciation, 10%		3.48
Oil used		57.95
Filling pots, lighting and refilling		21.09
Total average cost		$101.30

The value of the fruit in the different plots, computed to the acre basis, was secured through the owners of the orchards who furnished the figures of the actual returns for this fruit during the period of observation, and it, together with the average cost of heating, will be found summarized in tables 16 and 17.

The writers do not believe it to be necessary for them to comment on the results, as the tables are self-explanatory. They hope that it may prove to be of some value, in that it shows the actual behavior of heated and unheated Eureka and Lisbon lemon trees in the Corona district for the year following the freeze.

The observations presented here were made possible by the hearty co-operation of the lemon growers owning the orchards in which experiment plots were located. All of the expense of picking, loss of fruit due to cutting, information as to cost of heating, value of crop, and other factors have been furnished by these growers.

The writers' only concern has been to secure reliable data to add to the subject of the practical value of orchard protection as a whole.

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165. Fundamentals of Sugar Beets under California Conditions.
166. The County Farm Bureau.
167. Feeding Stuffs of Minor Importance.
168. Spraying for the Control of Wild Morning-Glory within the Fog Belt.
169. The 1918 Grain Crop.
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172. Wheat Culture.
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175. Progress Report on the Marketing and Distribution of Milk.
176. Hog Cholera Prevention and the Serum Treatment.
177. Grain Sorghums.
179. Factors of Importance in Producing Milk of Low Bacterial Count.
181. Control of the California Ground Squirrel.
182. Extending the Area of Irrigated Wheat in California for 1918.
183. Infectious Abortion in Cows.
184. A Flock of Sheep on the Farm.
185. Beekeeping for the Fruit-Grower and Small Rancher, or Amateur.
186. Poultry on the Farm.
187. Utilizing the Sorghums.
188. Lambing Sheds.
189. Winter Forage Crops.
191. Pruning the Seedless Grapes.
192. Cotton in the San Joaquin Valley.
193. A Study of Farm Labor in California.
196. Dairy Calves for Veal.
197. Suggestions for Increasing Egg Production in a Time of High-Feed Prices.
198. Syrup from Sweet Sorghum.
199. Onion Growing in California.
200. Growing the Fall or Second Crop of Potatoes in California.
201. Helpful Hints to Hog Raisers.
202. County Organization for Rural Fire Control.
203. Peat as a Manure Substitute.
204. Blackleg.