CITRUS FRUITS

BY

J. E. COIT

The Rural Science Series

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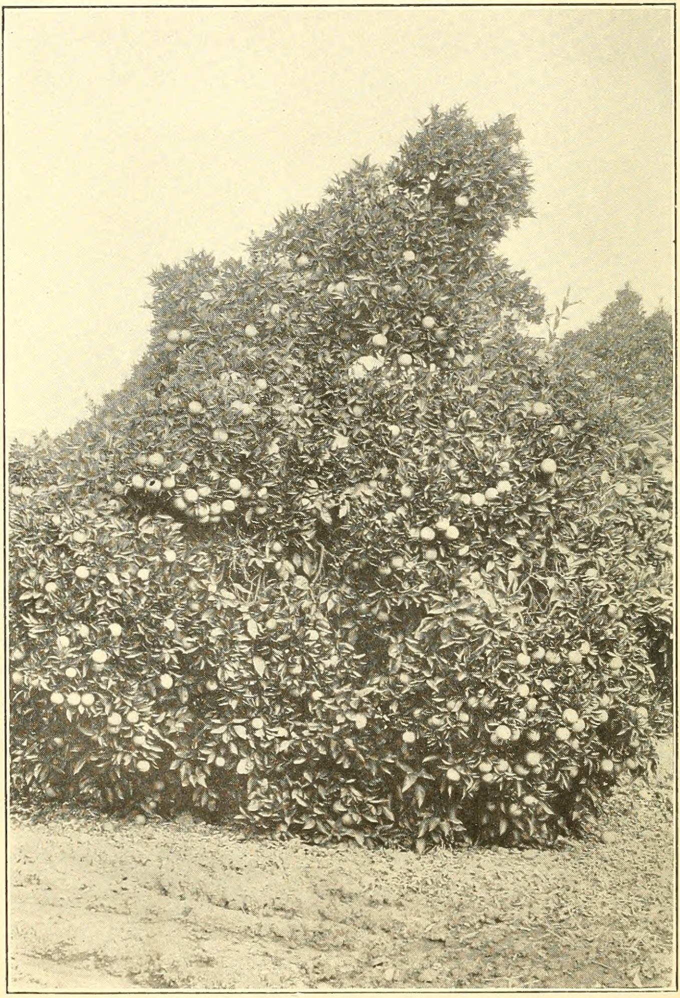

THE WASHINGTON NAVEL ORANGE

CITRUS FRUITS

AN ACCOUNT OF THE CITRUS FRUIT INDUSTRY
WITH SPECIAL REFERENCE TO CALIFORNIA
REQUIREMENTS AND PRACTICES
AND SIMILAR CONDITIONS

BY

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PREFACE

THE citrus industry has now reached a high state of development in both California and Florida. Furthermore, it is progressing with rapid strides. Old World practices and precedents have been largely ignored in the development of an industry characteristically American in spirit and new in methods. The readiness with which the growers adopt new and better methods is an indication of the virility and youthful vigor of this new industry.

The literature has hardly kept pace with the industry and is scattered through a large number of periodicals and reports. On this account, it is largely unavailable to those who need it most. The last comprehensive work published in California was that of Lelong in 1902. This quickly ran out of print and for the last six years has been rare.

The present volume represents an attempt to discuss underlying principles in such a way as to emphasize the importance of certain stable fundamentals upon which the rapidly changing superstructure is built. It has also been the aim to describe the industry as it exists to-day, and bring together in orderly arrangement all the information available at this time which is worth while.

The author has enjoyed the coöperation and assistance of many friends. The chapter on History and Development has been read and criticised by J. M. Guinn of Los Angeles. Professors E. J. Wickson, E. B. Babcock, B. A. Etcheverry, W. T. Horne, and H. J. Quayle, together with Messrs. W. S. Reed and E. O. Essig, have kindly read and criticised parts of the manuscript. E. G. Dezell of the California Fruit Growers' Exchange read the chapter on Marketing. I am indebted to my co-worker, I. J. Condit, for contributing parts of the chapters on insects and fumigation. For cordial coöperation in taking the atmometer records reported on in Chapter XII, I am under obligation to W. M. Mertz of the Citrus Experiment Station. Some historical and other data used in Chapter XIV on "Frosts and Orchard Heating" has been taken from the excellent graduating thesis of Carl Nichols.

For the use of certain illustrations I am indebted as follows: to Carl Nichols for Nos. 10, 14, 15, 64, 65, and 86; to W. I. Jones for Nos. 57 and 58; to the Roeding & Wood Nursery Company for Nos. 110, 111, & 119; to L. H. Moore for Nos. 113 and 120; to Professor H. S. Fawcett for No. 128; to Professor H. J. Quayle for Nos. 139, 141, 142, 143, 144, 145, and 147; and to Professor C. W. Woodworth for No. 151.

J. ELIOT COIT.

BERKELEY, CALIFORNIA,
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CHAPTER I

HISTORY AND DEVELOPMENT OF THE CITRUS INDUSTRY IN THE SOUTHWESTERN UNITED STATES

Citrus seeds were first brought into California from the peninsula of Lower California, where peoples of Spanish descent have cultivated various kinds of European fruit trees and vines since the year 1701. In 1768 the Jesuit missionaries were supplanted by the Franciscans, some of whom under the leadership of Junipero Serra pushed northward into the territory which is now the state of California. These hardy pioneers founded the first mission in Upper California at San Diego in 1769, and proceeding northward established a chain of missions extending four hundred miles along the coast, the last being established at Somoma in 1823.

At a number of these missions, vineyards and orchards were planted. Cuttings of grapes and figs, and seeds of oranges, pomegranates, citrons, olives, pears, dates, and other fruits were brought from the older missions on the peninsula. At several missions the remnants of the old orchards may still be seen, partly inclosed by the adobe walls which were built to protect the trees from wandering herds of cattle.

The San Gabriel Mission near the present city of Los Angeles, by reason of the abundance of water and the large number of neophytes brought into service, gained rapidly in wealth and productiveness. The exact date when orange seed were first planted at this mission is not known, as the archives of the mission church are lost. It is certain, however, that the first California orange orchard of any size occurred at San Gabriel, and various writers agree that this orchard must have been planted in 1804 or the following year. This first orchard covered about six acres of ground and was composed of about four hundred seedling trees, a few of which were still bearing in 1885.

Although this orchard was not planted for financial gain, and it is doubtful if any fruit was ever sold from it, the success of this pioneer planting established the fact that the climate and soil conditions were quite favorable to the production of citrus fruits.

Soon orange trees distributed from the missions began to be planted in court-yards and gardens in various places, the fruits being either all consumed at home or given away to friends. Perhaps the largest number of trees in any private garden were the thirty-five trees transplanted from San Gabriel about the year 1834 to Aliso Street in Los Angeles, by Don Louis Vignes. It remained, however, for William Wolfskill, a Kentucky trapper of German blood, who had come to Los Angeles overland in 1831, to forecast the commercial possibilities of this fruit. Wolfskill secured orange trees from the San Gabriel Mission in 1841 and planted a two-acre orchard in what is now the city of Los Angeles, on the spot now occupied by the Arcade passenger station of the Southern Pacific Railroad. The fruit from this orchard sold to such advantage that it was increased in size to about twenty-eight and finally to seventy acres. It is said that Wolfskill was the first to ship a full car of oranges to Eastern markets. They were sent to St. Louis in 1877 and arrived in good condition after having been a month in transit. The freight charge is said to have been $500. The last crop disposed of in his lifetime sold on the trees for $25,000.

The success of the Wolfskill orchard stimulated others, and in 1853 Matthew Keller secured orange seeds from Central America and also from Hawaii. From these he raised young trees with which he planted an orchard opposite that of Wolfskill. In 1857 L. Van Leuven planted orange trees at Old San Bernardino, and in the same year L. F. Cram planted a small orchard at Highlands. Myron H. Crafts planted two hundred orange trees at Crafton in 1865.

In September, 1870, J. W. North of Knoxville, Tennessee, bought four thousand acres of desert land which is now occupied by the city of Riverside. Judge North carried on an advertising campaign in the Eastern states to attract colonists to this land. Settlers began to arrive the following winter, and in the spring of 1871 the first orange seeds were planted.

This means of settling the country was used in various parts of California. Pasadena was first known as the Indiana Colony, the lands being purchased in 1873, distributed in 1874, and orange orchards planted as soon as the ground was leveled and irrigation water provided.

Frank A. Kimball planted orange and lemon trees at National City in San Diego County about 1870.

A large proportion of the trees planted at this time were purchased from the nursery of T. A. Garey in Los Angeles (Fig. 1). Garey imported a large number of varieties from various places during the years 1868 to 1875. He is said to have received shipments of trees from Australia, southern Europe, and Florida, as well as from the nurseries of Ellwanger and Barry of Rochester, N. Y., and Sir Thomas Rivers of Sawbridgeworth, England.

Fig. 1. — Thomas A. Garey, a pioneer citrus nurseryman.

The fruit from these primitive orchards was either consumed in the neighborhood of its production or hauled to Los Angeles and there shipped to northern ports by water. Southern California still lacked railroad connection with the Eastern markets and there was no incentive to grow more oranges than sufficed for local consumption.

Orange trees were first planted in the central and northern part of California in the early sixties. The first planting of which we have record was at Bidwell in Butte County in 1859. In a great many cases these early plantings proved successful, and it was soon apparent that areas of greater or less extent, suitable for the growth of citrus fruits, existed in many scattered locations all the way from San Diego in the south to Shasta County in the north.

The commercial development of citrus culture may be said to have begun with the completion of the Southern Pacific Railroad's connections with the East. The Valley line was completed in 1876 and the Southern line to New Orleans in 1881. The exhibition of the first fruits of the Washington Navel orange at Riverside gave another impetus to citrus planting, but the greatest development came with the completion of the Santa Fe's competing line of railroad, which was opened up about 1885. The first special train loaded exclusively with oranges left the River Station, Los Angeles, February 14, 1886, for the East via the Southern Pacific and Union Pacific Railroads.

In February ,1879, what was probably the first of a series of annual citrus fairs was held at Riverside. The different citrus-growing communities of southern California took great interest in these fairs, and the prizes together with the prestige which they carried were vigorously competed for. It was at these early citrus fairs that the great superiority of the Washington Navel orange, the history of which is given on another page, became apparent. The climate and soil conditions in California proved eminently suited to this variety of orange, which here attained a perfection truly marvelous. The strong demand for these oranges in the Eastern markets and the high prices received by some brought on a period of frenzied planting and speculation. A great deal of worthless nursery stock, quickly and cheaply grown on Chinese lemon roots, was planted, and many orchards were set out on lands more or less unsuited to citrus culture. This wave of rapid expansion culminated in 1885–86, when drouth, frosts, scale insects, and the lack of a coherent marketing organization conspired to rudely awaken from their golden dreams many who had rushed into the business with insufficient knowledge and capital to weather a period of depression.

In 1884, at the Cotton Exposition held in New Orleans, the twenty varieties of oranges grown and exhibited by Riverside took first premium in competition with the world. This fact was heralded far and wide and proved of great value in advertising the California citrus business in general and Riverside in particular.

In the early days of the industry there was no adequate horticultural inspection or quarantine service, and as a consequence a number of kinds of very destructive scale insect pests were introduced on nursery stock imported from various parts of the world. In this way the cottony cushion scale (*Icerya purchasi*) was introduced from Australia in 1868. In twenty years this scale spread throughout the orchards of Los Angeles County. So serious was this pest that the industry, in Los Angeles County at least, was on the verge of extinction.

In the spring of 1888 Albert Koebele was sent to Australia by the U. S. Department of Agriculture to study the cottony cushion scale in its native land. The following year Koebele succeeded in introducing the *Novius cardinalis*, a small predaceous ladybird beetle, which at once attacked the scale and preyed upon it to such an extent that it was checked in its spread, and in many localities it was almost exterminated. As a consequence, in 1891, the shipments from Los Angeles County suddenly increased from 781 to 2212 cars, a net gain of 1431 cars, due, at least in large part, to the good work of the ladybird. Since the introduction of this predaceous beetle the white scale has been held in check and is not now feared by citrus growers.

The fight with the cottony cushion scale had hardly been won, however, when other difficulties appeared. Although the orchards produced large crops it became more and more difficult to successfully market the fruit. The season of 1892–93 was particularly disastrous as far as net returns were concerned. The growers were not organized, and as long as each grower attempted to market his own fruit he became an easy prey to the miscellaneous assortment of commission men, agents, and speculators who at that time infested the markets and who in many cases, it is said, secured secret rebates from the railroads. In Riverside and in all the older sections, where there was any quantity of fruit to ship, account sales in "red ink" were received without number, and it frequently happened that the larger crop a grower had, the more he was indebted to his packer at the end of the season. As a result of these failures to successfully market large crops, a few of the growers began to associate themselves together for mutual protection and to provide better packing facilities. Stimulated by the success of some of these associations in gaining concessions from the railroads and in many other ways securing better returns for their members, a large percentage of the growers assembled at the Chamber of Commerce in Los Angeles on April 4th, 1893, the declared purpose of the meeting being: "To provide for the marketing of all the citrus fruit at the lowest possible cost under uniform methods, and in a manner to secure to each grower the certain marketing of his fruit and the full average price to be obtained in the market for the entire season." At this meeting a coöperative packing and marketing organization was formed, which, while not entirely satisfactory, was a great improvement over the old methods and served to prepare the way for the Southern California Fruit Exchange, which was organized October 21, 1895. At first the Exchange handled about 32 per cent of the total shipments, but the proportion of the crop handled has gradually increased till at the present time the Exchange ships about 62 per cent of the total crop.

On March 27, 1905, the California Fruit Growers' Exchange was incorporated, and on September 1, following, succeeded to the business of the Southern California Fruit Exchange, this change in name being deemed advisable in order that the marketing organization itself might in name as well as in fact become general throughout the state rather than remain local to southern California. The Exchange is now an association of three groups or classes of organizations: the one hundred and fifteen local associations; the seventeen district exchanges; and the central exchange. For a detailed description of this rather complex organization see pages 345 to 353.

CALIFORNIA CITRUS SHIPMENTS

SEASON	CARLOADS	SEASON	CARLOADS	SEASON	CARLOADS
1890–91	4016	1898–99	10875	1906–07	29820
1891–92	4400	1899–00	18400	1907–08	32729
1892–93	5871	1900–01	24900	1908–09	40592
1893–94	5022	1901–02	19180	1909–10	32648
1894–95	7575	1902–03	23871	1910–11	46394
1895–96	6915	1903–04	29399	1911–12	40673
1896–97	7350	1904–05	31422	1912–13	18960
1897–98	15400	1905–06	27610	1913–14	48548

Not the least important factor in building up the citrus industry has been the protective duties imposed upon citrus imports by the Congress of the United States. Such protective duties have prevailed since July 4, 1789, when a general tariff bill was passed which included a 5 per cent ad valorem duty on all citrus fruits. Since that time the duty has been gradually, though not uniformly, increased by the enactment at different times of nineteen changes in the law. By the Underwood-Simmons tariff act, effective October 4, 1913, the duty is one-half cent per pound on oranges, lemons, pomelos, and limes. Orange peel or lemon peel, preserved, candied, or dried, one cent per pound; citron or citron peel, preserved, candied, or dried, two cents per pound. Citric acid, five cents per pound. Citrate of lime, one cent per pound. Orange and lemon oil, ten per cent ad valorem. Bergamot, neroli, or orange flower oil, twenty per cent ad valorem. The free list includes fruits in brine; lemon, lime, and sour orange juice containing not more than two per cent of alcohol; and orange and lemon peel not preserved, candied, or dried.

California citrus culture, among all horticultural industries, is peculiar in that the people who have built it up have been, in many cases, retired business men or professional men from the New England and Central states. Persons who have lost their health in the process of gaining wealth have bought and developed citrus properties, the management of which, by requiring a life in the open sunshine and dry air, has resulted in renewed health and steadied nerves. These people brought to the industry much needed capital, commercial habits, and business ability. Citrus culture appeals to people of intelligence and refinement, and such are being drawn from many occupations. Now since the automobile has come into such general use, the wealthy business man of the city builds a residence in his orange orchard in the suburbs, while along the interurban electric lines may be found the small orchards of the superannuated minister, the retired high school teacher, the lawyer, the doctor, as well as of those drawn from other walks of life.

The result of this has been the development of an industry characteristically American in spirit and new in methods. The sons and grandsons of pioneers from the West and middle West have little regard for the precedents and practices of the Old World citrus-producing regions. European methods are practically ignored in systems of cultivation, irrigation, and pruning. In their readiness to organize among themselves along business lines and work together for the better picking, packing, and marketing of the fruit, the California citrus growers are probably in advance of any other class of fruit growers on earth.

The citrus industry has also been greatly benefited by various government agencies, whose endeavor has been to increase knowledge through scientific investigations and disseminate this new information through free lectures and pamphlets, by experiment farms, and by operating for months at a time free demonstration trains on the railroads. There have been three principal agencies engaged in this work: the University of California Agricultural Experiment Station, the United States Department of Agriculture, and the State Horticultural Commission. The university work may be said to have begun with the analyses of oranges and lemons in 1885 and continued to date, covering a multitude of problems affecting the industry. The university conducts a special correspondence course on citrus fruits for the benefit of growers everywhere. The agents of the Department of Agriculture have rendered valuable service to the industry in many ways. The State Commission of Horticulture has done much good work in preventing the entrance into the state of new pests and checking the spread of pests already introduced. It has distributed many valuable publications, the one prepared by Lelong [1] in 1902 being of special value to the industry.

A large number of strong, loyal agricultural and horticultural periodicals throughout the state have broadcasted useful information and fanned the flame of popular interest.

Still another upbuilding agency has been the Chambers

[1] B. M. Lelong, "Culture of the Citrus in California," 1902.

of Commerce in the various towns and cities. By maintaining interesting and attractive exhibits with free stereopticon lectures for visitors and tourists, and by preparing large exhibits for distant expositions, they have done a great deal to advertise the industry.

Citrus culture in California will always be a popular occupation because it appeals to a man from so many sides. It appeals to his love of the beautiful; beckons him to healthful outdoor life; stimulates that inborn desire in man to make things grow; satisfies his appetite, and last, but by no means least, it tempts him with offers of large financial rewards. Successful citrus culture calls for a combination of the science and the art of horticulture; requiring both skill and industry, it gives healthful occupation to the mind as well as the body. While a good many seedling orchards still persist in the older sections, they are gradually yielding (Fig. 2) to the activities of the woodchopper.

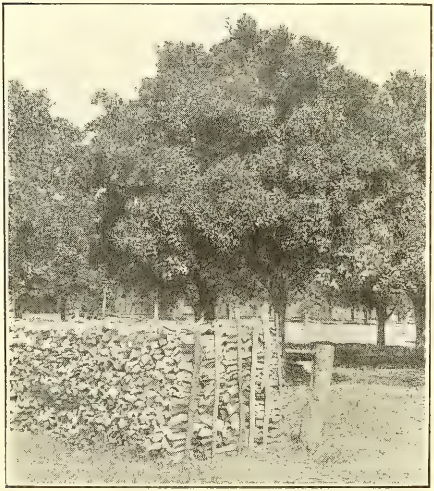

Fig. 2. — The passing of the old seedling orange groves.

HISTORY OF THE WASHINGTON NAVEL OR BAHIA ORANGE

The earliest illustrated description of a Navel orange on record was published in Rome by a monk of the Society of Jesus, John Baptiste Ferrarius, in 1646, in one of four books called "The Hesperides or About the Golden Apples, Their Culture and Use." The picture reproduced on page 52 of Lelong's "Culture of the Citrus in California," from John Johnson's book, will be seen on close comparison to be an artful copy from Ferrarius. This was certainly not the Washington Navel as we have it to-day, but merely one of the many Navel forms which have appeared from time to time. It is not unlikely that still other kinds of Navels will appear in the future.

Orange trees were taken to Brazil by the Spaniards at a very early day and were more or less widely planted in those parts of the country best suited to their culture. Some time about the year 1820 or possibly earlier there appeared near the village of Bahia a form of Navel orange which was remarkable for its many good qualities. This was what we now know as the Washington Navel. It was hastily propagated and planted to a considerable extent. Specimens were sent to London and the form became known abroad under the name *Bahia*, after the village where it originated. At Bahia it was called simply "*Lavanja de Umbigo.*"

Circumstantial evidence from several directions all points to the probability that from the very beginning one characteristic of this Navel orange was to produce occasional branches which bore fruit differing from that of the rest of the tree. In this way a modified form came into existence, the fruit of which was scant in amount, large in size, with a coarse exterior, and interior full of rag. Unwittingly this form was propagated along with the true Bahia. After years of experience the best Brazilian growers became aware of this sporting habit and were careful to select buds for propagation from the best type only. The peasants, however, did not comprehend the situation, and as the demand increased, continued to cut bud wood indiscriminately. On account of the publicity given the fruit sent to London, a trade in nursery trees sprang up. Agents from Rio de Janeiro went to Bahia and secured what was available, including both the prototype and the false type. Thus it is natural to suppose that the stock on the Rio de Janeiro market must have consisted of some lots of Bahia, some of false Bahia, and some mixed lots.

There is a tradition that this Bahia Navel was introduced into Florida some time previous to 1835, but that the trees were killed in the freeze of that year. It is said that the Bahia Navel was introduced into Cape Colony, South Africa, by a Mr. Brehm of Uitenhage about 1840. The subsequent record of these trees shows that Brehm's importation consisted entirely of the false form. On this account the Bahia was held in ill repute in South Africa, until between 1894 and 1900, when a number of importations of the true Bahia were made direct from California. The fruit of these has been found equal in every respect to the best California product, and most of the old orchards have now been budded over.

From Brazil the Sweet orange was first introduced into New South Wales, Australia, by Captain Hunter, who accompanied Gen. Arthur Phillip at the founding of the colony in 1788.

Orange growers in Australia early introduced the Bahia Navel direct from Brazil. One writer in 1858 states that Navel oranges were for sale in Australian markets, and that they brought a much higher price than other varieties. I have been unable to discover the exact date of introduction, but oranges were exported in considerable amounts from New South Wales in 1860, and it is perhaps safe to assume that at least a part of these were Bahias, since a writer in the *Victorian Farmer's Journal* in 1862 states that on account of the high prices received, the "Bahia Navel" was largely grown. From these statements it would seem that the date of the introduction of the Navel into Australia should be given as not later than 1850. Australian writers are not unanimous in praise of the Navel and this indicates that both the true and the false form existed there as early as 1860. We may conclude, therefore, that this orange was grown commercially and was marketed under the name of Bahia or Navel orange as early as 1860.

S. B. Parsons, a nurseryman of Flushing, Long Island, owned a small nursery at Blue Spring, Florida. Wishing to secure this Bahia Navel for propagation and sale, he ordered trees in 1868 from Thomas Rivers, a large nurseryman of Sawbridgeworth, England, who had received his stock from the Azores, to which place they were said to have been brought from Brazil. (In all probability they were not.) This orange proved not to be the Bahia Navel, and has since been known as the Parsons Navel. Thomas Rivers also sold some of the same lot of trees to

A. B. Chapman of San Gabriel, California, in 1870 or 1871. Some of these were propagated and sold by Mr. Chapman as the Rivers Navel.

Thomas A. Garey, a well-known California nurseryman and author of a book on orange culture,[1] established a citrus nursery in Los Angeles in 1865. Some of his associates now living inform me that he imported citrus seeds and trees from Australia, Mexico, Central America, and southern Europe. He is said to have secured the Navel in 1870, and it is an open question as to where he got it, with the probability strongly in favor of Australia. I have a copy of his catalogue dated 1876, in which he lists it as "Bahia Navel," but cautions his customers against its shy bearing. Some persons who bought trees from him at that time condemn them as worthless, while others claim that they were identical with the Washington Navel. Garey must certainly have secured at least a preponderance of the false type of Navel. In 1873 J. C. Wallace of Los Angeles imported four Navel trees from Australia, all of which proved to be the false form and have been budded over. From this time this false form of Bahia Navel became known in California as the "Australian Navel" to distinguish it from the true Bahia. The Parsons Navel trees distributed by A. B. Chapman under the name of Rivers Navel also came to be known as Australians. In fact, any forms which differed from the true Bahia of the "Tibbet" tree type were very likely to be called Australians, and on account of this name they were supposed by many to have originated in Australia.

[1] "Orange Culture in California," by T. A. Garey, San Francisco, 1882.

I can find no evidence whatever in support of the statement made by Lelong in 1888 that "The Australian Navel was introduced by Louis Wolfskill in 1874." The successful importation of the true Bahia took place as follows:

In 1870 William Saunders, then in charge of the government propagating grounds at Washington, D. C., through the assistance of a lady missionary stationed at Bahia, Brazil, had twelve trees of the Bahia Navel orange propagated and sent to Washington in tubs. All twelve of these were true Bahia, and after being placed in the greenhouse at Washington were used indiscriminately as a source of buds from which were propagated a number of trees for distribution, many of which were later sent to Florida and California. All twelve of these original trees for some reason passed out of existence. The first lot propagated was distributed to California and Florida, and one tree from this lot was planted in the orange house at Washington, where it still remains. The common idea that this tree in Washington is the original tree imported is wrong. It was propagated from one of the original twelve.

The active settlement of Riverside, California, began about 1870, and was extensively advertised in the East by Judge North, the founder of the Colony. Among other settlers attracted were Luther C. Tibbet and wife. Early in 1873 Mrs. Tibbet (Fig.3) was in Washington just previous to starting to her new home at Riverside, California. While visiting the government propagating gardens, Mr. Saunders offered to give her some trees of this Bahia orange and she gladly accepted two trees, which she carried to California, where she and her husband planted them beside their cottage in Riverside on land which they had homesteaded. According to present street nomenclature the spot formerly occupied by the Tibbet cottage is on Central Avenue near Palm Avenue. The fruit from these trees first attracted attention at a private meeting of fruit growers in the winter of 1877–88, at which time the Navel trees sold by Thomas A. Garey had been in bearing several years. In February, 1879, the Southern California Horticultural Society (J. De Barth Shorb, President, and L. M. Holt, Secretary) held a citrus fair at Riverside. At this fair Mr. T. D. Cover exhibited fruit from the Tibbet trees and was awarded first prize over other Navels exhibited from Orange County, which came from trees imported from Australia by Mr. Garey. The difference between the two forms was recognized by expert fruit growers; the Tibbet oranges being called Washington Navels because Mrs. Tibbet, probably forgetting the name "Bahia," always said in answer to in-

FIG. 3. — Mrs. L. C. Tibbet, who first brought the true Navel orange to California.

quiries that the trees came from Washington. All other kinds of Navels were called Australians because it was supposed that they all came from Australia.

A. S. White of Riverside writing in the *Riverside Press and Horticulturist* under date of June 26, 1880, says, — "It (Washington Navel) was first exhibited at the Riverside Citrus Fair last year (1879), where it attracted great attention, its appearance being so unlike the other Navels on exhibition, which were from the stock imported into California from Australia. The marked points of difference between the two Navel oranges lie in their external appearance. Instead of being like the Australian, ribbed lengthwise, it is smooth and more globular. The skin is of a finer texture, has more of a satin-like appearance, and shows a much higher color, being of a bronzy-gold tint."

An editorial (presumably by L. M. Holt) in *Riverside Press and Horticulturist*, in 1883, says: "We have but two varieties as yet of the so-called Navel orange. The first was introduced into California from Australia. Both varieties, the Washington and Australian Navels, are now being grown quite extensively though the trees are young yet, and I must confess it is at times a puzzle to distinguish one from the other, under test conditions, and I believe I am not alone in this position."

After studying a number of the discussions in the early literature, the writer is of the opinion that since both the true and false form of Bahia orange existed in Australia, that T. A. Garey's original importation in 1870 was mixed and that at least some trees sold by him were the true Bahia. How else can we account for the fact that certain reputable and apparently experienced men insisted for years that some of the trees sold by Garey bore fruit identical with that of the Tibbet trees at Riverside. If this is true, then the Tibbet trees were not the first genuine Bahia Navels to reach California. It is a fact beyond dispute, however, that the Tibbet trees are the ones which attracted attention and were undoubtedly the direct cause of the great boom in the orange growing business which began in the early 80's.

Giving Mrs. Tibbet two trees, Mr. Saunders sent several trees to Florida and some to California. Alexander Craw, then foreman for J. M. Asher, a nurseryman of San Diego, is said to have received two of these trees. It might be argued that Mr. Garey secured his stock of Bahia from Craw or even from Mr. Saunders at Washington. This is barely possible, but in view of the shortness of time thus allowed to work up the stock, and the letters of his contemporaries stating the contrary, it is hardly probable.

For two or three years after the Tibbet trees began to be propagated in Riverside this orange was known as the Washington Navel. In 1883, however, a determined effort by the people of Riverside was made to change the name to Riverside Navel in order (according to L. M. Holt in *Ontario Fruit Grower*, May 16, 1883) that Riverside, the town where this variety happened to be first tested, might get the benefit of the advertising which would follow the use of this name. O. H. Conger of Pasadena and others vigorously opposed this to such good purpose that the name Riverside Navel became a synonym.

Luther C. Tibbet is known to have been rather improvident. He never owned any orange trees other than the two his wife brought from Washington. He permitted his homestead to pass out of his hands, but he and his wife

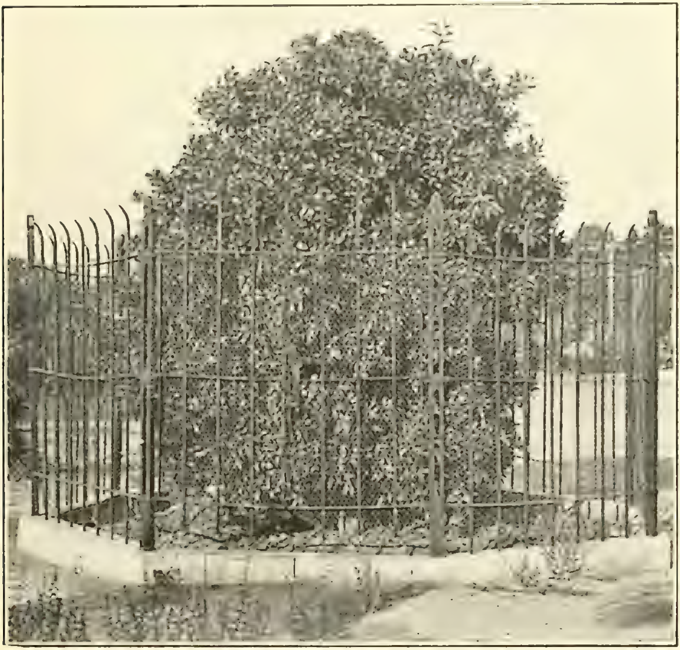

FIG. 4.— One of the original Washington Navel orange trees brought to California.

were allowed to live in the cottage during the life of Mrs. Tibbet. After her death Tibbet was cared for at the County Hospital until he died July 1, 1902.

In 1903 Louis Jacobs was the owner of the Tibbet homestead. He gave one of the trees to Frank A. Miller, proprietor of the Glenwood Hotel, who had it removed to its present location in front of the hotel May 7, 1903. President Roosevelt, a guest at the hotel at the time, assisted in transplanting this tree, for the care of which Mr. Miller is now responsible.

Citrus Acreage in Counties in California having more than 10,000 Trees in 1910

County	Number of Trees	Acres
Los Angeles	3,283,500	43,780
San Bernardino	3,149,250	41,990
Tulare	2,985,000	39,800
Riverside	1,966,705	25,222
Orange	1,149,605	15,328
Ventura	503,137	6,708
San Diego	395,974	5,279
Butte	146,673	1,957
Santa Barbara	144,270	1,924
Fresno	106,928	1,746
Kern	78,500	1,033
Sacramento	55,780	744
San Louis Obispo	39,000	520
Placer	33,115	441
Yolo	18,575	247
Glenn	16,540	221
Tehama	13,565	180
Sonoma	11,270	150
Colusa	11,000	146
Solano	11,000	147
All other counties	56,797	754
Total for state	14,176,184	188,317

About the same time the other original tree was given to the city by Mr. Jacobs and it was transferred to a small plot of ground at the head of Magnolia Avenue. J. H. Reed, then tree warden of Riverside, placed a substantial ornamental iron fence around it which affords protection from any thoughtless or selfish person. The city of Riverside is responsible for the care of this tree. Both the original trees are at this date in a healthy and flourishing condition, and the one on Magnolia Avenue especially is producing fair crops (Fig. 4).

CITRUS GROWING IN ARIZONA AND SONORA

The citrus industry of Arizona is hardly more than twenty-five years old, although occasional orange trees may have been planted at a very much earlier date. The first plantings of any importance were along the Arizona Canal west of Scottsdale in the Salt River Valley. The Ingleside orange grove on the foothills of Camel's Back Mountain was the largest of these early plantings, and it was due largely to its success that the acreage was increased in this locality.

Another important prospective citrus area is on Yuma Heights near Yuma, where an old orchard ten or twelve acres in extent has served for many years to indicate the possibilities of this area. The lack of water development has been the chief hindrance to the planting of additional acreage.

While California received its first orange seed from Sonora, this country has been very backward in its citrus development, chiefly for the reason that it has been isolated from home markets and handicapped by the tariff in reaching American markets.

Geographically Sonora belongs to the Arizona and southeastern California areas as the climate and soil conditions are very similar. The chief commercial orchards are situated near Hermosillo, in the valley of the Sonora River, and near Guaymas. The production of fruit at Guaymas was greatly reduced in 1905 by a serious infestation of the red scale. The variety chiefly grown at Hermosillo is the sweet seedling orange. The production gradually increased and in 1908 about 250 cars were sent in bond through the United States to Canada, which they enter duty free.

The oranges produced in southern Mexico, especially in the states of Jalisco, Morelos, and San Luis Potosi, where the climate is more tropical, differ in character from those grown in Sonora, being inferior for shipping. Much of southern Mexico is infested with the Morelos orange maggot, *Trypeta ludens*, and this interferes with the marketing of the fruit.

CHAPTER II

CITRUS GEOGRAPHY AND CLIMATOLOGY OF CALIFORNIA

Citrus fruits originated in India and the Malay Archipelago and are generally regarded as tropical fruits, yet it is a curious fact that the greatest commercial success with them has been obtained in semitropical countries. This statement applies especially to oranges and to a less extent to limes and pomelos. The bulk of the oranges which supply the markets of the world are produced in countries which experience a certain degree of frost, such as California, Spain, Florida, Palestine, Australia, Japan, and Italy. Oranges grown in moist tropical countries are lacking in tartness, color, shipping and keeping qualities. All of these qualities, so desirable in a marketable orange, become more marked as we approach the line where frequency of frosts makes the culture of the trees unprofitable.

The citrus producing lands of California are scattered from San Diego to Shasta County, a north and south distance of four hundred and fifty miles. It is a peculiar fact that there are orange orchards in California in the same latitude with New York City and Lincoln, Nebraska. This is made possible by the peculiar topography of the state, whereby the mountain ranges are so situated that the cold winds of the north are shut out from interior valleys, and the full effects of the abundant winter sunshine allowed to accumulate. Along the southern coast also the mild moisture laden breezes from the Pacific modify the climate of the country between the mountains and the sea without interference from northern blasts, which are diverted eastward by the mountain barrier in northern California. From the point of view of the fruit grower, longitude is more important than latitude. Fig. 5 shows the distribution of the citrus areas of California.

CLASSIFICATION OF CITRUS AREAS

The areas where climatic conditions permit the growth of citrus trees may be roughly grouped into three divisions and designated as the Southern Coast, Interior Valleys, and Northern Coast Divisions, in the order of their importance as citrus producing areas.

The Interior Valleys Division includes the Sacramento, San Joaquin, Upper Santa Ana, Coachella, Imperial, and Colorado Valleys and embraces all the country not immediately adjacent to or within the influence of the ocean. The Southern Coast Division includes all the citrus country between the mountains and the sea as far north as Santa Barbara. The Northern Coast Division includes all the country within the influence of the sea from Santa Maria as far north as northern Sonoma County. The amount of rainfall varies much in different parts of the state, but the rainy season is fairly uniform, being from November to March inclusive throughout each of these

Fig. 5. — California citrus areas.

areas. Rainfall in the summer is very rare and thunder and lightning exceedingly rare especially near the coast.

As the citrus industries of these three divisions differ in many particulars, we will discuss each division separately.

The Southern Coast Division

The climate of this section is characterized by an equable temperature with cool summers and warm winters.

FIG. 6. — Four-year-old Valencia orange grove in Los Angeles County.

The rainfall is about 18 inches in the northern but decreases in the southern part. The air is quite moist as compared with the interior, and there are frequent fogs and overcast skies. The prevailing breezes are from the Pacific Ocean, which has a surface temperature not far from 60° F. at all seasons of the year. The extent of the ocean influence depends upon local topography, being narrow in Santa Barbara County and widening out toward the south and including the San Gabriel Valley which contains the most highly developed and largest, contiguous citrus area in the state. Fig. 6 shows a representative orange plantation in southern California.

In general, the soils of this region are deep and very fertile, being heavier near the coast and lighter in character toward the interior. The two prevailing soil types are the Placentia series, resulting from the weathering of reddish granite, which outcrops at many places, and the Maricopa series, which are alluvial in nature, being an ancient flood plain. These latter soils are darker in color and often contain smooth cobbles and bowlders in variable amounts. Less important soil types are the black adobe sometimes found on the foothills and the light sandy soils of the river bottoms.

While the prevailing breezes are westerly, this section of country is occasionally visited by characteristic hot northers which blow with force for several days at a time from the northeast. At such times the air becomes excessively dry and high temperatures prevail. Such desiccating winds are sometimes quite injurious to vegetation and cause a severe loss of water from plants and soil. It is fortunate that such winds are not of more frequent occurrence.

The southern coast is especially adapted to the growing of lemons, which here produce a larger proportion of high-priced summer fruit. Stored lemons also keep better and expensive storehouses are not needed as is the case in interior valleys. The cool summers also make it possible to hold Valencia oranges on the trees until the following October and November, when very high prices are often realized. This section of country is also well suited to the production of nursery stock, which is grown in very large quantities, the San Gabriel Valley being the center of this industry.

The Washington Navel orange here produces very heavy crops, but the fruit ripens later and is somewhat inferior to that produced in interior valleys both as regards color, texture, flavor, and shipping qualities.

The Interior Valley Division

The climate of all the interior valleys is characterized by conditions more or less extreme. The air is nearly always dry and this permits rapid radiation, causing a wide range in temperature each day. Rainfall is fairly abundant in winter in the northern valleys and less so toward the south. The air is free from fogs and dew in summer and constant sunshine is the rule. The days are often very hot, while the nights are always cool.

The floors of the valleys are, as a rule, frosty in winter and on this account the principal citrus areas are found along the foothills, above the frost line, and where irrigation water is available. Such areas are usually at an elevation of from 500 to 1500 feet above the sea, and from 100 to 500 feet above the floor or "draw" of the valley. In such locations a few feet in the perpendicular is of far greater importance to the citrus grower than many miles in the horizontal. That is to say, whether the orchard is planted in a "draw" or on a bluff above it, yet on the same ranch, may mean more for the success or failure of the grove than whether the trees are planted near Holtville or at Oroville five hundred and fifty miles distant. Cold air is heavy and on quiet nights flows down and collects in the lowlands, leaving the foothills above the frost line.

In the central valleys oranges ripen very early and as some of these are far to the north of the Coast Country, the unusual procedure of shipping earliest ripening fruits southward to market is accounted for.

The largest producing district in this division lies on the eastern foothills of Tulare County, including Woodlake and Porterville, at an elevation of four or five hundred feet above sea-level. One of the typical soils of this district is known as the Porterville clay loam adobe, which is a residual soil characteristic of the higher foothill slopes. Lower down the valley slopes are found soils of the San Joaquin series, which are sometimes characterized by "hog-wallows" and a certain amount of hardpan. The valley floor is composed mostly of alluvial soils of the Hanford series.

In the northern Sacramento Valley the soils are very variable, but are mostly of a reddish color. They are in large part sedimentary soils of the San Joaquin, Stockton, Alamo, and other series. While there are many exceptions, it is true that these soils, especially on the east side of the valley, are quite generally underlaid by a stratum of dense, impervious hardpan which occurs at variable depths. Where hardpan is near the surface, the land is not suited to citrus fruits unless it be dynamited and the hardpan thoroughly broken up.

The Northern Coast Division

In outline this division is very irregular, consisting in places of a narrow strip between the mountains and the sea and extending occasionally into valleys where the hills are low and do not entirely shut off the cool, moist sea-breezes. East of the bay region the coast influences extend far inland, following the Sacramento River and tempering the climatic conditions at the junction of the San Joaquin and Sacramento Valleys to such an extent that the region between the cities of Stockton and Sacramento is really intermediate in climatic characteristics. The climate of the Northern Coast forms a strong contrast with that of the interior valleys. It is comparatively free from extremes of temperature, being warm in winter and cool in summer. The winter rainfall is usually heavy and there is much fog in summer. Here green, grass-covered hills are the rule instead of the bare rocky buttes of the interior.

There are no large commercial citrus areas within this district, yet oranges and lemons are grown in yards and gardens and the product is used for local consumption throughout the district. The total amount of summer heat is small, and oranges do not yield well as a rule nor is the fruit high in sugar content. The color also is poor on account of the lack of abundant sunshine, and the trees are subject to the ravages of many insect pests and fungous diseases which are not able to survive the hot summers of the interior valleys. The trunks and branches of trees on the coast are apt to become covered with a growth of lichens and algæ which should be removed with alkali sprays.

The soils of the coast country are chiefly deep rich residual soils formed by the gradual weathering and breaking down of the local rock masses.

THE FROST HAZARD

It has been asserted that certain districts in California are free from frost. This is hardly true, for a certain frost hazard exists in all districts both north and south. Almost all districts on the other hand embrace certain areas which are comparatively frost free. One thing which usually impresses the stranger from the East most forcibly is the sharpness with which the frost lines are drawn. There are many ranches of a hundred acres or less which are divided by these frost lines into citrus lands, walnut lands, and alfalfa lands. It is often very difficult to accurately judge the frost hazard on any given piece of land unless there be an old orchard alongside upon the history of which, together with the local topography, an estimate may be based. Failures due directly to faulty judgment in regard to the frost hazard are almost without number.

In recent years the science of orchard heating as described in Chapter XIV has enabled growers to insure their crops against occasional frosts, but where orchards must be heated many nights each winter the expense is quite likely to interfere with the profits.

We may conclude then that throughout the citrus divisions of the Southwest there are specially favored districts where citrus fruits grow to perfection and are seldom injured by cold. Within each of these districts, however, there are many localities of irregular outline and extent which on account of local topography are quite out of the question as citrus lands. On this point Lelong [1] writes as follows:

[1] "Culture of the Citrus in California," 1902.

"Wherever cold currents of air from high altitudes flow to the valley without interruption, it will not be safe to attempt citrus culture at any elevation within the sweep of these currents. On the other hand, wherever the descending currents are cut off or turned aside by spurs of the mountains, leaving the warm atmosphere of the days undisturbed during the nights, there orange and lemon culture may be engaged in with little danger from frost. In other words, the eddies of air currents must be selected and the main flow of these currents must be avoided.

"Everybody who has traveled along the Sierra foothills, parallel with the valleys, particularly in the winter season and at night, will recall his surprise at the sudden changes of the temperature of the atmosphere within short distances. He may also remember to have noticed tender plants and shrubs seared and frost-bitten, while just over a ridge or cone the same plants and shrubs were in full leaf and growing luxuriantly. Want of attention to these facts has caused many a disastrous failure in the cultivation of citrus fruits in California."

ATMOSPHERIC HUMIDITY

In the interior valleys which are fanned by dry desert breezes, the amount of atmospheric moisture is very low, and this together with the great heat tends to produce oranges of high sugar content and with very desirable deep red color. Dry air also discourages the growth of certain diseases affecting the tree, as well as certain scale insects, lichens, and algæ which cannot endure the desert conditions. On the other hand, lemon trees under such climatic conditions tend to bear only one crop a year, and the proper curing and keeping of lemons is made more difficult. The moist and foggy coast country with its cool sea breezes brings about a somewhat different phase of the industry. Here lemons tend to bear a con-

Fig. 7. — Typical scene in Los Angeles County. Windbreak of *Grevillea robusta* on right.

tinuous crop the year round, and the fruit may be easily stored in open sheds and kept in good condition for six or eight months. Oranges near the coast are six or eight weeks later in ripening than those of the interior, and the trees are subject to a larger number of the insect pests and diseases to which the citrus tree is heir.

WINDS

Strong winds are a serious hindrance to the citrus grower. The young foliage is badly torn or may even be

Fig. 8. — *Pinus radiata*, a native pine used as a windbreak.

blown from the trees; the fruit is bruised, scarred, and covered with unsightly callous marks; the trees are prevented from forming symmetrical heads; and in some cases the soil itself is either blown away from the roots or banked too deep around the trunks of the trees. In some extreme cases, the traveling sand wears away the bark of young trees near the ground. As a rule, windy locations should be avoided in selecting a site for a citrus

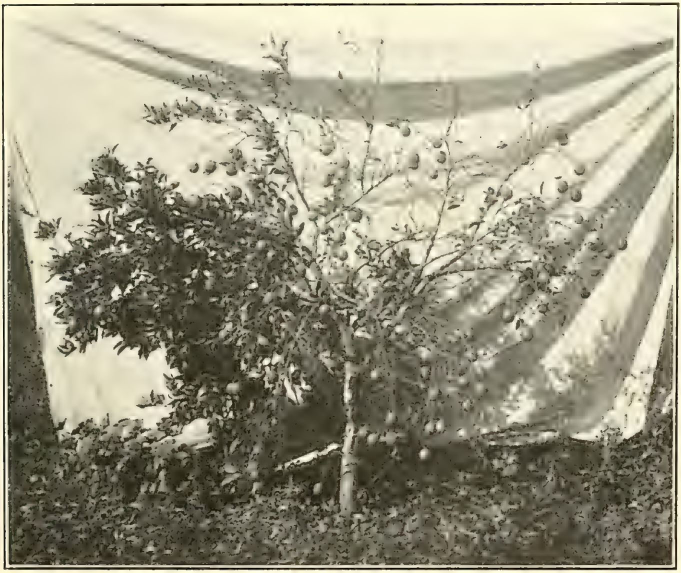

FIG. 9. — Orange tree denuded of foliage on windward side by three days of desert wind.

orchard. In some cases, however, where all the other conditions are right, the force of the wind may be broken by growing windbreaks of cypress, eucalyptus, or cedar. Care should be exercised that the windbreak is not allowed to grow too thick and become a "wind-stop," as this may interfere with atmospheric drainage and make a frost pocket of the grove. A live windbreak is objectionable on the ground that the roots appropriate the plant food and water from one or two rows on either side and seriously interfere with the fruiting of the orchard trees. This trouble may be obviated to some extent by digging a trench ten feet from the windbreak and three feet deep every second year and cutting all the feeding roots. Care should be used in selecting varieties of trees for windbreaks that they may not be host plants for insects which affect citrus trees. The pepper tree, *Schinus molle,* for example, makes an excellent windbreak and is largely used in interior valleys where the black scale is of less importance. Near the coast such trees may have to be fumigated occasionally at great expense. Figs. 7 and 8 show windbreaks of the silk oak (*Grevillea robusta*) and Monterey pine (*Pinus radiata*), which are much used in parts of California. Fig. 9 illustrates the damaging effect of the wind.

SUNLIGHT

While a certain amount of sunlight is absolutely necessary for plant growth, there are places in California where citrus plants are over-illuminated. Sunburn of the fruit and tree trunks and even of the leaves often occurs in the dry interior valleys, where the lack of moisture in the air permits the actinic rays of the sun to strike the trees with full force. In such situations, the fruit borne on the outside of the trees and fully exposed to the light is inferior and often ruined, while the fruit which is screened by foliage may be of the very finest quality. It is the custom among nurserymen to shield citrus seedlings from the light by growing them, for the first six or eight months, under lath screens so arranged as to reduce the total light about 75 per cent. Running the lath north and south will provide alternating light and shadow for any given seedling as the sun moves from east to west.

CHAPTER III

CITRUS BOTANY, GROSS STRUCTURE, AND HABITS OF GROWTH

Citrus fruits differ from olives, figs, dates, and pomegranates in being of comparatively modern origin. They emerged from the wild state in the Malay Archipelago and southern Asia. Certainly citrus fruits were not known by civilized peoples until comparatively recent times. The ancient Egyptians did not know the citrus fruits. The Romans did not know the orange or any other edible form except perhaps the citron at the beginning of the Christian Era.[1] While the Old Testament makes frequent mention of olives, pomegranates, figs, and other fruits, no mention is made of any citrus fruit unless we except the word "hadar" translated "goodly trees" (Leviticus 23 : 40) as referring to the citron. Risso,[2] one of the most able of the early writers on citrus, compared the ancient texts and claims that this word merely refers to any beautiful or fine tree. It is likely that the Hebrews became acquainted with this fruit at the time of the Babylonish captivity. Be this as it may, the Jews believe this word refers to the citron, or *etrog* as

[1] De Candolle, "Origin of Cultivated Plants," p. 181.

[2] Risso and Poiteau, "Histoire Naturelle des Orangers."

it is called by them, and to this day they present themselves at the synagogue on the day of the Feast of Tabernacles, as commanded in Leviticus, with a citron in their hands together with an unopened date palm leaf, a three-parted branch of myrtle, and a willow twig.

The citron, known by the Romans as *Malum persicum*, the apple of the Persians, was transplanted to Italy about the third or fourth century.

The lemon was not brought to southern Europe until after the tenth century, and the earliest Italian reference to it is dated 1250 A.D.

The bitter or sour orange was unknown to the early Greeks and Romans. It probably originated in eastern India and spread westward slowly. When it reached Mesopotamia it received the Sanskrit name *nagarunga*, which was changed to *verunga* and *arangi*. In medieval Latin it became *arancium* and finally *aurantium*, the present Latin name from which our English word *orange* is derived. The Crusaders saw the bitter orange in Palestine. It was taken by the Arabs to Sicily in 1002, spread from there to Spain, from whence it was taken to Florida soon after the settlement of that Colony. In Florida the bitter or sour orange ran wild, and dense thickets exist there to-day which yield the greater part of the sour orange seeds planted by California nurserymen.

It is most remarkable that so good a fruit as the sweet orange should not have been known to ancient writers, yet they make no mention of it. In fact the sweet orange was not introduced into Europe until the beginning of the fifteenth century, when the Portuguese brought improved forms of it from south China. A number of writers speak of the sweet orange as cultivated in Spain in the sixteenth century. At a very early date the Portuguese carried the orange to Brazil, where it ran wild as it did in Florida. From Brazil the orange spread southward into Paraguay, part of Uruguay, and northern Argentina where large areas are now covered with a natural growth of wild sweet orange trees.

CLASSIFICATION

The genus *Citrus* belongs to the family *Rutaceæ* and represents the highest development within the family. There are no species of citrus native to either North or South America. A relative is the prickly ash or "toothache tree," *Xanthoxylum americanum*, of the southeastern United States.

No two systematic botanists appear to be agreed as to the proper classification of the many different species. This is probably due to the fact that several of the species hybridize readily and it is very difficult to determine which of the forms are of hybrid origin. The writer makes no pretense to having solved this perplexing problem by independent botanical research. He has simply studied the different schemes proposed and from them arranged a practicable, working classification for the use of students, fruit-growers, and others who desire a simple bird's-eye view of the ten species in which they are chiefly interested.

Persons particularly interested in citrus botany are referred to Hume, "Citrus Fruits and their Culture"; to Bonavia, "Oranges and Lemons of India"; and to Swingle, "Citrus" in "Bailey's Standard Cyclopedia of American Horticulture."

CITRUS	*trifoliata*	the deciduous orange (*Poncirus trifoliata*).
	bergamia,	Bergamot orange.
	sinensis,	common sweet orange.
	Aurantium,	sour stock, Seville, or bitter orange.
	nobilis	the King orange. *Var. deliciosa* — the Mandarin or kid-glove orange. Tangerine. *Var. unshiu* — the Satsuma orange.
	decumana,	the pomelo (grapefruit), shaddock.
	japonica,	kumquats.
	Medica,	citron of commerce.
	Limonia,	sour lemon, sweet lemon.
	aurantifolia,	sour lime, sweet lime.

All of these ten species are now grown, to some extent at least, in California, although some of course are very much more important than others.

Citrus trifoliata. — This is the only deciduous orange. The fruit is not edible. It is highly ornamental and very hardy to cold, being used in yard and garden plantings and for hedges as far north as Washington, D. C. It is used to a certain extent in Florida and more generally in Texas as a stock upon which to bud edible oranges. Its use as a stock in California was never widespread, and is now almost obsolete. *Citrus trifoliata* has recently been used to a considerable extent in breeding work, the object being to combine the cold resisting qualities of the *trifoliata* with the good qualities of the more tender species which bear edible fruit. It is native to Japan and China and was introduced into Europe more than one hundred years ago. This species is now by some put in the genus Poncirus, becoming *P. trifoliata.*

Citrus bergamia. — The Bergamot orange from which the oil of bergamot is made is grown commercially in Europe. In California it is grown only as an occasional specimen or as a hedge plant in gardens.

Citrus sinensis. — The ordinary sweet oranges including such varieties as Washington Navel, Valencia, Mediterranean Sweet, Ruby Blood, and a long list of others.

Citrus Aurantium. — This is the sour or bitter bigarade orange, the fresh fruit of which is hardly edible, but which is coming to be used more and more in the flavoring of marmalades and various other by-products. Seedlings of this orange have almost entirely superseded others as a stock upon which to grow all kinds of citrus fruits in California. The reason for this is its superior resistance to gum-disease and foot-rot. The seed from which this "sour stock" is grown comes chiefly from the wild thickets in Florida. In Europe this form is often called the Seville orange.

Citrus nobilis. — The description of this species was based on a form very like the King orange. It includes the *var. deliciosa*, the ordinary Mandarin oranges such as the Tangerine and the *var. unshiu*, which is the Satsuma orange.

Citrus decumana. — Here are included the pomelos, often incorrectly called "grapefruit," [1] and the shaddock. They are vigorous growing trees with very dark green leaves, very prolific in bearing. The pomelo is growing rapidly in public esteem, but the shaddock is inedible. The shaddock is the largest of all the citrus fruits, but has an extremely thick skin and bitter juice. It is the only citrus which has hairs or pubescence on the young twigs and under sides of the leaves, and is grown only for ornament or curiosity.

Citrus japonica (recently referred to the genus *Fortunella*). — The Kumquats, Kin-Kans, or golden oranges, small bushy plants from Cochin-China. The fruits are small, with mostly acid pulp and sweet aromatic rinds, for preserving and for decorations.

[1] The term "grapefruit" has, chiefly through the influence of "the trade," become adopted by common usage, and it is hardly worth while now to insist on the use of the more correct term.

Citrus Medica. — The citron from which the candied citron sold by grocers is made. The form known in California as the Chinese lemon and much used in the early days as a stock is thought to belong here.

Citrus Limonia. — The lemons including both the sour lemons and the sweet lemons.

Citrus aurantifolia. — The limes including both the sour Mexican and Rangpur limes and the sweet limes which latter are considered to be of hybrid origin.

THE CITRUS PLANT

The Root

Citrus trees differ from many plants in having no root-hairs whatever upon the fibrous, feeding roots. The feeding roots are comparatively large, very abundant, and grow very rapidly. Those sheared off each year by the plow in turning under a cover crop are quickly replaced. In shallow soils, however, where most of the fibrous roots are near the surface, it is unwise to be too reckless with the large turning plow. Under arid conditions the feeding roots are not confined to the surface layer of soil, but where there is no layer of hardpan to interfere they distribute themselves throughout the soil usually between the eighth and thirty-sixth inch levels. In very deep, well aërated soils they may forage much deeper.

The large main roots serve in a double capacity; as braces to hold the tree upright against the wind, and as conveyors of water and food between the fibrous feeders and the trunk. Large perpendicular roots known as tap-roots are not essential to the health or well-being of the trees and are invariably cut when the young nursery trees are dug for transplanting. Subsequently the sweet orange root will devote itself mainly to sending out laterals, while the sour orange will usually send down two or three strong tap-roots in the place of the one which was cut. The pomelo shows much variation in regard to the formation of tap-roots.

Wood Structure and Growth

Citrus wood is very closely knit in structure, being hard, strong, and tough. It is light in color, with very fine grain and with no apparent heart wood; that is, there is no difference in color between heart wood and sap wood. The rings observable in a cross section are close together and are of no value in determining the age of the citrus tree, as they are in the case of pine or oak trees. This is on account of the fact that the citrus tree forms several rings each year according to the number of vegetative growths. The citrus tree does not grow at a uniform rate during the season, but makes three or more growths of new twigs and leaves each year, with corresponding rest periods. The heaviest growth is in the spring just before blooming, the flowers being borne on the new shoots. Another smaller and more irregular growth is made in mid-summer, and a third in the late fall. The number of growths made and the times they occur vary with the local weather conditions and the method of irrigation.

The main framework branches of old lemon trees often present a curious flattened shape next the trunk. The greatest diameter is perpendicular, but the width of the rings is much thicker on the lower than the upper side, the center of growth being crowded close to the bark on the upper side. This curious condition is entirely normal in the lemon and greatly strengthens the branches, enabling them to carry a much larger load without breaking.

There are two sap currents in the trunk and branches, one consisting of dissolved mineral matters taken from the soil water by the roots, which passes up through vessels in the wood to the leaves; and another, consisting of elaborated plant food, and other complex substances, which passes down through the inner bark and nourishes every growing part, even the tips of the longest roots. It should be remembered that the action between root and leaf is reciprocal. The most remote tip of the longest root must await the return of the elaborated sap from the leaves before it is able to grow a fraction of an inch. For sake of emphasis we repeat: the roots of a plant are quite as dependent upon the leaves for elaborated food as they are upon the soil for raw food, for roots cannot use raw mineral food. That the downward current of elaborated sap takes place through the bark is proved by the swelling which occurs just above the point of constriction when a label wire is overlooked and allowed to remain, on a young tree.

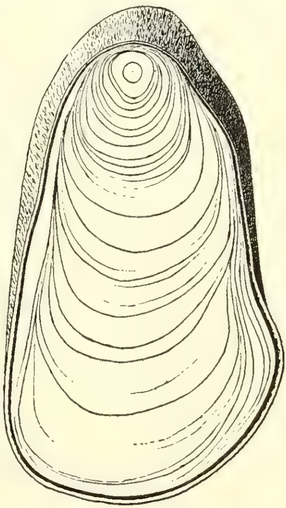

Fig. 10. — Growth rings in a flattened brace limb of lemon.

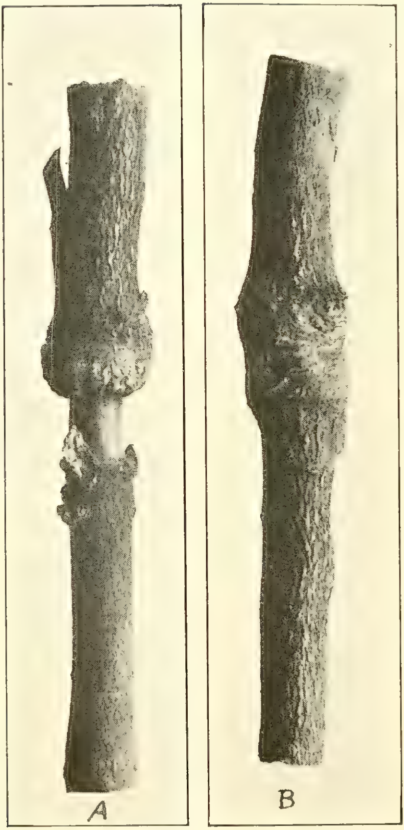

Fig. 11. — Result of experiment which shows that a girdled orange tree may grow new bark if treated in time. *A*, untreated; *B*, treated.

Advantage is taken of this fact in the process known as "ringing" which is chiefly used with grapes and pears. A ring of bark half an inch wide is removed from the small branch which bears a fruit cluster. The fruit and leaves continue to draw food from the roots through the wood, but as the branch is prevented from returning its proportionate share of elaborated food to the trunk and roots, it soon accumulates an extra amount which causes the fruit to grow to an unusually large size. By this method a Navel orange was produced which weighed $3\frac{1}{4}$ pounds and measured 18 inches in circumference.[1]

[1] *Scientific American*, Dec. 14, 1912, p. 515.

The line which separates the two currents of sap is known as the cambium and is roughly represented by the line of cleavage when a strip of bark is pulled away from the trunk. It is on this line that growth takes place, the cells dividing continually, one part going to build wood and the other causing a thickening of the bark.

Citrus trees are apt to form large quantities of gum along the line of the cambium, when stimulated by the growth of fungous parasites, or by other causes, the exact nature of which are not clearly understood.

Many trees are unable to grow new bark direct from the cambium, but heal over wounds by pushing new tissue out from the sides of the wounds. The citrus tree will often grow new bark direct from cambium laid bare by gophers or gum-disease. Occasionally a tree which has been entirely girdled will grow new bark and recover. The bark of citrus trees is also peculiar in that it retains some green matter or chlorophyll and continues to function as a leaf until the tree reaches a great age.

Leaves

With the exception of *Citrus trifoliata*, all citrus trees are evergreen; that is, the bulk of the leaves do not fall before the new leaves have expanded. A few of the oldest leaves may fall at any time of the year, but the period of heaviest fall is in April and May after the spring growth has taken place. The normal life of an orange leaf depends on the kind of wood upon which it is borne. Leaves on the fine fruiting brush usually remain on the tree for about fifteen months, while leaves on vigorous upright vegetative growths will remain green and in flourishing condition for three and even four years. The leaves on the trunks of nursery trees, if protected and not removed, will usually remain for several years. It is customary to remove these leaves at the time the tree is dug for the purpose of reducing transpiration.

In the case of the trifoliate orange the leaves fall in the autumn, the tree remaining bare during winter and until after the blooming period in spring.

Citrus leaves vary in shape and size with the different species; the pomelo and Seville orange having broad wings on the petioles, while the sweet orange has a very narrow wing and the citron none at all. The width of these wings will vary a good deal, being wider on the vigorous shoots and very much smaller on the fruiting brush. The edges of the sweet orange leaf are entire, while with the lemon and lime the edges are indented or crenate. Most, if not all, of the stomata or breathing pores are situated on the under side of the leaves, and this is a distinct advantage when the upper surfaces of the leaves become coated with dust from the roads during the dry season, or with cement dust from near-by cement mills.

One striking characteristic of all citrus leaves is the presence of numerous glands, which may be easily seen with the unaided eye, although they do not project above the surface of the leaf. These glands are filled with a fragrant and aromatic oil which is very volatile and gives to the freshly crushed leaves their characteristic odor. This odor varies with the different species. One method of distinguishing between sweet and sour stock seedlings in the nursery is by recognizing the odor of the crushed leaves.

Thorns

Sharp, slender thorns are characteristic of most kinds of citrus trees. Seedlings of the sweet orange have perhaps the most formidable thorns and these are a serious hindrance in harvesting the fruit and pruning the trees. The trifoliate orange has short, thick thorns which are very numerous. Certain cultivated varieties are practically free from thorns, and this quality adds much to their popularity. Thorns are borne in the axils of the leaves, and their size, in a given variety, depends largely upon the vigor of the shoot upon which they occur, being long on rapidly growing shoots and short and inconspicuous on the fruiting brush. The Navel orange and Eureka lemon are practically thornless varieties; yet on water-sprouts long sharp thorns may sometimes appear.

Thorns are objectionable not only on account of the difficulty occasioned in picking fruit, but also on account of the injury done to the fruit itself. When the wind tosses the branches about, the fruit is stabbed on many sides by the thorns, giving an excellent opportunity for inoculation and consequent fungous decay. In dry weather when small wounds are quickly dried (and perhaps, to a certain extent, cauterized by the escape of oil from the broken oil-cells) there is less decay of fruit on the trees from this cause. While this is true, the constant rubbing or pricking of a fruit against the point of a thorn will so irritate the rind as to cause a very ugly callous to form on the skin and thus ruin the market value of the fruit.

There is a widespread belief among citrus nurserymen and others that thorns may be largely eliminated from any variety by careful selection of budwood through several bud generations. We know of no published data of scientific experiments to determine this point and doubt very much whether the grounds for this belief are sufficient. It can do no possible harm to select only thornless budwood for propagation, and where this happens to result in the separation of pure-line mutants which vary in thorniness much good may be done. On the other hand it is difficult to conceive of how progress can be made by selection within the pure-line.

Flowers

Citrus flowers are large, showy, and fragrant, and are borne in great profusion. They are mostly waxy white, although in the lemon and citron the backs of the petals are tinged with purple. The flowers are mostly perfect or complete, consisting of a green calyx with three to five lobes, subtending white petals, four to eight in number, which are thick, fleshy, and covered with oil glands. The stamens are numerous, twenty to sixty in number, their filaments (stalks) being more or less united. The style and stigma are large and conspicuous. The exudation of white mucilage by the stigma is quite copious, as is also the watery nectar in the base of the flower cup. The pollen is golden yellow and is produced in abundance except in certain varieties. The orange has flowers borne in cymes on shoots of the current year's growth. In the case of the lemon, kumquat, and others, the new growths are sometimes so short (the leaves appearing as mere bracts), that the flowers have the appearance of being borne on old wood.

FIG. 12. — Valencia orange blossoms.

The flowers of the orange and pomelo appear during April and early May. Occasionally a bunch here and there or even an entire tree may bloom at some other season, but the fruits from such off-season blooms will usually be abnormal in shape and inferior in quality. Lemons bloom and set fruit the year round with the period of most abundant bloom coinciding with that of the orange.

Lemon trees are peculiar in that they bear flowers of several kinds. Those that produce fruit are perfect, containing both stamens and pistils. There are other flowers borne by the same tree in which the pistils are reduced to a mere rudiment while the stamens are large and well developed. In addition to these there are certain abortive buds, observed on the Eureka lemon chiefly, in which the petals do not develop but remain closed, the stigma forcing its way out between them. Only the perfect lemon blossoms set fruit, although the second kind mentioned may aid in pollination. Lemons require about nine months from blossom to maturity of fruit. A few fruits will come

Fig. 13. — Lemon blossoms showing perfect, partly aborted, and aborted pistils.

up to size in six months, while some will remain undersized for a year and finally turn yellow, at which time they are picked regardless of size.

Pollination

The larger number of fruits, such as apples, plums, grapes, and strawberries, require pollination in order to set fruit. Some kinds of citrus fruits require pollination in order to set and mature fruit, but a large number do not. Many forms of citrus bear parthenocarpic or seedless fruits, and with these pollination is not only unnecessary, but is apparently a disadvantage, inasmuch as it results in some cases in the formation of seeds which are objectionable.

In Florida a large number of varieties are grown commercially, and as most of them contain seeds it is probable that a large proportion at least require pollination for their best development. Florida writers are strangely silent on this point. In the citrus districts of the Southwest it happens that the five varieties chiefly grown — Washington Navel and Valencia oranges, Eureka and Lisbon lemons, and Marsh pomelo — are more or less parthenocarpic. Those kinds which contain some seeds, as the Lisbon lemon for instance, are able to set and mature fruit without pollination, which results merely in the formation of seeds.[1] The Washington Navel orange flowers contain no pollen whatever and in the Eureka lemon viable pollen is rare except at certain seasons, yet these varieties produce quite

[1] Unpublished Report on Pollination Experiments by the Writer.

as well when planted in solid blocks of hundreds of acres far from other varieties, as they do in mixed plantings.

T. Ikeda [1] in a series of brilliant experiments has shed much light on this interesting subject. His principal results may be summarized as follows:

1. Certain varieties of oranges require pollination in order to set fruit.

2. Certain varieties of oranges which ordinarily contain seeds will without pollination set and mature a small number of parthenocarpic fruits.

3. Many varieties of oranges are uncongenial, cross-pollination being followed by dropping of flowers and young fruit.

4. Cross-pollination between seed bearing and parthenocarpic varieties may result in the setting and maturing of fruit containing viable seeds, provided the pollen used is that of a congenial variety.

5. Parthenocarpic varieties do not require the stimulus of pollination in order to set and mature fruit.

6. The pollen-tube may reach the ovule as soon as 30 hours after pollination. Fusion of male and female cells may begin 48 hours after pollination. Fertilization is completed in from 48 to 72 hours after pollination.

7. In the Washington Navel and Satsuma oranges the embryo-sacs usually disintegrate instead of developing into embryos capable of being fertilized.

Occasionally a few normal embryo-sacs are produced in both Washington Navel and Satsuma oranges.[2] Thus

[1] Tomochika Ikeda, "On the Parthenocarpy of Citrus Fruits," *Jour. Sci. Agr. Soc. Tokyo*, Vol. 63, 1904.

[2] The factors which influence the frequency of occurrence of

a few seeds may be produced provided the particular fruits having the normal embryo-sacs happen to be pollinated with viable pollen from congenial varieties. It is the remoteness of the chance of this occurring under ordinary field conditions that accounts for the comparative seedlessness of these fruits. Apparently there is nothing in the

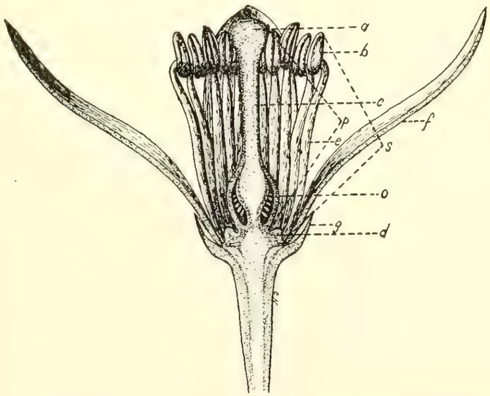

FIG. 14. — Orange flower × 2. *p*, pistil; *a*, stigma; *c*, style; *o*, ovary; *s*, stamen; *b*, anther; *e*, filament; *d*, nectary; *g*, sepal; *f*, petal.

structure of the blossoms of either the Washington Navel or the Satsuma orange which would interfere in any way

normal embryo-sacs have not been fully worked out. Experiments now being carried on by the writer seem to indicate that the climate factor is most important. Normal embryo-sacs of Washington Navels occur much more frequently at Riverside than at Whittier where they are very rare. For this reason plant-breeders wishing to use the Navel as a maternal parent in cross-breeding work may expect greater results from crosses made at Riverside or other interior points.

with the germination of pollen or normal extension of the pollen tube.

The occasional seeds sometimes found in Washington Navel oranges as they occur on the market are undoubtedly due to cross-pollination with some other variety by insects or other agencies. The question as to what would be the result should these seeds be planted and reared to maturity has already been answered by the experiment of W. H. Backus of Riverside, a part of whose report is here quoted.[1]

"Some years ago when almost every one was budding over their seedlings to Navels, I thought the result might be too many early oranges. At that time I did not think the Valencia the most desirable late orange, as a California orange should have high color in addition to being late.

"To obtain this desirable feature, together with high color quality and medium size, I tried hybridizing the Mediterranean Sweet on the Washington Navel, three successive seasons, cutting all the oranges when ripe for seed. Altogether I secured about fourteen hundred seeds that were well matured.

"These were planted in the seed bed, but owing to my lack of experience in nursery work, a large percentage of the little trees, of the first and second plantings, died when about three inches high. One peculiar thing to me was that over 90 per cent of the seeds sprouted from two to six shoots each.[2]

"The young nursery stock was much neglected for three

[1] *Riverside Daily Press*, March 2, 1909.

[2] An interesting record of polyembryony.

or four years, when I took buds from the most thrifty to bud over old trees. Although these buds stand 16 to 18 feet apart in an old grove, still they made a rapid growth, equal to a straight seedling, and are now about 25 feet high.

"The disappointment came when they began to bear. Many were of no value at all; the best were early, some apparently earlier in ripening than the Navel, but generally of good color, sweet and seedless. The trees were exceedingly thorny and some much more thrifty than others; many appeared to be good bearers while others were shy or very late in coming into bearing. Consequently almost all have been rebudded or dug up."

Polyembryony

A peculiar thing about citrus seeds is the fact that a variable proportion of them will give rise to from one to ten distinct seedlings each. This is known as polyembryony and is due to a number of adventitious embryos appearing in the embryo-sac. Some of these bud embryos may develop into seedling plants along with the sexual embryo which requires fertilization in order to develop. This explains why seedlings in the seed bed often appear to grow in bunches even though the seeds were planted separately. As only one of the seedlings arising from any given seed is the result of pollination and fertilization, it follows that the others must be vegetative seedlings, and, in case the seed is from a known variety, will reproduce the variety true from seed without the necessity of budding. It is impossible, however, to distinguish the sexual

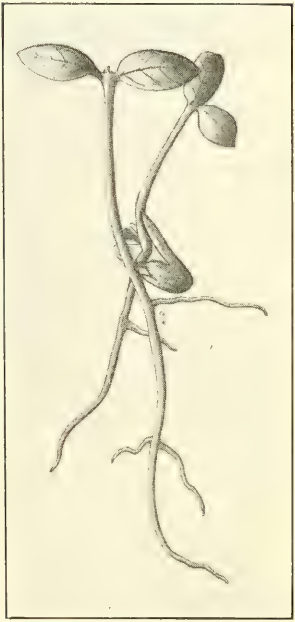

Fig. 15. — Polyembryony. Two orange seedlings from one seed.

seedling from the others in the early years of growth, except in the case of crosses between forms which have very differently shaped leaves. It would be impracticable to propagate Navels true from seed on account of the rarity of seeds and the necessity of pollinating the flowers, but it would be a simple matter with seedy varieties were it not for the difficulty above mentioned.

Structure of the Fruit

According to Bonavia,[1] the citrus fruit consists morphologically of two whorls of transformed leaves, one going to make the rind and the other to make the group of carpels or sections of the fruit. Each carpel is supposed to be a leaf folded over in such a way that its two edges meet in the center on the axis of the fruit and along which the seeds are borne. The number of these sections or divisions varies considerably even in the same variety. The little juice sacks or vesicles within each carpel are supposed to be transformed oil glands of the leaves. As

[1] E. Bonavia, "Oranges and Lemons of India," Vol. I.

varieties of double flowers are formed by the growth of an additional whorl of petals, so varieties of double fruits may come about by the growth of additional whorls of carpels, and this is what has taken place in the case of the Navel orange, as any one may observe by making a number of thin transverse sections through the apical end of a Navel orange, and studying these sections. The vesicles in citrus fruits are multicellular and are attached by a stalk in nearly all cases to the outer wall of the carpel, only a very few being attached to the sides. These vesicles are fed directly by fibro-vascular bundles branching from the stem and running through the white spongy tissue which composes the inner part of the rind. The seeds vary in number from none as in the Navel to fifty or more in the *trifoliata*. They are attached to the inner edges of the carpels.

Citrus fruits in common with other fruits are not to be considered as so much dead matter after they are plucked from the tree. They live and breathe (transpire) for many months. They also lose water and shrink in size and weight as a result of giving off carbon dioxide and water vapor. If protected from infection by decay-producing organisms, oranges or lemons will keep one year or more, when kept moist and cool, but will eventually die and collapse from enzymatic fermentation. If they are allowed to lose moisture, they will dry up into balls as hard as wood. An understanding of the vital processes going on in citrus fruits is highly important in connection with the curing of lemons and pomelos. (See Chapter XVI.)

Chemistry of the Fruit. — Citrus fruits from the same tree may vary much in their composition. Commercial Cali-

ANALYSES OF CALIFORNIA ORANGES AND LEMONS
(From Bull. No. 93, Univ. Cal. Agr. Exp. Station)

A. PROXIMATE ANALYSES NAME OF VARIETY	WASH. NAVEL	MED. SWEET	PAPER RIND	MALTA BLOOD	EUREKA LEMON
Average weight in grams	300	202	138	177	104
Water, per cent . . .	85.82	85.19	84.76	85.68	83.82
Organic matter, per cent	13.95	14.32	14.77	14.39	15.61
Ash, per cent	.42	.47	.46	.42	.56
Rind, per cent . . .	28.4	27.0	19.2	31.0	32.0
Pulp less juice, per cent	27.7	24.0	25.9	24.0	24.5
Seeds, per cent . . .		0.8	1.6		0.12
Number of cc. of juice, average	107	86	65.4	71	38
Solid contents of juice by spindle	12.80	12.60	12.10	13.55	11.90
Total sugars in juice (by copper inversion), per cent	9.92	9.70	8.71	10.30	2.08
Cane sugar in juice (by polariscope), per cent	4.80	4.35	3.48	5.85	0.57
Citric acid, per cent .	1.02	1.38	1.35	1.61	7.66
Nitrogen in fresh fruit, per cent	0.211	0.154	0.228	0.168	0.151
Albuminoids in fresh fruit, equivalent to nitrogen, per cent .	1.31	0.96	1.43	1.05	0.94

B. ANALYSES OF ASH	ORANGES	LEMONS
Potash (K_2O), per cent	48.94	48.26
Soda (Na_2O)	2.50	1.76
Lime (CaO)	22.71	29.87
Magnesia (MgO)	5.34	4.40
Peroxide of iron (Fe_2O_3 and alumina (Al_2O_3)	.97	.43
Br. oxide manganese (Mg_3O_4) . . .	.37	.28
Phosphoric acid (P_2O_5)	12.37	11.09
Sulphuric acid (SO_3)	5.25	2.84
Silica (SiO_2)	.65	.66
Chlorine (Cl)	.92	.39

fornia oranges contain about 30 per cent rind and 40 per cent juice when freshly picked from the trees. The percentage of juice increases as the fruit is cured for the water in the rind is lost first by evaporation and transpiration. California Navel oranges will analyze about 10 per cent total sugars, $4\frac{1}{2}$ per cent of which is cane sugar, the remainder being a mixture of other fruit sugars. Navel oranges contain about 1 per cent of citric acid. Lemons contain about 2 per cent total sugars, of which $\frac{1}{2}$ per cent is cane sugar, and $7\frac{1}{2}$ per cent of citric acid.

Harvest Season

In California, oranges and lemons are harvested throughout the year. The orange season begins with Navels about November 15 in central California and moves southward. The last Navels are shipped from southern districts about May 1. During May and a part of June miscellaneous varieties including seedlings and some late Navels are gathered and shipped. The Valencia harvest begins in central California in June and continues southward, the last of the crop going forward from the coast districts in November and thus overlapping the Navel crop of the next season.

Lemon trees are picked over once each month or about ten times a year, the trees bearing fruit in all stages of growth from the blossom to the mature fruit at all times. Lemons should not be allowed to ripen on the tree. They should be picked when they have reached a diameter of $2\frac{4}{16}$ inches in summer and $2\frac{5}{16}$ inches in winter and spring, regardless of color.

Longevity

Citrus trees are naturally long lived. If planted on deep, rich soil and given good care, they should bear profitably for fifty years or more. Much has been said in print about a natural limit of profitableness in the case of the Navel orange. This limit is sometimes placed at twenty-five years. The writer believes this to be a mistake. Navel oranges as well as other kinds of citrus will live and produce generous crops to a very great age, provided they are growing on deep, fertile soil and are well cared for.

CHAPTER IV

VARIETIES

As stated in a previous chapter, the first oranges grown in California were seedling sweet oranges. Unlike the apple and peach, the sweet orange will come fairly true from seed, the fruit from practically all seedlings being marketable. Each tree, however, varies from its neighbors in many minor characters, such as size, productiveness, season of ripening, seed content, flavor, and shipping qualities. The fruit from an orchard of seedlings lacks uniformity, which is one of the chief requisites of a commercial fruit product. Seedling trees grow very large, so large in fact that it is expensive to gather the fruit and often difficult or impracticable to inclose the trees in fumigating tents. For these and other reasons the old seedling orchards have been gradually cut down and replaced by budded trees or top-worked to improved varieties, until at the present time comparatively few remain.

During the transition from seedling to budded orchards the question as to which of the many varieties available would prove the most profitable was a favorite subject for discussion.

By 1885, enterprising nurserymen had introduced most of the important varieties of the world, and these were tested alongside many local seedlings of special merit. Probably as many as one hundred different varieties were given trial. At the early citrus fairs such imported varieties as the Du Roi and Pernambuco were to be seen exhibited side by side with California productions such as Asher's Best and Bostram's Prize. The elimination of the less profitable varieties took place rather rapidly, and by the year 1900 we find the Washington Navel orange occupying more land than all other varieties of oranges combined. At this time the two fittest survivors, the Navel and Valencia, dominated the field.

DESCRIPTIONS OF VARIETIES OF ORANGES

Washington Navel (*Bahia, Riverside Navel*). — Form rounded, slightly tapering at apex, somewhat longer than wide; small umbilicus; size variable, $2\frac{1}{2}$ to $3\frac{1}{2}$ inches in diameter; color orange when grown near coast, deep orange when grown in interior valleys; juice abundant, orange colored; flavor excellent, acid and sugar well blended; vesicles large, spindle shaped; skin $\frac{1}{8}$ to $\frac{1}{4}$ inch thick, varying from smooth to pebbly; size of secondary orange under umbilicus variable, often $\frac{3}{4}$ inch in diameter. Seeds none, except in very rare cases.

Tree semi-dwarf, vigorous, very precocious, prolific, thornless or with thorns only on vigorous shoots; appearance of blossoms normal except for the fact that the anthers are cream colored and contain no pollen whatever. Introduced from Bahia, Brazil, 1870, by the late William Saunders, then in charge of U. S. Government propagating grounds at Washington, D. C.

The Washington Navel well deserves the title "King of Oranges." Under the climatic conditions of California and

Arizona this variety approaches very nearly to the ideal orange. The dry air, bright sun, and cool nights, operating in conjunction with the skill of the grower and packer upon the natural qualities and character of this orange, have made it the greatest commercial orange in the world. These

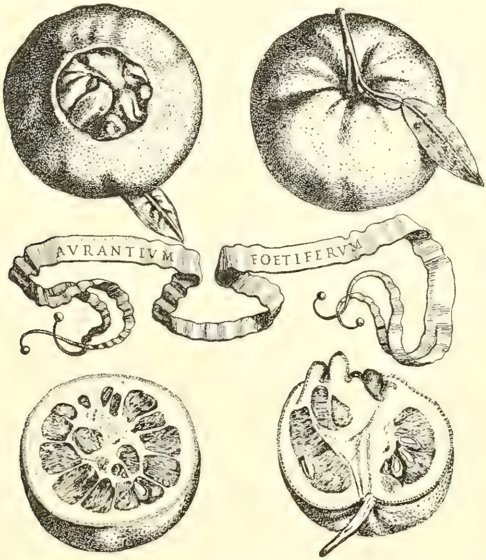

FIG. 16. — The earliest known illustration of a Navel orange. From Ferrarius' "Hesperides," 1646.

thornless trees combine heavy and regular yields with a high color of the fruit, a silkiness of texture, and a general finish which is almost perfect. It is solid and full of juice of exceptionally high flavor, but it is entirely lacking in seeds. It is a very good keeper and travels well to the most distinct markets. It possesses moreover a natural trade-mark, in the shape of a navel-like mark, which is beyond imitation and which is of great market value. More than eight million boxes of Washington Navels are now being grown and shipped out of California annually, and the prices received are encouraging a rapid increase in acreage.

In California, the Washington Navel reaches its highest development in quality on the gravelly soils of the foothills in the warmer interior valleys. The yield, however, is not as heavy as it is near the coast, where the fruit tends to ripen later. On the deep heavy soils of the coast country, the skin tends to be somewhat thicker with a rougher surface and paler color.

One characteristic of the Washington Navel is its tendency to sport or throw out occasional branches bearing fruit of a different type. By far the larger number of these sports are retrogressions, and careless cutting of bud-wood for propagating purposes from trees containing such sports has resulted in a great lack of uniformity in existing orchards. Occasionally sports are found which possess some character of supposed value, and by the propagation of these new varieties have appeared. Among such offspring we note the following: Thomson, Buckeye, Navelencia, Nugget, and Australian.

Thomson. — Fruit of medium size; skin thin and very smooth in texture; ripens early. The quality of the Thomson is somewhat inferior to the Washington Navel, but it has a superior appearance. For certain markets in some large cities where appearance rather than quality determines demand, it commands a premium of from twenty-five to fifty cents a box over the Washington Navel. For this reason, it is being grown on an increasing commercial scale.

The Thomson was introduced by A. C. Thomson of Duarte, Los Angeles County, about 1891, and is generally thought to be a bud sport from the Washington Navel. Considering the story told by Mr. Thomson of his method of producing this form, it is possible that it may be a periclinal chimera!

Buckeye. — Fruit medium in size with peculiar bands or ridges of deeper orange color; skin smooth and of fine texture; ripens early. Introduced by R. M. Teague at San Dimas, California.

Navelencia. — Fruit medium to large, smooth and thin-skinned; season said to be somewhat later than Washington Navel; more susceptible to frost than Washington Navel. Originated by A. C. Thomson, at Duarte, California.

Nugget. — Fruit oblong, medium in size, smooth, solid, and thick skinned, often with an objectionable but characteristic crack or slit in the skin on one side; young twigs slender and willowy, tree umbrageous with very brittle wood. Originated by J. P. Englehardt at Glendora. Introduced by R. M. Teague at San Dimas, California.

Australian. — Fruit very variable, rough, coarse; navel often closed; skin thick, especially near stem end. Tree

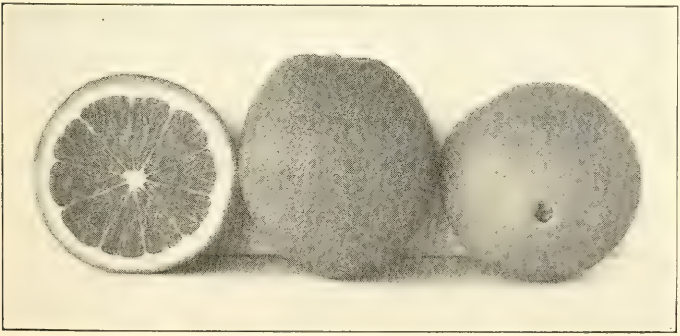

Fig. 17. — One type of Australian Navel orange.

large with upright, open growth, shy bearer. Strictly speaking, there is no such thing as the Australian Navel. The term is a misnomer in the same sense as the term English walnut is when applied to the Persian walnut. In common usage, however, the name applies to a certain rough-fruited and shy-bearing sport of the Bahia Navel, which was unwittingly introduced into California from Australia in an effort to secure the true Bahia. Some persons go further and call any undesirable sport an Australian, thus using the term as an adjective rather than as a noun. Some other persons apply the term Australian to the rank growing wood resulting from water sprouts in the tops of the trees, which tend to produce coarse, rough fruit. This latter is clearly an improper use of the term.

Valencia. — Form oblong, somewhat flattened with depressed ring at apex, tapering toward base; size medium, color pale orange deepening with maturity; skin smooth or slightly pebbled, thin but tough; juice plentiful, flavor subacid; seeds variable, sometimes three to six, often none; season late, from June to November. Tree large, vigorous grower, prolific, thorns few and small.

The Valencia hangs on the tree well during the summer but in interior valleys it is apt to turn green again in late summer. When grown in such situations, it should be harvested in May and June. In deep heavy soils near the coast, it can safely be held till November or December.

This famous orange originated in the Azores. Thomas Rivers, the English nurseryman, imported it, with other varieties, from the Azores into English glass-houses and first catalogued it in 1865 under the name "Excelsior." S. B. Parsons, a Long Island nurseryman, bought trees from Rivers and brought them to America about 1870. He kept them in his greenhouse for several years and then moved them to his nursery near Palatka, Florida. Parsons sold some of these trees to E. H. Hart, of Federal Point, Florida, who gave the variety the name "Hart's Late" or "Hart's Tardiff." Fruit was first exhibited before the Florida Fruit Growers' Association on April 25th, 1877.

A. B. Chapman, of San Gabriel, California, imported a number of varieties of citrus from Thomas Rivers about 1870–72. One variety labeled Navel, turned out not to be a Navel, but of distinct value on account of its ripening very late in the season after other varieties were off the market. Finally, at the suggestion of a Spanish laborer, Mr. Chapman called the orange "Valencia Late" and many trees were propagated and sold under this name.

California nurserymen early secured stocks of Hart's Tardiff from Florida, and many thousands of trees were planted. When it became evident that these were the same as the Valencia, the latter name was adopted and is now used exclusively in California. This name has become so well fixed in the trade and market reports as well as in the every-day speech of the people that it is idle to attempt to change the name in order to conform to the rules of horticultural nomenclature.

The fame and popularity of the Valencia orange has been greatly advanced in California by the wonderful record made by a superb orchard of this variety owned by C. C. Chapman at Fullerton in Orange County.

Mediterranean Sweet.—Form round or somewhat flattened; size medium to small; color deep orange; skin of fine texture; juice abundant, very sweet; seeds few, small; season April to May; tree semi-dwarf with small narrow leaves very thickly set, almost thornless.

Introduced and renamed by T. A. Garey of Los Angeles about 1870. Secured from Thomas Rivers of England.

Paper Rind (*Paper Rind St. Michael*). — Form round; size small, solid with high specific gravity; color yellow, or pale orange; skin very thin and very smooth; juice abundant, colored, with rich vinous flavor; seeds three to six in number, medium sized; season March to May; tree semi-dwarf, medium thorny, very productive. Introduced from the island of St. Michael.

Ruby (*Blood*). — Form round or slightly oblong, sometimes navel marked; size medium; color deep orange or reddish when fully mature; skin smooth; juice deep orange in color changing to red as fruit matures; flavor very rich and vinous; seeds many; season March and April, tree of medium size, compact growth, almost thornless. Imported from Mediterranean districts.

Jaffa. — Form round; size medium; color deep orange; skin smooth or slightly pebbled; juice abundant and of excellent quality; seeds many, large; season March to May; tree medium sized, more resistant to cold than most other sweet oranges, almost thornless. Imported from Palestine, where it is largely grown.

Joppa. — Form oblong, slightly shouldered; skin thin, somewhat pebbled; juice abundant, sweet, and of fine flavor; seeds few or none; season March to July; tree large, thornless. Originated in 1877 by A. B. Chapman of San Gabriel, California, from seed secured from Joppa, Palestine.

Crafton (*Crafton Late*). — A late seedling, originated by Myron H. Crafts, several large budded orchards of which are still in bearing in the vicinity of Crafton, California. It is marketed during May and often brings very good prices.

LEMONS

In the early days of the industry a large number of European varieties were tested, but few were found suitable to the California conditions. Many seedlings were raised also, most of which proved disappointing in some important respect. At present new plantings are limited chiefly to two varieties, the Eureka and the Lisbon. While a few old orchards of Villafrancas are still maintained, but few are being planted. The Eureka is rapidly gaining in popularity

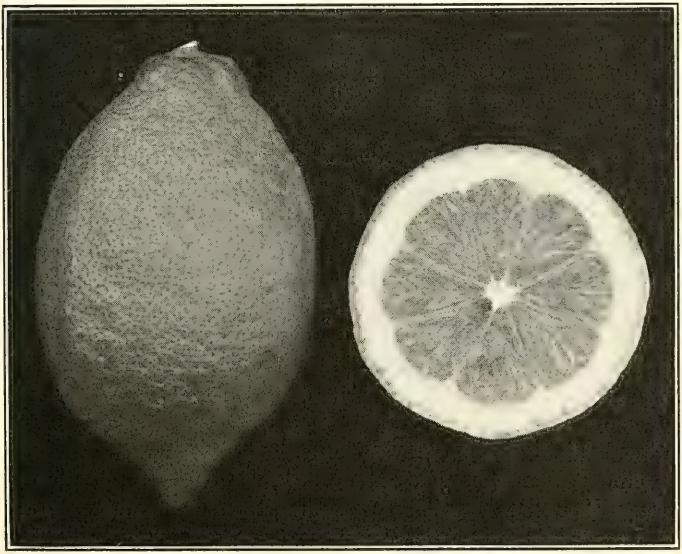

FIG. 18. — Eureka lemon, uncured.

over the Lisbon and it appears that this will soon be the only variety planted on a large scale.

Eureka. — Form oblong, apex nippled, base tapering; size medium; rind smooth, glossy, sweet; juice abundant, clear, strongly acid, flavor good; seeds few, often none.

J. H. Needham, in an essay before the Pomological Society at Covina in 1898, says: "The advantages of the Eureka are its comparative freedom from thorns, its tendency to early bearing, and when properly trained to enormous crops when it comes into full bearing, and its continuous blooming and setting of lemons all the year, especially in sections comparatively free from frost. The objections are its tendency to set its fruit on the tips of the branches, and the inclination to grow long canes with but few laterals and to drop its leaves on the long canes or branches, thus leaving the limbs and fruit too much exposed to the hot rays of the sun in the heated term of summer."

The Eureka lemon originated from a seed planted about 1870 by C. R. Workman in Los Angeles. Workman and Preston began to propagate it, but later sold all the stock to Thomas A. Garey, of Los Angeles, who propagated it extensively and sold it under the name Eureka.

Lisbon. — Form oblong or obovate, apex oblique, nippled with a characteristic crease to one side of the nipple, base tapering sharply to calyx, which is large; rind thin, smooth, sweet; juice abundant, clear, and strongly flavored; seeds few, sometimes none; tree large, a strong, vigorous grower, foliage thickly set, not precocious, very thorny.

The Lisbon bears its fruit uniformly throughout the tree. The heavy foliage protects the fruit from sunburn. The tendency is to bear one large crop maturing in winter, with a small amount of summer fruit. Introduced from Europe.

Villafranca. — "Form oblong, slightly pointed at the blossom end, rind thin, without any trace of bitterness; acid strong, juicy; nearly seedless. Tree almost thornless, branches spreading and somewhat drooping, foliage very abundant, which protects the fruit from sunburn. The tree is a strong grower and is considered less susceptible to cold than most varieties. Introduced from Europe.

"The advantages claimed for the Villafranca are that it makes a more compact tree and bears its fruit more uniformly over the entire tree, but it requires at least one year longer to come into bearing, and the fruits on young trees

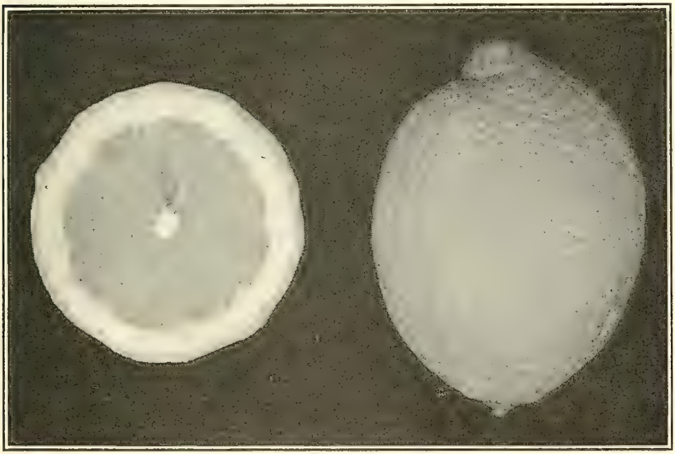

FIG. 19. — Lisbon lemon, uncured.

are shorter when they have the requisite diameter for picking than either the Eureka or the Lisbon."[1]

Other varieties still to be found in old orchards and collections are Bonnie Brae, Genoa, Sicily, Messina, and Milan.

POMELOS

Marsh. — Form flat or obovate; size small to medium; color light yellow; rind smooth, variable in thickness; juice

[1] Lelong, "Culture of the Citrus in California," p. 167.

FIG. 20. — Seedless pomelo, flowers and fruit. From Volckamer's "Hesperides," 1708.

abundant; flavor fair; pith large, open; seeds none or one to six; season March to July or later; hangs on trees well all summer.

According to Hume,[1] this variety was introduced by C. M.

[1] "Citrus Fruits and Their Culture," p. 120.

Marsh of Lakeland, Florida, about 1895 or 1896. The original tree was a seedling growing in Lakeland, and was at the time of the freeze fully sixty years old.

The Marsh is the chief variety of pomelo grown commercially in California and Arizona, although the following may be occasionally met with and are doubtless deserving of a wider planting. While seedlessness is a very desirable character in a fruit, it should not be allowed to outweigh such characters as flavor, juiciness, and quality. California is in need of a variety of pomelo better suited to the conditions than any now available.

Nectar (*Duarte Seedling*). — A seedling tree brought from Florida and fruited at Duarte, California. The fruit is round and solid with smooth skin of pale yellow color. The seeds are few and the flavor excellent.

Duncan. — A flat fruit with rather thick skin and flesh of grayish green color, seeds few, season late, quality good. Introduced from Florida.

Triumph. — A fine-appearing fruit and full of juice as well as seeds, of which there are many. Somewhat lacking in flavor.

Imperial. — Size medium to large, rind very smooth, medium thin, and of fine texture; little rag; juice abundant and of fine aromatic flavor. R. M. Teague says of this variety: "It is one of the best keepers and shippers. The tree is a strong upright grower and a heavy cropper."

Colton (*Colton Terrace*). — A seedling grown at Colton, California. Size medium to large, heavy, subacid, and delicately bitter; seeds many; skin smooth; oil cells very small; light lemon color, turns slightly orange color when mature.

Pink-fleshed. — A prolific variety imported from Cuba. Flesh deep pink, coarse, and of poor quality. Seeds many; tree very large and ornamental.

MANDARINS

The Mandarin oranges grown commercially in California are practically all of one variety, the Dancy, commonly known as the tangerine. On account of the confusion in name, it may be well to emphasize the fact that "tangerine" is the trade name for one variety of Mandarin orange, the proper name for which is Dancy. The Satsuma

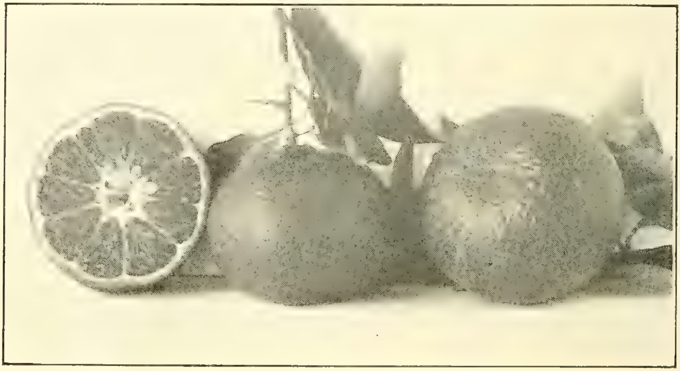

Fig. 21. — Dancy Mandarin orange.

is not grown commercially in California and is represented only by occasional specimens in gardens and nursery collections. Such collections often contain specimens of King, Beauty, Mikado, Oneco, and a few others.

Dancy. — Form oblate; size medium; color very deep orange red; glossy; rind smooth, except about stem end, which is nippled, apex depressed; segments separating readily; juice abundant, colored; flavor rich and sprightly; seeds five to ten or more, small; season January to February. Tree of upright growth, fruit borne largely on the extremities of the branches; somewhat thorny. Parent tree raised from seed by Col. George L. Dancy at Buena Vista, Florida. Introduced into cultivation about 1872.

Satsuma (*Unshiu*). — Size small to medium, 2 to 3 inches in diameter; shape flat, a little pointed next the stem; color bright orange; skin rough, wrinkled next the stem, very loose and easily separated from the flesh; core, almost none, represented by a cavity often three-eighths inch in diameter in center; seeds none; flesh orange color, darker than the skin, not so juicy as some; flavor very sweet, rich, very aromatic, peculiar; quality very good; season early.

This variety is thornless and a dwarf grower. It will endure more cold than any other variety of edible citrus fruit except perhaps some of the hybrids mentioned below. Should be worked on *Citrus trifoliata* stock or sourstock. Introduced from Japan about 1876.

MISCELLANEOUS VARIETIES

Swingle-Webber Hybrids. — In 1892, W. T. Swingle and H. J. Webber of the U. S. Department of Agriculture undertook to produce new and improved varieties of citrus fruits by hybridization on an extensive scale. Several new types have been produced, examples of which are Citranges and Tangelos. The citranges are crosses between the common sweet orange and the trifoliate orange. The Rusk, Willits, Norton, Colman, Savage, and Rustic have been described. The fruits of these hybrids are intermediate in character between their parents. They are not nearly so good as sweet oranges, but they may be used for making soft drinks, pies, and marmalades. Their special advantage lies in their resistance to cold, which enables them to grow a hundred miles or more beyond the northern limit of the sweet oranges.

In California they are as yet grown only as specimens for exhibition purposes.

The Thornton is a loose skinned tangelo which resulted from crossing the pomelo and tangerine. The juice is sweet, lacking the bitter of the pomelo. The Sampson tangelo is the result of crossing the pomelo with pollen of Dancy. The skin is loose like the tangerine, but the flavor includes some of the bitter of the pomelo. The Weshart and Trimble are crosses between the Dancy and Parson Brown.

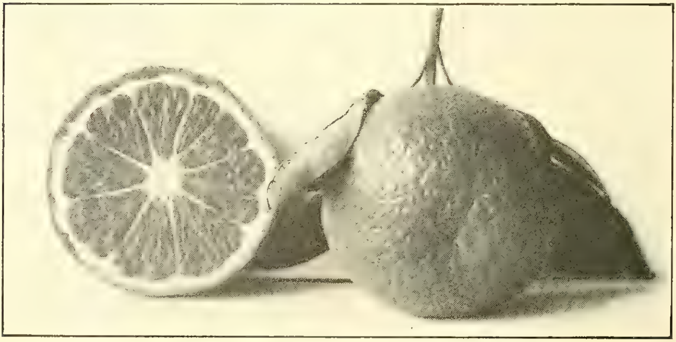

FIG. 22. — Satsuma Mandarin orange.

The fruits are larger than the Dancy, which they resemble otherwise.

Several thousand hybrid seedlings of several generations are now being grown by the Department of Agriculture and additional varieties of merit may come to light in the future.

Citron. — Citron is not grown commercially to any extent in California, although good specimens of the plant may be found in many parts of the state and there is at least one good-sized orchard. The tree is small in stature with a shrub-like growth. It is more tender to frost than the orange, but less tender than the lime. As early as 1880, experiments showed that California-grown citron, when properly processed or candied, was equal in every respect to the imported article. The consumption of candied citron in the United States is very small compared with that of oranges and lemons, and this probably is the main reason why so little interest has been taken in it. There appears to be no good reason why California should not produce all the candied citron consumed in this country. Most of the varieties of Europe have been introduced for trial. The Corsica appears to be one of the best.

Shaddock. — The shaddocks are of no commercial importance. Occasional trees may be found in collections and in yards and gardens throughout the citrus belt. They appear to vary in resistance to cold, some being as hardy as the orange. The fruit is very large, round, oblate or pear shaped; skin very thick, sometimes two inches thick; seeds many or none; flesh pale yellow or reddish, juice acid and often very bitter; in some forms the young growth is pubescent. Trees ornamental, but not more so than the pomelo, which is both useful and ornamental.

Lime. — Three kinds of limes are grown for home use to a limited extent in California. The Sour or West India lime, together with the Rangpur, are used for cooling drinks while the Sweet lime is eaten out of the hand like the orange. Limes have never been grown commercially in California. All but the Rangpur are very tender to frost, even much more so than the lemon. The Rangpur is said to be fully as hardy as the lemon. In the early days a sour form of Mexican lime was much planted as a hedge plant around orange orchards. They proved too tender for most localities and were difficult to fumigate and keep free from

FIG. 23. Nagami kumquat. (82)

scale insects. For these reasons they have mostly disappeared.

Kumquat. — In California the kumquats are used chiefly as ornamentals, although a few find their way into the markets and an occasional small shipment is sent out of the state. They are especially suited to pot culture, when budded on *Citrus trifoliata* root, and are convenient to move about as desired on verandas and in formal gardens. The fruit is small, about one inch in diameter, with sweet aromatic rind. The fruit may be eaten fresh or made into delicious preserves. The Marumi kumquat is most hardy to cold. It has round fruit, borne in great abundance, ripening in October. Twigs somewhat thorny. The Nagami kumquat is oblong, slightly pear shaped; fruit golden yellow; rind smooth, aromatic, and spicy. Tree thornless, slightly more tender to frost than Marumi.

Sweet lemon. — This form of citrus is met with only in collections, as there is no market demand for a sweet lemon. It is a question whether this should be grouped with the lemons or with the oranges. The fruit is like a lemon in shape but the flowers are white like those of the orange.

The Trifoliata. — In the early days this species was grown to a considerable extent in California as a hedge plant. These hedges have been largely done away with, and as the plant is not needed as an ornament, it is rapidly becoming rare in the state.

CHAPTER V

THE CITRUS NURSERY

THE day of the seedling orange grove is past in California. Now all trees for new plantings are budded as a matter of course. Many of the large planters prefer, and find it highly profitable to grow their own trees. Yet the business of raising citrus trees for sale has reached large proportions. Citrus nursery stock not only fills the home demand, but is shipped in large quantities to many foreign countries.

THE SEED-BED

The first step in the production of a citrus tree is the raising of the root or stock upon which the desired variety is to be budded. The comparative value of all the different stocks will be discussed in Chapter X. We will simply say here that at present the demand is about as follows: sour-stock, 85 per cent; sweet-stock, 9 per cent; pomelo, 5 per cent; and all others, 1 per cent. Sour-stock seed comes from the wild thickets of Florida and Cuba, and is sold in California for from $30 to $50 a bushel. Between five and six hundred bushels of sour orange seed was planted in California in the year ending June 30, 1913.

Fig. 24. — Citrus seed-bed under lath.

This seed may be secured in the fall and kept in a cool, dark cellar. It should not become excessively dry. Sour seed runs about 30,000 seeds to the bushel, half of which should come up and produce trees.

Sweet orange seed is secured from the various seedling orchards in California. It will not endure drying, but must be handled quickly and kept moist. The seed stores do not keep sweet seed on hand in quantity, but on receipt of an order will send a man with a seed separating machine to a cull heap near some packing-house, secure the amount of seed desired, and forward immediately to the purchaser in a wet condition. Such seed must be planted at once. The price is usually from $18 to $25 a bushel, which contains about 35,000 seeds. Pomelo seed is secured either locally or from Cuba. It will stand drying to a small extent only. Rough lemon seed may be handled much like sour orange seed.

After the freeze of January, 1913, it was found by experiment that the seed in oranges which had been frozen was viable, although dark in color. Almost as good germination was secured with seed from frozen as from sound oranges.

It is an established custom in California to grow citrus seedlings under a lath shelter, although one large nurseryman near the coast has broken away from this custom and has secured good results by planting entirely in the open. In the hot interior some shelter is necessary, but the trees grow in height faster and are ready for market quicker if grown under shelter anywhere. The shelters are covered with one-inch laths alternating with one-inch openings, supported by uprights set at convenient distances.

The lath are usually nailed to cross pieces in sections of suitable size to be handled by two men. The shelter rests about eight feet from the ground and the lath should run north and south.

The soil for the seed-bed should be deep, sandy loam, free from stones and well-drained. Virgin soil is best, but if that is not obtainable, good, rich grain land will answer. It should of course be worked up into a fine state of tilth, leveled, and slightly firmed with a light roller. If dry seed is used, it should be soaked for twenty-four hours before planting. If the bed is to be irrigated by running water through furrows, the ground is laid off in rows twelve inches wide with very shallow furrows about eight or ten inches wide. A broad, shallow, slow stream of water is needed to soak through such rows. The seed is planted broadcast on these wide rows, every sixth row being left vacant for a walk. In case the bed is watered from above by automatic sprinklers, as is usually the case, the seed is broadcasted over the entire surface of the ground except for a twelve-inch path every ten feet. In some cases the seed is simply planted about one inch deep in the loose soil and then thoroughly watered. In most cases, however, the seed is gently pressed into the soil with a board and covered from $\frac{1}{2}$ to 1 inch deep with clean coarse river sand especially provided for the purpose. This covering of sand prevents the ground from baking and also keeps the surface dry. The seeds are placed about one inch apart each way and if half of them or even an average of thirty to the square foot grow, the stand is considered satisfactory.

One of the greatest dangers to the seed-bed is the possibility of infestation by the "damp-off" fungi. This disease works very rapidly, covering a large area in a single night and killing the seedlings just after they come up. This trouble may usually be prevented by keeping the surface of the ground as dry as the requirements of the seedlings will permit. The covering of sand allows the water to pass through to the roots while the surface dries again very quickly. The usual time of planting is April, and most of the plants should be large enough to sell one year after planting.

After the seedlings are two months old they may be watered more generously every two or three weeks as necessary. All weeds should be kept out of the beds, and a sharp watch must be kept for gophers, moles, and ants. The plants are sold for from $20 to $50 a thousand when they are about a foot high. The beds are usually gone over twice, the smaller plants remaining for two years. It is hardly necessary to point out that the plants first pulled from the bed are much more desirable than those which require two years to reach marketable size. In ordering seed-bed stock "first pull" plants should always be specified.

No manure or compost of any kind should be used in the seed-beds for fear of encouraging the "damp-off" fungi, which are usually more serious in proportion to the amount of freshly decaying organic matter in the soil. A moderate dressing of commercial fertilizer high in nitrogen will accelerate the growth of the plants. Often no fertilizer is used.

After the seedlings have safely passed the stage when they are liable to damp-off, they may become infected with brown-rot gum-disease. In such cases they will exude gum just above the ground and may be girdled and killed. Where there is any large amount of such gumming, a thorough spraying with bordeaux-mixture is recommended. Sour-stock is very resistant to gum-disease in the orchard, but this is not always the case in the seed-bed.

When seed-bed stock is to be dug, the soil is first thor-

FIG. 25. — Citrus seed-bed in the open.

oughly wet, the roots slightly loosened with a long tined spading-fork, and the plants drawn by hand. A varying proportion of the plants will have a crooked or Z-shaped tap-root known as "bench-root." When the seed-coat is tough, the root has difficulty in piercing it and often makes several turns before getting out. This may be partly prevented by soaking the seed over-night before planting. All such plants are inferior and should be discarded. All

FIG. 26. — Bench-rooted orange seedling.

plants which have gum-disease should also be thrown away. After grading, the plants are tied in bunches and their tops chopped off squarely with a hatchet about eight inches above the crowns. They are then packed tightly in boxes or bags with the tops exposed and with moist sphagnum moss about the roots.

Citrus seed-beds are likely to become infested with scale-insects or other pests, especially if situated near infested orchards. In many counties, horticultural inspectors have strict regulations in regard to the admission of nursery-stock shipped from other counties. Such local regulations are by no means uniform for the whole state. It is wise to confer with the appropriate officer in each case before the plants are dug in order to learn just what kind of treatment will be required. Usually the plants are dipped, all but the roots, in the following solution :

Resin	20 lb.
Caustic Soda	8 lb.
Fish Oil	3 pt.
Water	100 gal.

PLANTING SEED-BED STOCK

For the planting of seed-bed stock, a deep rich loam, free from stones, should be selected. It should contain just enough clay to stick together well when the trees are balled. The site for the planting should be as free from frost as possible, as newly set buds are very susceptible to cold. The stock is planted eighteen inches apart in rows three and a half or four feet apart. Especial emphasis is here laid upon the fact that the roots of citrus plants are very susceptible to injury from drying, and if a plant is left in the sun, with its roots exposed, for more than a few moments, it is almost sure to fail to grow. The best plan is to take all the plants into the field in the boxes of sphagnum covered with wet sacks. Only a few should be handled at a time and in such a way as not to expose the roots at all. The plants are usually set with a dibble or spade, great care being taken to get the roots in straight and not to set the plants deeper than they grew in the seed-bed. In planting citrus trees of any size or kind, it is a safe rule not to vary the depth of planting. The soil around the plants should be well firmed to bring the roots in close contact with moist earth. Irrigation water should follow the planters down each row as the work proceeds. After the soil is well irrigated the plantation should be gone over and those plants which on account of their small size did not have a part of the top trimmed off at the seed-bed should be cut back about fifty per cent. These small plants which escaped the trimmer's hatchet are almost sure to die unless headed back in the same proportion as the others.

Budding stock handled as described, and properly cultivated and irrigated, should be large enough to bud at the end of one or two years, usually eighteen months. An application of about one-half ton per acre of special nursery stock commercial fertilizer will save time in growing the plants to budding size. Every effort should be made to encourage a vigorous growth. It is false economy to bud seedlings which are too small; the ideal size being from $\frac{3}{8}$ to $\frac{7}{16}$ inch in diameter three inches from the ground.

PROPAGATION

Many writers make the statement that citrus trees are propagated by budding, grafting, cuttage, and layerage. This is somewhat misleading, inasmuch as budding is the universal method employed in America. Lemon cuttings may be made to root, but orange cuttings are so difficult as to be out of the question entirely. The few lemon trees that have been grown from cuttings have been inferior and have mostly passed out of existence. Layering is never used and grafting is very rarely resorted to except in the case of old trees which have been frozen to the ground. Most old trees which are top-worked are budded. The writer has seen buds successfully placed directly into orange trunks which were a foot and a half in diameter, although such a practice is rare and not to be recommended.

Cutting Bud-wood

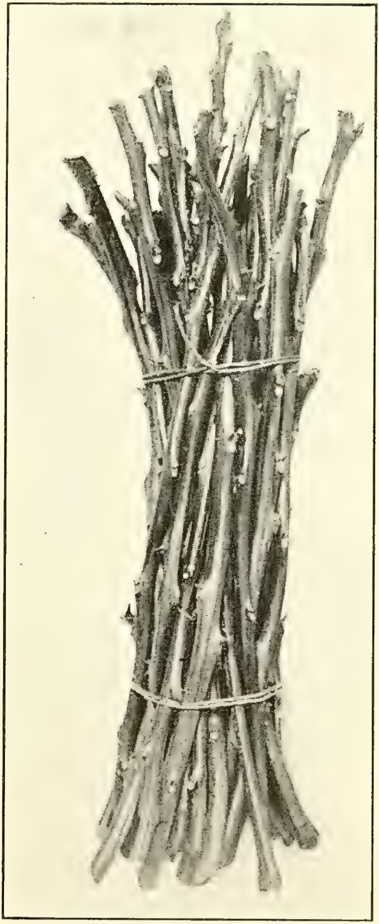

Fig. 27. — Orange bud-wood.

The success of the citrus orchard depends to a very large extent upon the care used in cutting the bud-wood. This is due to the fact that a certain proportion of the trees in many orchards belong to undesirable types. This particular phase of the subject will be reserved for a more extended discussion in Chapter VII. Suffice it to say here that too much pains can hardly be taken in selecting the mother trees from which the buds are to be cut.

Citrus buds should be cut from round, plump wood taken from the fruiting branches. It is usually easy to find plenty of suitable bud-wood on lemon trees, but with oranges, and especially Navel oranges, this is often difficult for the reason that the best trees are devoting their energies to bearing rather than to growing plump bud-sticks. The small angular fruiting twigs are not large enough to use to advantage. On this account it becomes necessary to give Navel mother trees a preparatory pruning a year before the buds are wanted. The trees are thinned out and cut back uniformly in all parts in order that there may be a more vigorous growth of fruiting wood. This pruning should not be carried too far or water-sprouts may result. Bud-sticks about a foot long and the size of a lead pencil made up of one- and two-year-old wood is best. Current growth is too tender and three-year-old wood contains many blind buds or buds which will be very slow to start. Uniformity in starting the buds is much to be desired, and the more care is used in collecting buds of the same degree of maturity, the more uniform the nursery will be. The leaves are cut off, leaving a short stub for a handle. The cutting may be done in mid-winter and the accumulated wood buried in slightly moistened sand for two or three months. The wood will cure and callous on the lower end, and cured wood is supposed to give more uniform results. Most budders prefer to keep the bud-wood in boxes of moist sphagnum because the sand will dull the budding knives unless the wood is carefully washed. It is not necessary to cure the buds, but it is often more convenient to cut the buds all at one time and keep them until used. It is best to select bud-wood as free from thorns as possible for the reasons given in Chapter III.

A great deal of argument has been indulged in over the question of whether buds from sucker growths or water-sprouts are as desirable as buds from the fruiting brush. It is unwise to use buds from rank growing water-sprouts because an excess of food is one of the chief causes of variation; and as these buds have a great excess of food, they are somewhat more likely to grow into sporting trees than are buds from fruit wood. This does not mean, however, that good trees have not been grown and may not again be grown from sucker buds. We simply take the position that it is an unwise policy for the reason given.

Time of Budding

Citrus stock may be budded at any time of the year or whenever the bark will slip, but the best time is during the months of October and November, in which case the buds usually remain dormant until spring. Stocks upon which the buds fail, may be rebudded in April or May. It often happens, unfortunately, that a certain proportion of fall set buds start into growth immediately, thus exposing a few inches of very tender growth to the dangers of winter. In such a case, the number of orchard heaters set in the nursery should be increased and the fires started at the first indication of frost.

Method of Budding

In California, the usual method of insertion is the shield or T method. The bud-stick is grasped firmly with the tip toward the operator. With a very sharp budding knife the bud is cut by inserting the blade about one-half inch below and drawing it beneath the bud and out about one-half inch above, thus cutting a bud about one inch long. The bud is held firmly between the thumb and the knife blade while a slit is cut in the bark of the stock about three inches above the ground and one-half inch long. At the top of this slit, a cross cut is made with the edge of the blade of the knife inclined downward. The bud is then inserted in this slit, being careful to have the leafscar or bottom of the bud down. The back of the point of the knife is then placed on the leafscar and the bud pushed down until the upper end is below the cross cut, and in any event until the pressure of the bud begins to split the bark beyond the previously made slit. A strip of waxed cloth is then wrapped quite firmly around the stock five or six times so as to cover the bud completely.

Fig. 28. — Cutting a bud.

Some budders prefer to leave the eye exposed but this is not necessary. Buds are usually set on any side as regards the points of the compass, or in other words, the side most convenient to the budder. The bark usually slips, and the buds take better, directly under a small branch.

Some budders prefer to use the inverted T method. The cross cut in the bark of the stock is made lower and the bud pushed upward instead of downward into place. The inverted T is somewhat better for fall budding, as the cross cut or obstruction when placed below the bud tends to produce a quiescent state which is desired during winter. The cross cut when placed above the bud tends to produce a strong lateral growth and is therefore best for spring budding.

Fig. 29. — Making incision in stock.

Most seedlings tend to branch close to the ground and as a result buds are often placed quite close to the ground. This is a mistake in most cases, especially when using sour orange as a stock. This stock owes its popularity largely to its resistance to gum-disease, but when buds are placed low this resistance is much reduced. The object should be to keep the wood of the scion as far from the ground as practicable in order to avoid gum-disease infection, which comes from the soil. If, on the other hand, buds are placed too high, a crooked and ugly trunk will result. While high budded trees are less comely and do not sell as well on account of the crook in the trunk, still they are the more to be desired, especially when intended to be

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planted on heavy soils or near the coast, where gum-disease is prevalent.

After about ten days, the buds should be unwrapped and examined. If they have taken, as evidenced by a grayish line of callous tissue forming around the edges, the wrappings are loosened, to be removed entirely after about thirty days in the case of the fall buds and twenty days in the case of spring buds, or whenever the bud is well healed.

Fig. 30. — Inserting bud.

In the case of fall buds which have remained dormant, as they should during winter, the tops of the stock are cut back in the spring to within six inches of the buds in order to increase the sap pressure and force them into a more uniform growth. The promptness with which a bud starts depends to some extent on its age and position on the bud-stick. Uniformity of growth is greatly to be desired in the nursery, and such cutting back tends to force all the buds to start more nearly at the same time. The six inches or more of stock which is left affords a certain protection to the young shoot and reduces the possibility of the bud being involved in any dying back which may occur. After the young shoot has grown eight or ten inches the stub of the stock is sawed off smoothly, the edges trimmed with a sharp knife, and the cut surface covered with liquid grafting wax.

In the case of spring set buds, the same custom prevails except that sometimes the stocks are only partially cut back at first. With late set buds there is sometimes a danger of the superabundance of sap during hot weather "drowning out" the buds if all the top of the stock is removed too suddenly. Occasionally the tops are "lopped" or cut half through and bent down in the middles, in order to gradually change the flow of the sap. They are removed entirely after a month or six weeks.

Fig. 31. — Tying inserted bud.

Citrus budding is often done by expert budders by contract at about $10 a thousand, the budder guaranteeing a 95 per cent stand and furnishing his own buds, wrapping cloth, and the like. Eight and a half dollars a thousand is a common price when buds are furnished. This of course applies to regular fall budding.

Training the Young Tree

In order to insure a perfectly straight trunk the young trees are trained to stakes. The stakes may be set soon after the buds have started growth. The stakes used in California are ordinary building laths. They are driven into the ground close by the stock on the side next the scion. As the young shoot grows it is tied to the stake with soft raffia. A tie is made every three inches, the raffia being drawn up snugly under a leaf. The rough unfinished surface of the lath is an advantage, as it prevents the raffia from slipping down. Careful attention to tying is necessary in order to secure straight trunks. While going over the trees for tying it is also necessary to remove any side branches which may put out, as well as the numerous suckers which arise from below the bud. These sprouts should be rubbed off with the thumb while still very young, and this necessitates going over the trees every three or four weeks during the first summer.

Nursery trees should be allowed to grow three feet tall and then headed back to 27 or 30 inches. This will insure the main branches being set upon stronger wood than if the terminal bud was pinched as soon as it reached the desired height. Branches which are to be the framework of the future tree are encouraged to put out on all sides and distributed over the upper twelve inches. From three to six main branches are sufficient. The old custom was to allow the framework branches to arise from near the same point. Experience has shown that such branches split down badly and require much bolting when the trees grow old. This is being abandoned, especially with lemon trees, in favor of the less comely but more desirable distribution of main branches.

Fig. 32. — Orange buds in nursery row tied to lath stakes.

Often a tree will make several growths before it reaches the top of the stake. The end of each growth is marked by a ring or node of thickened tissue. There is a widespread belief that a tree with several of these nodes on the trunk is to be preferred to one which made one growth to the top of the stake. The reason assigned is that it indicates slow growing and heavy fruiting qualities. It is doubtful whether there is sufficient basis in fact for this belief, although there are some arguments in its favor. It is not unlikely that in the case of the Washington Navel orange there may be some correlation between the number of nodes and fruitfulness, but this is probably not the case with lemons.

The citrus nursery should be thoroughly cultivated and irrigated and the trees kept in vigorous growth. Commercial fertilizer should be applied liberally, usually a ton to a ton and a half to the acre of a complete fertilizer high in nitrogen. One or two years are required to grow a marketable tree. We find, therefore, that a total of from four to six years is required from planting the seed to setting the trees in orchard form.

Trees are graded and priced according to caliper measurement one inch above the bud. Well-grown one-year trees are often acceptable, but usually two-year trees are much better. Prices in California vary from fifty cents to one dollar and a quarter a tree.

PREPARING TREES FOR SHIPMENT

Citrus trees may be dug with naked roots, cut back to the trunk, shipped long distances, and planted with perfect success; but on account of the fact that it is difficult to always see that the tender roots are not exposed, there is much loss from the carelessness of laborers, and the custom of balling trees has become general in California. Balled trees are much less perishable, may be handled with more assurance, do not require all the top to be removed, do not need to be reheaded, and make a somewhat better showing the first year. On the other hand, the cost of

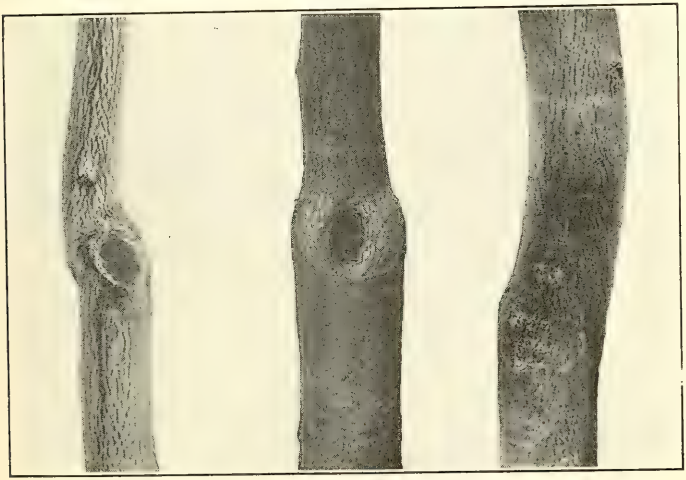

Fig. 33. — Healing of the bud union.

balling is great and the freight on thirty to forty pounds of earth with each tree adds considerably to the cost.

It is recommended, therefore, that trees be balled where the distance to be transported is short or when inexperienced men are to do the planting. Where the owner is able to look after the planting personally the trees may be dug with naked roots and a considerable saving on freight and expense of balling will result. Where trees are to be moved only a short distance, as from one part of a ranch to another, the following method is sometimes used. Short sections of ten-inch pipe are placed over the trees and driven into the ground, thus cutting all roots but the tap-root, which is cut with a spade. The trees are

Fig. 34. — Balling orange trees in the nursery.

then moved and the core of earth containing the trees is slipped out of the pipe into the hole prepared, the pipes being used again and again.

When trees are to be balled, a trench a foot wide and fifteen inches deep is dug alongside of a row of trees and with careful work the tap-root may be cut and the tree lifted with a ball of earth. This is carefully wrapped in old sacking and firmly tied with strong cord. The top is cut back somewhat, the leaves removed from the trunk, and the trees are ready for shipment. A baller and tyer work together and in good soil should turn out about one hundred and seventy-five trees a day. Counting the men engaged in digging trenches and defoliating, a crew of twenty-five men should dig and ball about fifty trees a day for each man in the crew. When a few balled trees are shipped, they must be boxed at considerable expense. In the case of carload lots, they are simply stacked closely together in ordinary box cars, the balls resting on a layer of moist straw on the bottom of the car. *En route* the balls should be kept moist, but not so wet as to start growth. California now produces upward of a million and a quarter citrus trees a year, many of which are shipped to various foreign countries including South Africa, New Zealand, and India. Foreign shipments always go forward with bare roots firmly packed in sphagnum moss.

CHAPTER VI

HORTICULTURAL INSPECTION AND QUARANTINE

California has had much experience with horticultural statutes. Many different laws have been passed and amended from time to time during the last thirty years. During this time there has been hardly a session of the state legislature which has not changed the law in some particulars. The citrus industry is so vitally concerned with the activities of the State Commission of Horticulture as to warrant a description of this important agency.

In March, 1908, the State Commissioner of Horticulture published a handbook containing all the laws together with the court decisions and legal opinions relating thereto, corrected to that date. More recent laws, together with a number of quarantine orders, may be found in the Commissioner's "Monthly Bulletin," Vol. II, pp. 337–351, 1913.

The ordinances of the different counties relating to the movement of nursery stock from one county to another may be secured from the respective County Horticultural Commissioners.

THE STATE COMMISSIONER OF HORTICULTURE

This official is appointed by the Governor for a term of four years or until his successor is appointed.

While the state law, approved April 26, 1911, directs the Commissioner to collect books, pamphlets, and periodicals and acquire all possible information by correspondence for the furtherance of the horticultural industries, still his principal function is that of a police officer. He is by virtue of his position the state horticultural quarantine officer, and as such is responsible for the rigid exclusion from the state of injurious insects and plant diseases, and the prevention of any further dissemination of such pests as are already established in certain localities within the state.

In order to enforce the state quarantine law approved January 2, 1912, the Commissioner maintains an office with a force of inspectors at San Francisco, another at Los Angeles, and a third at San Diego. These inspectors go through the cargoes of every ship arriving from any foreign port or from Honolulu, and the baggage of every passenger. If any plants, fruits, or seeds are found to be infested with injurious insects or diseases, they are fumigated at the expense of the owner, or treated in such a way as to kill the pests. If this is impracticable, the plants are destroyed or, at the option of the owner, returned whence they came. In some cases the State Commissioner may, with the written approval of the Governor, issue a quarantine order against certain fruits or plants from certain countries. Such articles are then considered contraband and, if an attempt is made to introduce them, are confiscated and destroyed by the inspectors regardless of whether they are infested or not.

The State Commissioner may appoint the County Horticultural Commissioners or their agents special quarantine officers for the purpose of inspecting shipments coming from the Eastern states or Europe and billed to interior points in California. The common carriers are by law forbidden to deliver to a consignee within the state any shipment of horticultural goods until such shipment has been inspected, declared free from pests, and formally released in writing by a duly appointed horticultural in-

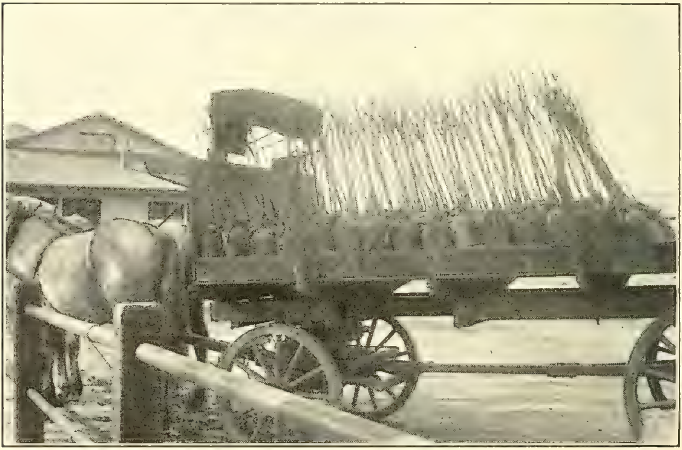

FIG. 35. — A shipment of defoliated balled orange trees.

spector. The inspector may exercise his discretion in regard to the disposition of infested shipments. He may rid the plants of pests by fumigation or other means and then release them upon payment of the costs; or if in his judgment the infestation is severe or the pest particularly dangerous, he may destroy the goods or cause their reshipment out of the state.

As an example of a quarantine order now in force we may cite Order No. 21, which forbids the shipment of any of the forty listed host plants of the citrus white fly, *Aleyrodes citri* and *Aleyrodes nubifera,* from North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas into the state of California. This order prevents California growers from securing nursery stock or scions of new varieties in any of the above mentioned states. By special arrangement, however, the citrus seeds planted by nurserymen which come from Florida and Cuba are admitted, provided they are sent in care of some designated agent of the Commission, who fumigates them before delivery to consignee.

Another quarantine order prevents the importation from Hawaii of mangoes, oranges, avocados, and other fruits which are hosts of the Mediterranean fruit fly, *Ceratitis capitata.* Still another order forbids the shipment into California from Mexico of oranges, mangoes, or other fruits which are hosts of the Mexican orange maggot, *Tripeta ludens.* These latter, however, have now been superseded by national quarantine orders.

It has long been the custom of the State Commissioner of Horticulture to hold two meetings each year which are known as State Fruit Growers' conventions. One meeting is usually held at some convenient place in the northern part of the state and the other in the southern part. The proceedings of these conventions are brought together, edited, published, and distributed free by the State Commissioner. The meeting held at Davis in June, 1914, was the forty-fifth such convention. The printed proceedings of these conventions represent a very fertile source of information for the student of California citriculture.

THE COUNTY COMMISSIONERS OF HORTICULTURE

The California State law providing for County Horticultural Commissioners has been amended many times. The present law, approved March 25, 1911, provides: that whenever a petition, setting forth the legitimate need for a Commissioner and signed by twenty-five or more resident freeholders who are possessed of horticultural properties, is presented to the county board of supervisors, said supervisors are required to appoint a County Horticultural Commissioner from the list of eligibles, who must have passed the examinations held by the state board of horticultural examiners. The term of the County Commissioner is four years.

Many of the duties of the County Commissioner are prescribed by county ordinances, and these vary in the different counties. The Commissioner is usually required to keep informed as to the particular localities within the county where pest infestation is serious. He must have the orchards and ornamental plantings inspected, and when in his judgment the scale insects have increased in any orchard until they constitute a public nuisance, he must serve written notice on the owner to abate the nuisance by fumigating, spraying, or otherwise within a certain time limit. If this order is not complied with, the Commissioner may enter the premises and abate the nuisance, the cost of such work becoming a lien on the property. If the cost of the work is not paid, enough of the property may be sold at public auction to satisfy the lien.

Such ordinances have been tested in the courts and found constitutional, the acts of the County Commissioners being upheld in each instance.

County Commissioners may appoint local inspectors in outlying towns and fruit districts within the county. The Commissioner also renders an annual report to the State Commissioner and a monthly report to the board of supervisors of his county.

As special state quarantine officers it is the duty of the County Commissioners and their agents to inspect every shipment originating outside of the state, as well as those coming from other parts of the state which arrive in their territory.

It is also the duty of the Commissioner to inspect every outgoing shipment of horticultural goods before it is accepted by a common carrier. The law requires common carriers to accept only such packages or lots as bear a statement signed by the Commissioner or his agent certifying that the goods are free from injurious pests. We find, therefore, that every package of horticultural goods is inspected twice, once at the point of shipment and again at the place of delivery.

THE NECESSITY FOR INSPECTION

The question may arise in the mind of the reader as to whether this complex system of quarantine and inspection is worth while. The answer to this question may be found in the following quotation from California Experiment Station Bulletin No. 214, by H. J. Quayle.

"That insect pests are one of the important factors in the citrus fruit industry of California is shown by the fact that more than half a million dollars are expended annually in their control. This amount includes only what is actually expended in fumigation and spraying, and does not take into consideration the loss of fruit from improperly treated trees or trees not treated at all. The cost of fumi-

Fig. 36. — Two-year-old orange trees balled, ready for market.

gation in one county alone amounts to $200,000 annually. Furthermore each county maintains a horticultural Commissioner, and many of them a corps of inspectors, primarily on account of insect enemies, who are charged with the quarantine and inspection work, the cost of which in some of the counties may run as high as $25,000 annually. All of this vigilance seems to be warranted by thirty years' experience of the most important fruit section of the United States.

"It has been estimated that the average cost of fumigation per tree, taking the whole of the citrus belt, amounts to about 30 or 40 cents, which means an expense of approximately \$30 to \$40 per acre, and this is done on an average about every other year. This is intensive insect fighting, but when the improved market value of the fruit is considered, it is money judiciously spent with such a valuable crop as the orange or lemon."

In conclusion we may say that the benefits of exemption from scale insects is clearly reflected in the prices asked for land and bearing orchards in scale-free localities. The annual tax of 15 to 20 cents a tree for fumigation is especially unwelcome and growers in scale-free localities do well to exercise every possible precaution to prevent the introduction and establishment of such relentless tax-gatherers as the insect pests and plant diseases have proved themselves to be.

CHAPTER VII

IMPROVEMENT OF CITRUS TREES BY BREEDING

The production of citrus fruits in California and Florida is increasing at a rapid rate. The shipments from these two states for the season 1913–14 reached a total of about sixty thousand cars. Thousands of acres of young orchards are just coming into bearing, and the near future will undoubtedly witness a large increase in production. The problem of how to make a profit in the business in spite of the heavy production will loom large in the future.

Undoubtedly a great deal may be accomplished through the marketing organizations by securing better distribution of the fruit and increased consumption through proper advertising. Yet it is a fact that much loss is at present due to a lack of varieties which are well suited to the climatic and soil conditions under which they are grown, to ignorance in regard to adaptation of varieties, and to sports or aberrant forms which occur throughout the citrus growing districts much more commonly than is generally recognized.

Through carelessness or ignorance in the selection of bud-wood many poor or even worthless types have been propagated and widely planted. The poor financial showing made by many orchards is due largely to the preponderance of trees belonging to aberrant forms.

While some progress may be made toward improved varieties through hybridization, the writer is strongly of the opinion that much better and quicker results are to be secured through the careful selection of desirable bud-sports which occur rather frequently on trees of the old standard varieties.

HYBRIDIZATION

The object of hybridization is to secure seedlings which combine the desirable characteristics of two or more parent trees. The flowers of the selected parent trees are cross-pollinated by hand, using great care in excluding foreign pollen.

Cross-pollination is a very easy operation and may be performed successfully by any one willing to use a little care and perseverance. The structure of the citrus flower is very simple and a knowledge of the functions of the different parts is easily acquired by the study of the diagram at Fig. 14. The essential organs of the flower are the stamens and pistil. The anthers bear the pollen grains, each one of which when placed on the stigma will germinate and send a tube down through the style and into the ovary. The male nucleus from the pollen grain passes down through this tube and comes in contact with the female egg-cell of the ovule with which it fuses, thus bringing about fertilization and the combination of the characters of the two parents. A separate pollen grain is needed for each seed, and the parental characters may be combined in a different way in each case. After the ovaries have been fertilized they grow into viable seeds. It is not always necessary for citrus flowers to be pollinated and fertilized in order to produce fruit. The Navel orange for instance rarely contains seeds and on that account is known as a parthenocarpic fruit.

When cross-pollination is accurately performed, it is necessary to place paper bags over the blossoms which are to be used as a source of pollen, before the buds open. This is necessary in order to prevent the possibility of the mixing of pollen by insects. The pollen may be gathered and dried on papers and stored in small bottles for use, but it is often convenient to cut the twigs, bag and all, and carry them to the tree which is to be used as a female parent. Large buds just ready to open should be selected and all the smaller buds and open flowers on the twig removed. The petals are pried apart with a small pair of forceps and an anther bearing ripe pollen is taken from a blossom within one of the bags and placed firmly upon the stigma, pressing it down into the drop of white mucilage. If no mucilage appears on the stigma, it is evidence that the bud is immature. The camel's-hair brush commonly used in cross-pollinating fruits is not satisfactory in citrus work on account of the copious excretion of mucilage by the stigma. It is wise to cross-pollinate several buds on each twig, as many are apt to drop off. After the pollen has been placed on the stigma, the small immature anthers must be removed from the flower for fear that the pollen produced later by them may interfere with the results. In the case of the Navel orange this is not necessary, as the anthers do not produce pollen. After the operation has been completed a paper bag should be placed over the twig and tied with string. After two or three weeks the paper bags may be replaced by cheesecloth bags, which remain on till the fruit is picked for seed.

The value of crosses or hybrids produced in this way cannot be determined for several years, or until the trees

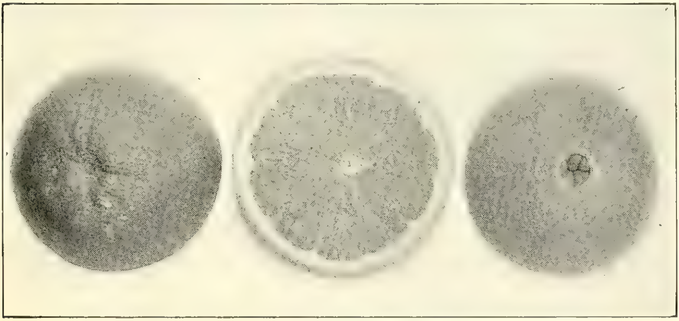

Fig. 37. — Type of standard Washington Navel orange.

have been reared to fruiting. By top-working buds taken from the young seedlings into old trees the fruit may be secured earlier.

The improvement of citrus fruits by this method is very slow and the results uncertain. Moreover it is doubtful whether an entirely new variety of orange or lemon, however good, could gain much recognition in California in the face of the popularity of the Navel and Valencia oranges and the Eureka lemon. The history of the industry in California has shown a constant elimination of varieties rather than the acquisition of new ones. The greatest field for hybridization work lies with the pomelos. There is at present no thoroughly satisfactory variety of pomelo suited to the climatic and soil conditions of California. The feeling of the growers in regard to better varieties of oranges and lemons was clearly shown some years ago when E. J. Wickson sent out a circular letter to determine the most urgent needs along the line of citrus breeding. The response of the growers was significant. They replied that what was needed most was a Washington Navel which would color earlier; a Navel which would hang on the tree like a Valencia; a Navel that would not split; a Navel that would not puff; and a Navel more hardy to frost. Some growers wanted a Valencia that would not turn green a second time, or a Valencia without seeds.

The most expeditious way of securing the results desired by the growers is by selecting and propagating those sports from the varieties mentioned which approach most closely the desired types. Such bud variations occur quite frequently in citrus trees. They present a vast field for the work of improvement of types.

VEGETATIVE MUTATIONS OR BUD-SPORTS

Citrus trees, in common with other plants, are observed to vary in several ways. There are fluctuations or unstable differences which come and go in response to the various complex stimuli produced by changing conditions of soil and climate, or, in other words, changes of food and environment. There are also sudden changes known as mutations which result in new forms that are stable and form the starting point of new strains or varieties.

Fluctuations are of two kinds, regular and fortuitous. As an example of regular fluctuation we may cite certain influences of climate and soil which produce substantially

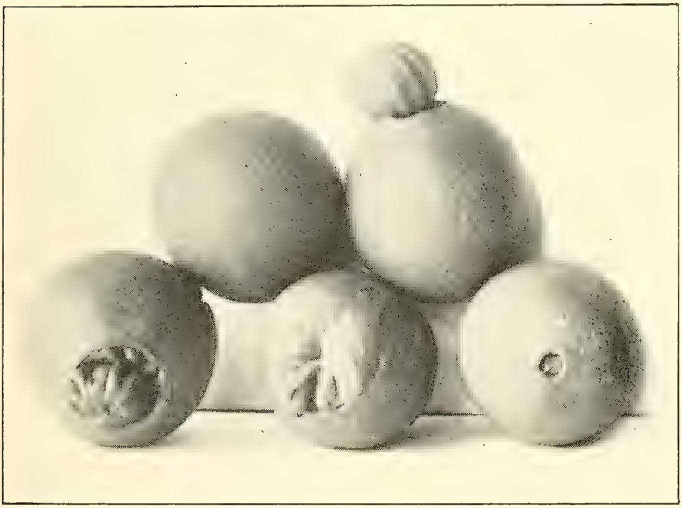

Fig. 38. — Washington Navel oranges showing fluctuations in the navel; such variations cannot be preserved by budding.

the same effect upon every plant of the same variety. Navel oranges grown in the hot Imperial Valley are much redder in color than those grown within the influence of ocean fogs near the coast. Oranges grown on light sandy soil are of larger size than those grown on stiff clay soil. Under the head of fortuitous variations may be included many of the common malforms and monstrosities such as double oranges, oranges with protruding navels, fingered lemons, and various other teratological curiosities which may be found in the cull-heaps near the packing-houses.

Mutations occur as sporting branches which show a different combination of characters from the rest of the tree. The immediate cause of mutations is not at present understood. They originate during the division of some single cell in the vegetative tissue which results in daughter cells containing the same determiners for characters but segregated and recombined in such a way as to produce characters visibly different from those of the parent stock. Thus appear new characters which, from the standpoint of the man who is growing the fruit, may be either valuable, neutral, or objectionable.

When a shoot arises from tissue which has been formed by mutating cells, the shoot represents a new variety or sport variety which may be propagated by the ordinary method of budding. Sometimes more or less reversion to the old type occurs in the young trees. The cause of this has been observed to be due to the mode of origin of the sporting shoot. If the shoot arises from within the area of mutating cells in such a way that only these cells are used in the forming bud, then the resulting shoot will be composed exclusively of new cells and the sport may be propagated true without reversion. If on the other hand the shoot arises on the edge of the area of new cells in such a way as to include both kinds of cells in its structure, then there arises a mixed branch or " sectorial chimera " which may be expected to constantly produce branches of various kinds. Some will be like the original plant, some like the new form, and some in turn will be mixed depending upon the kind of cells occurring at the point where each bud has its origin. The "Nomadic Albinism" described by Savastano [1] was probably a sectorial chimera.

FIG. 39. — Variegated sport. Note white areas in leaves. From Volckamer's "Hesperides," 1695.

Sectorial chimeras are not uncommonly met with in citrus trees. The writer has found excellent specimens in commercial orchards and some have been kept under

[1] *An. del. Stazione de Agrum. e. Fruit.* Vol. 1, 1911, XXIX.

constant observation and study for five years. A Valencia orange tree in an orchard near Whittier was evidently propagated from a bud with mixed cells, for it still bears year after year on all its branches both typical Valencia oranges and a small, very rough, and worthless mutation. A twig here and there will produce typical Valencias, while

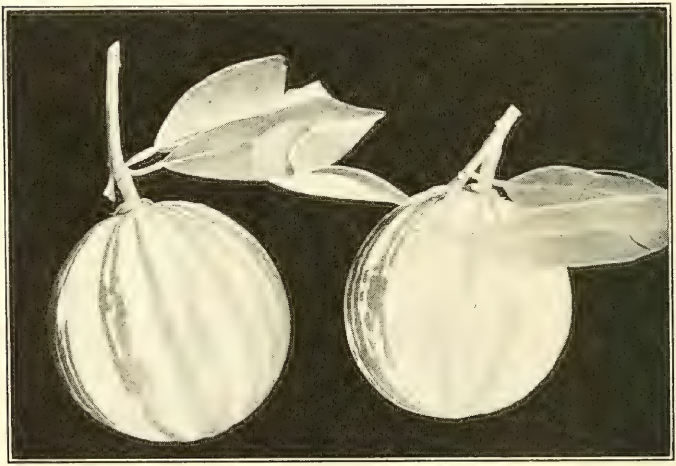

FIG. 40. — A variegated sport of Valencia orange. Notice white margin of leaves.

others will produce curious mixed oranges having certain sectors of the fruits composed of mutant tissue. The owner of this tree endeavored to get rid of the worthless type by pruning it out, but mutant branches continually returned, and it requires frequent pruning to keep them suppressed. In this case the mutant tissue happens to occur irregularly scattered or mixed with the tissue of the original form. Such a mixture has been called a "hyper-chimera."[1]

Mutations often occur in the cells which begin the formation of the minute ovaries in the blossom buds. As the ovary grows in size the mutation appears as a sector of the fruit which differs in color, ripening season, or thickness of skin from the rest of the fruit. Such curious fruits have been called "spontaneous chimeras." These striped oranges and lemons are often found by the pickers, who usually incorrectly attribute the phenomena to the influence of cross-pollination. When we consider that these mutations are always formed before pollination takes place, the inadequacy of the theory of pollen influence is evident.

When mutation occurs at the base of the ovary it is not possible to continue it by propagation as no buds occur on the fruit. When, on the other hand, mutation occurs on the trunk or branches in a position where an adventitious bud may arise, then propagation is easy.

As before stated, many mutations showing various types of fruit and different bearing habits have occurred in the orchards, and through ignorant and careless cutting of bud-wood many of the worthless forms have become widely disseminated and now make up a considerable proportion of the trees in our commercial orchards. A vital need at the present time is a careful study of individual trees by each grower, who should determine which trees, if any, belong to unprofitable types and top-work

[1] H. Winkler, "Über Propfbastarde und Pflanzliche Chimären," Ber. Deuts. Bot. Ges., 25: 568–576. E. Baur, "Propfbastarde, Periklinalchimären und Hyperchimären," *loc. cit.*, 27: 603–605.

them to the most desirable types. In this way the average cost of production may be greatly reduced. The great need for a study of the performance of individual citrus trees was emphasized by the writer in 1910.[1] Since then many such studies have been made, by far the most comprehensive of which are those of A. D. Shamel.[2] Out of a mass of material the following condensed quotations have been selected from the studies of J. H. Norton,[3] formerly Superintendent of the Citrus Experiment Station at Riverside:

Fig. 41. — Sectorial chimera of Valencia orange.

"The Navel orange grove from which the following data are taken is located in West Highlands, San Bernardino County. The trees are the same age and the soil condi-

[1] Coit, J. Eliot, "The Relation of Asexual or Bud-Mutation to the Decadence of California Citrus Orchards," Rpt. 37th California Fruit Growers' Convention, 1910, p. 32.

[2] Shamel, A. D., "A Study of the Improvement of Citrus Fruits through Bud Selection," U. S. Dept. of Agriculture, Bureau Plant Industry, Circular No. 77, 1911.

[3] Norton, J. H., "Variations in the Productivity of Citrus Trees," *California Cultivator*, Vol. XL, No. 10, 1913.

tions uniform. This grove contains 1525 trees planted 90 to the acre. The trees are about 16 years old and the grove is considered somewhat above the average in productiveness, yet the trees vary in yield from nothing to 426 pounds of fruit per tree.

"The following is the annual expense of this grove per tree:

"General care including taxes, water, pruning, and fumigating, ...	$1.14
Interest on Investment, ...	1.11
Total annual expense per tree, ...	$2.25

"The fruit from this grove was sold for $1\frac{1}{2}$ cents per pound on the tree. The trees that bore less than 150 pounds of fruit were maintained at a loss, while those yielding more than 150 pounds paid a profit. This is graphically shown in Figure 44.

"The curved line represents the yield per tree in pounds arranged in the order of yield. The horizontal line AB is the 'dead line,' and any tree the yield of which falls below this line was maintained at a loss. The shaded part of the curved line shows the trees that the owner realized no profits from. The shading above the line AB is due to the loss sustained by the trees recorded below the line. There were 490 trees or 32 per cent that yielded less than 150 pounds of fruit. This loss was made up by the profits from the next 646 trees, that is, the profit from 42 per cent of this grove was required to offset the loss sustained by 32 per cent. Seventy-four per cent of this grove therefore gave neither profit nor loss. This leaves the net income to be derived from 389 trees, or 26 per cent of the grove.

"The total yield of the grove was 280,254.5 pounds of

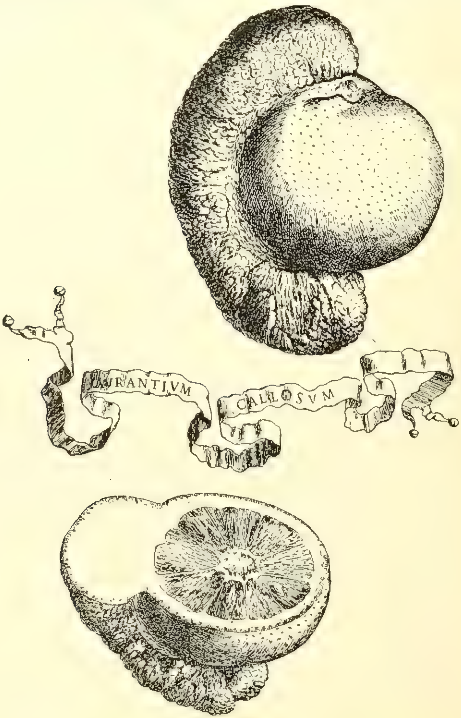

Fig. 42. — Orange showing sectorial chimera. From Ferrarius, 1646.

oranges which at $1\frac{1}{2}$ cents a pound, gave a gross income of $4203.81. The expense was $3431.25, leaving a net income of $772.56 or an average net profit per tree of

51 cents. Could the loss due to the 490 poor trees have been eliminated without increasing the production per tree, then the net profits from the remaining 1035 trees would have been $1125.96 or $1.09 per tree as compared with 51 cents profit per tree which was actually the case."

The record of this West Highlands orange grove may be considered fairly typical of a large proportion of the

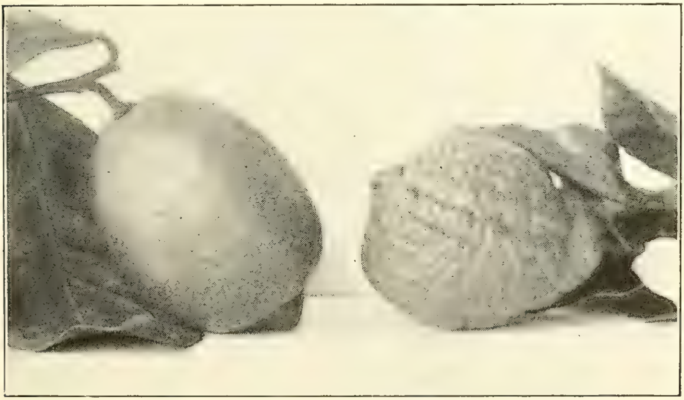

Fig. 43. — What is known as the "wrinkled sport" of Eureka lemon compared with normal fruit. Both from same tree.

groves in California. The differences of yield noted were due both to fluctuations and mutations, but the extreme differences were undoubtedly due to mutations. The average yield would be greatly increased by top-working those of the 490 poor trees which proved to be mutative to buds carefully selected from the tree which yielded 426 pounds. Many of the most progressive growers now keep accurate performance records and top-work the unprofitable trees as soon as they are discovered. In the case of the Australian and some other worthless mutations of Navel orange trees performance records are hardly necessary, as any experienced man should be able to recognize such poor types at a glance. For the segregation of trees which represent undesirable mutations, whose chief difference is that of yield, the performance record is indispensable.

There is no scientific evidence to warrant the belief that anything worth while may be gained by the selection and propagation of trees whose high yield is due to fluctuation. It is vital that the high yield be due to a true mutation in order that the type may be propagated and progress made. As a matter of fact, the standard type of Washington Navel is normally a heavy bearer and the majority of mutations observed are retrogressive. It is chiefly to counteract retrogression that top-working is practiced. Occasionally, however, mutations of peculiar value appear. The Thomson and the Navelencia may be cited as examples. It is not unlikely that a general increase in the amount of individual tree study by many growers may lead to the discovery of new mutations which may be of great value to the industry. For him who brings such mutations to light is awaiting both honor and financial reward.

THE SELECTION OF BUD-WOOD

The foregoing discussion emphasizes the fact that the selection of bud-wood is an exceedingly important matter, for if one does everything else in the most approved way

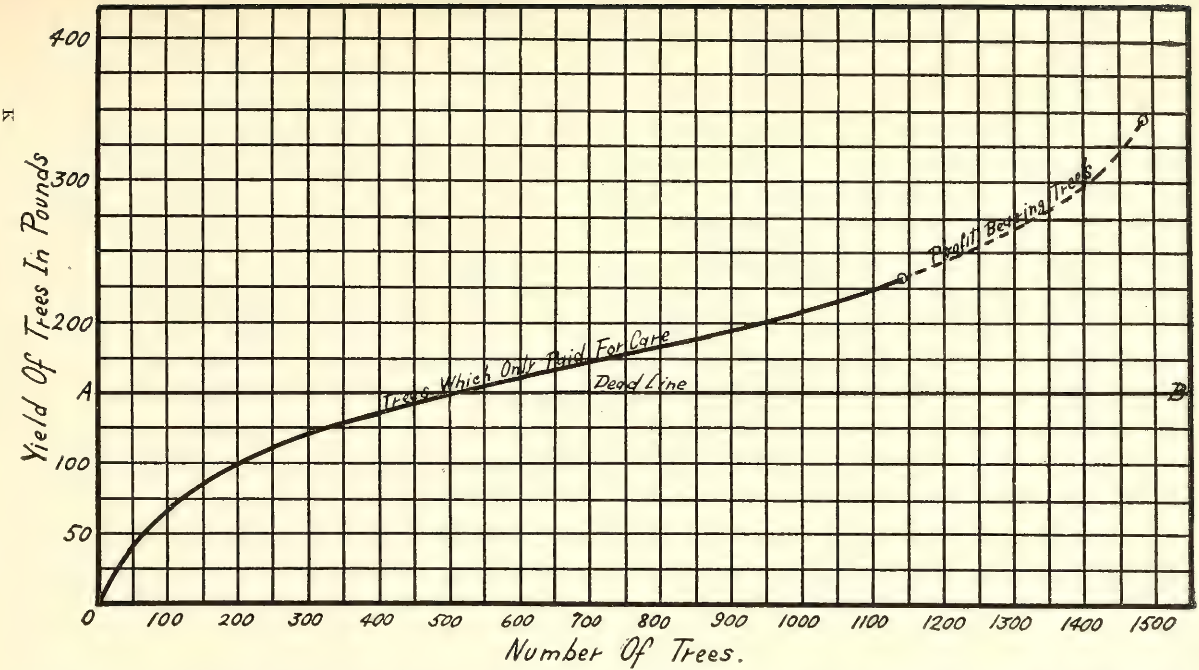

FIG. 44. — Chart showing by dotted line the small proportion of profitable trees, and by heavy line the large proportion of trees which only pay for their care. West Highlands orchard. (Adapted from Norton.) (129)

yet does not have the kind of trees which bear good fruit, he will not have good fruit. This question is of far greater importance in connection with citrus fruits than with deciduous fruits, for it appears that oranges tend toward mutation much more generally than apples or peaches. On account of failure to select buds with due care in the past, a surprisingly large percentage of bearing orange trees are unprofitable. The average orchard is a mixture of different types, some good, some bad. Every planter should either grow his own trees, or select his own buds and have a nurseryman grow the trees on contract, or at least buy trees from a nurseryman who has a reputation for carefulness in the selection of bud-wood.

It is of the very highest importance that all buds be cut from bearing trees while the fruit is on them and from trees which are known to have borne the ideal type of fruit on each and all of their branches for a series of years. It is a splendid plan to select certain typical mother trees in the orchard and keep an accurate record of the amount and quality of fruit produced. If off-type fruit is borne on any branch of a tree, no buds should ever be cut from that tree. In the case of the Navel orange, it happens that the best trees from which to cut buds present only fine fruiting brush which does not make satisfactory bud-wood. Such trees may be given a moderate pruning and thinning out over their whole tops and thus encouraged to produce plump twigs, more suitable for bud-wood, the following season.

In these days there is much talk about "pedigreed" nursery stock. Usually what is sold as pedigreed stock is stock whose scions are said to have been cut from a tree or trees which are said to have yielded exceptionally well. This is good as far as it goes, but it does not fully protect the buyer from ignorant or careless dealers. The unit of the plant is not the tree; it is the cell. The term "pedigree" may properly be referred to animals, not to plants. Our greatest source of mixed and worthless stock is the irresponsible amateur propagators who have been operating so extensively on vacant city lots and in yards and gardens since the price of trees has been high. Many of the trees produced in this way are beautifully grown specimens, but the buyer should beware of them unless he can satisfy himself by personal investigation that the buds have been properly selected.

CHAPTER VIII

JUDGING CITRUS FRUITS

A GREAT many different scales have been proposed from time to time for the judging of citrus fruits. In 1892 the Florida Horticultural Society adopted an official scale together with rules and regulations. In 1894 the Executive Committee of the Los Angeles Chamber of Commerce adopted an official scale for California.

These scales, while most excellent as ideals toward which to work, are but little used in citrus exhibitions for the reason that their use requires too much time. The judges are usually expected to judge hundreds of exhibits, sometimes aggregating twenty or more carloads of fruit, in twelve or fifteen hours. Obviously it is possible to use the score-card only in those classes where competition is very close, and in such cases the great value of the score-card with a fixed scale is clearly evident.

The Florida rules require seven specimens to constitute a plate entitled to entry. In California five specimens are required.

Interest in citrus judging has been greatly stimulated, in California, by the inauguration in 1911 of the National Orange Show, which is held annually at San Bernardino, and represents, for the Southwest at least, the citrus event of the year.

ORANGE SCORE-CARD

Size (uniformity)		5
Form (typicalness)		15
Stem		5
Size	3	
Color	2	
Rind		35
Color	10	
Texture	5	
Thickness	5	
Freedom from blemishes	15	
Navel or seeds		5
Size	3	
Shape	1	
Prominence	1	
Juice		30
Abundance	10	
Color	5	
Flavor	15	
Rag		5
Amount	3	
Character	2	
Total		100

ORANGE STANDARDS

Size. — Oranges for exhibit may be of any size from small, 250's, to large, 126's. The most desirable size is medium, 176's, which are $2\frac{15}{16}$ inches in diameter. Sizing should be accurate, one-half unit discount for each specimen varying $\frac{1}{8}$ inch from the size.

Form. — Fruit must have shape typical of variety and be free from creases or corrugations.

Stem. — Stem must be small, but close and square, level with surface of rind, sepals green and plump. For each missing stem deduct one point.

Rind. — Color must be deep orange, the darker the better. Bloom must be perceptible; texture smooth and fine with kid-glove finish; thickness $\frac{1}{8}$ to $\frac{3}{16}$ inch. In discounting for thick rind consideration should be given to the length of time fruit has been picked, as rind gradually decreases in thickness. Fruit must be free from blemishes such as insect injuries, decay, wind scars, or abrasions.

Navel or seeds. — Navel marks to be of good form and from $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter. The perfect orange should be seedless; discount for more than normal number of seeds for variety.

Juice. — The largest possible amount of juice is desirable. The perfect orange should sink in water. If fruit floats, discount according to degree of buoyancy. Color should be pale orange except in case of blood oranges, which should have deep red juice. Flavor should be fine, acid and sugar well blended, and otherwise characteristic of variety.

Rag. — The less rag the better. Character should be delicate and melting.

LEMON SCORE-CARD

Size (uniformity)		5
Form (typicalness)		15
Stem		5
Size	3	
Color	2	
Rind		35
Color	5	
Texture	5	
Thickness	5	
Freedom from bitterness	5	
Freedom from blemishes	15	
Seeds (absence)		5
Juice		30
Abundance	15	
Color	5	
Flavor	10	
Rag		5
Amount	3	
Character	2	
Total		100

LEMON STANDARDS

Size. — Lemons may be exhibited in any size from large, 250's, to small, 360's. The most desirable size is the 300, which is $2\frac{1}{8}$ inches in diameter. Sizing should be accurate. One-half unit discount for each specimen varying $\frac{1}{8}$ inch from standard.

Form. — Fruit must have shape typical of variety and be free from irregularities. Sunburned lemons are inequilateral and should be heavily discounted.

Stem. — Stem must be present, cut close and square, sepals green and plump. For each missing stem deduct one point.

Rind. — Color must be pale or whitish yellow; discount for bronze tints, green marks, or sunburn. Bloom should be perceptible; texture smooth and fine with waxlike finish; strong and elastic with uninjured oil cells. Thickness should be from $\frac{3}{32}$ to $\frac{3}{16}$ inch. Allowance for thick rind should be made for fresh lemons when exhibited. Just how much allowance should be made will depend of course on the amount of curing the lemons have undergone, and this is often difficult of determination by any except experienced persons. Fruit must be free from all blemishes.

Seeds. — The perfect lemon is seedless. Discount $\frac{1}{4}$ point for each seed.

Juice. — The largest possible amount of juice is desirable. Specific gravity should be 1 (equal to that of water), with buoyancy of $\frac{1}{2}$ oz. allowed to large sizes and $\frac{1}{4}$ oz. to medium and small sizes without discount. Color should be pale lemon yellow. Flavor must be clear and fine. Discount heavily for bitterness of rind.

Rag. — The less rag the better; character should be delicate and tender.

Pomelo Score-card

Size (uniformity)		5
Form (typicalness)		10
Stem		5
Color	2	
Location	1	
Size	2	
Rind		35
Color	5	
Texture	5	
Thickness	10	
Smoothness	5	
Freedom from blemishes	10	
Seeds (number)		10
Juice		25
Abundance	10	
Color	5	
Flavor	10	
Rag (tenderness)		10
Total		100

POMELO STANDARDS

Size. — Pomelos may be exhibited in any size from large, 28's, to small, 96's. The most desirable size is the 54, in which the fruits are $4\frac{1}{2}$ inches in diameter. Sizing should be accurate. One-half unit discount for each fruit varying $\frac{1}{4}$ inch from standard.

Form. — Fruit must have shape typical of variety and be free from irregularities.

Stem. — Stem must be present, cut close and square, sepals green and plump. For each missing stem deduct one point.

Rind. — The color should be ivory white, the texture smooth and fine. Thickness should be $\frac{1}{4}$ to $\frac{5}{16}$ inch. Fruit must be free from all blemishes.

Seeds. — Seedlessness is the standard for pomelos. Cut $\frac{1}{4}$ point for each average seed per fruit.

Juice. — The largest possible amount of juice is desirable. When placed in water the fruit should not rise more than $\frac{1}{4}$ inch above the water. Flavor must be characteristic of the variety with acidity and sweetness well blended.

Rag. — Rag should be tender enough to cut easily with a spoon.

SCORE-CARD FOR PACKED BOXES

Exterior appearance		40
Cleanliness	10	
Neatness	5	
Artistic quality of label	10	
Size and placing	10	
Stenciling	5	
Nailing		20
Position of cover	5	
Position of cleats	5	
Placing of nails	5	
Placing of strap	5	
Wrapping		20
Quality of paper	7	
Artistic quality of design	7	
Twist	6	
Placing		20
Facing	5	
Alignment	5	
Firmness	5	
Crown	5	
Total		100

STANDARDS FOR PACKED BOXES

Appearance. — Box material must be perfectly bright and clean and put together in a neat manner. The lithograph label must have artistic color qualities; it should be of original design, and the illustrations should be true to life. Box labels should be exactly 10×11 inches for oranges and 10×13 inches for lemons, including a $\frac{1}{4}$ inch border in each case. Combination labels are to be discounted. Labels should be placed flush with bottom of box, leaving space at top for stamping. This strip of bare wood should show the impressions of three rubber stamps as follows: in the right-hand corner, the number of fruit in the box; in the center, the variety of oranges or pomelos, and in the left-hand corner, the number of the packer. The name of the variety of lemons is not placed on the box for reasons explained in Chapter XVI.

Nailing. — The cover pieces must be perfectly parallel and the cleats must be above the cover. Cleats below the cover should debar the box from exhibit. Nails must be properly placed and driven home without showing print of hammer in wood.

Wrapping. — Paper should be strong and of good quality. Design should be artistic, and the twist should be carefully made.

Placing. — On placing fruit in the boxes the design on the wrapping paper should be made to face the openings in the side of the box. The alignment should be as nearly perfect as possible. Fruit should be firmly placed and the standard amount of crown is 1 inch at center.

Score Card for Feature Exhibits

Quantity and quality of fruit	50
Artistic qualities of plant decoration	15
Bunting and electric effects	15
Originality of design	10
Unity of expression	10
Total	100

CHAPTER IX

SELECTION OF SITE AND PREPARATION FOR PLANTING

SUCCESS with citrus fruits depends to a very large extent upon the proper selection of the site for the orchard. This is especially true in countries where the climatic and soil conditions vary widely in the same locality. It is poor policy to examine a piece of land or a bearing orchard without a program. This is especially true when different propositions are to be contrasted with a view to deciding on a purchase.

It is suggested that the following list of points be noted in going over every piece of land. Each point may be weighted after the fashion of a score-card and thus accurate comparisons between the different properties examined made easier.

PROPOSED SCORE-CARD FOR CITRUS LANDS

1. Price per acre.
2. Freedom from frost.
3. Water $\begin{cases} \text{Legal right.} \\ \text{Amount.} \\ \text{Quality.} \\ \text{Cost.} \end{cases}$

4. Continuity of tract.
5. Quality and kind of soil.
6. Drainage outlet.
7. Freedom from hardpan.
8. Freedom from stones and brush.
9. Freedom from alkali.
10. Freedom from waste land.
11. Susceptibility to wind.
12. Nearness to town.
13. Nearness to packing-houses.
14. Quality of roads.
15. Distance from scale infested orchard.

Additional Points for Bearing Orchards

16. Freedom from scale and diseases.
17. Freedom from mottled-leaf.
18. Uniformity of trees and record of yield.
19. Condition of trees as to pruning.
20. Adaptation of variety to district.

THE FROST QUESTION

One of the most important factors limiting the growth of citrus fruits is frost. The frost hazard of any given piece of land is at best a very uncertain quantity and may be judged only approximately even after years of experience and observation. Within the established citrus districts, as a rule, the elevated slopes of the foothills, preferably with a southern or western exposure, at an elevation of from 500 to 1500 feet above sea level and 100 to 500 feet or more above the bottom or "draw" of the valley, are the most frost-free locations. On lands subject to heavy frosts every year, the expense of orchard heating would be too great. Usually the heavy cold air flows down and collects in the valleys, leaving the higher lands above the frost line. There are notable exceptions to this general rule, however, for when the drop in temperature is accompanied by strong winds, as was the case during the blizzard of January, 1913, the high and supposedly frost free land may suffer most of all. Such blizzards are fortunately of extremely rare occurrence.

The frost hazard of any given piece of land (except that which is closely surrounded by old citrus groves) can only be found by exposing self-registering thermometers for several winters. If there are homesteads with yards and gardens in the vicinity, a study of the flowering plants may give some idea of the frost hazard. For example, if old and well established plants of bougainvillæa, *Solanum wenlandii*, poinsettia, or jacaranda are found which show no signs of having been killed back, it is fairly certain that a lemon orchard in the immediate vicinity would not be injured except perhaps in occasional and exceptional years.

THE WATER SUPPLY

In no citrus district of California is the rainfall sufficient for irrigation. The amount of water needed under different conditions will be discussed in Chapter XII, but it may be well to point out here that it behooves the buyer of citrus land or orchards to make a careful study of the character of the water supply. He should bear in mind that upon the water supply depends the life of the trees and that he should thoroughly understand the system of which his ranch is a part. Water rights in an irrigated country are often complicated and one should familiarize himself not only with the legal details, but with the present physical condition of the entire system.

In localities in which the water is pumped from wells located in the groves it is not uncommon for the gradual increase in use of water, which takes place as the planting in the neighborhood increases, to lower the water table to such an extent that the old wells have to be dug deeper and pumps of higher power installed. The indications are that as the industry grows and the value of water increases the number of law-suits will increase rather than diminish. The best water right is a share in an old and well established canal company which holds prior rights and draws its supply from the melting snows on the mountains, and which guarantees the delivery of a certain number of miner's inches per month per share.

SOIL ADAPTATIONS

California soils are famed for their great depth and fertility, and the soils of the citrus belt are no exception to the rule. There is a wonderful variation, however, in the kinds of soil now occupied by citrus groves.

We have the fine sandy soil of Anaheim, the bluish muck soils of Santa Paula, the black adobe of La Habra, the gravelly loam of Upland, the disintegrated granite of Riverside, the red loam of Redlands, the dry-bog of Porterville, the red adobe of Fairoaks, and the soft desert soils of Imperial. Citrus trees are now growing successfully in all of these soils and do not seem to be particularly partial to any one kind so long as the physical conditions are good. Of course it is easier as well as cheaper to cultivate a soft sandy loam than a sticky adobe, and easily worked soils are much more desirable from the standpoint of the man who is to till them.

What are these conditions then which make for success or failure and are more important than the type of the soil? In the first place, nothing is more fatal to success than to judge the value of a piece of ground by the nature of the surface soil. By digging or boring down to a depth of a few inches or feet, something entirely different from that seen on top may be encountered, which would doom the proposed planting to eventual failure.

It is not uncommon to find subsoils so hard that it is impossible for water and tree roots to penetrate them. On such soils trees are greatly restricted in their root development and the reservoir for water is much reduced. Such soils are apt to be too wet in the rainy season and are very difficult to irrigate properly.

On the other hand, the subsoil may be too coarse and open, unretentive of moisture, and deficient in plant food. Both heavy and light soils have advantages peculiar to themselves and a compromise between them, usually known as sandy loam, is nearly always the most desirable.

To sum up, then, the soil for a citrus orchard may be of any type, preferably a sandy loam; but it must be at least four or five feet deep; it must be free from hardpan or strata of coarse gravel; it must be well drained; and it should be so situated as to make irrigation easy. In some cases a thin stratum of hardpan a foot or two below the surface may be broken up with dynamite before the trees are planted. This allows the roots and the water to get through and may sometimes make otherwise undesirable land available for citrus trees.

Of the two most common conditions, a light surface soil over heavy clay subsoil is more to be desired than a heavy clay surface soil over sand or gravel.

The ideal soil is a rich, nearly level, friable, easily worked loam, eight or more feet deep, growing gradually lighter as the depth increases. This not only provides a great storehouse of plant food, but a great reservoir to hold water.

Alkali soils commonly occur on the floors of the valleys where it is usually too frosty for citrus trees. Occasionally, however, the question arises as to the susceptibility of citrus trees to alkali. Where the soil contains two-tenths of one per cent of total salts, the trees are likely to be injuriously affected. A total salt content of less than one-tenth of one per cent is usually considered safe. These figures will be found to vary some, however, according to the proportions of the different salts which taken together are known as "alkali," some of which (such as sodium carbonate) are much more injurious than others.

So-called acid soils are very rare in the citrus districts of the West. They are more apt to occur in wet, swampy land, or in recently cleared forest soil, where there is a large amount of vegetable matter in the ground. Such a condition can be definitely determined by chemical analysis. Soil acidity is easily corrected by an application of lime.

The question of the disposition of waste water is an important one, as in many places there are stringent laws against allowing it to flow into the roads or on to a neighbor's land. Theoretically there should be no waste water, as it should all be used on the land. In many cases, however, and especially on clay soil and with careless laborers, a certain amount of water will escape from the lower ends of the furrows and it may become necessary to dig a long ditch or even put in a very expensive pipe line to dispose of this waste water.

The question of insect pests should also be considered. A location far from any scale-infested orchard may mean that fumigation may not be necessary for many years, if at all, whereas a site on the windward side of a badly infested orchard will mean fumigation almost from the first, with all the attendant bother and expense.

Not the least important point to consider is the nearness to the railroad and packing-house, and the condition of the roads over which the fruit must be hauled. The labor problem also is important. Orchards near small towns have the advantage of a larger and more dependable labor supply, and this is quite an advantage at picking time and especially when frost fighting becomes necessary.

Clearing any leveling. — For reasons pointed out in Chapter XXI, it is very important in clearing land for citrus trees to dig the old trees out by the roots, being careful to get out all the large roots to a depth of several feet. Especially is this true where oak or sycamore trees have occupied the land, for the roots of these trees are especially apt to harbor the *Armellaria* fungus for many years.

On account of the high price of well located citrus land, it has become profitable to develop very stony ground. All the stones above the size of an orange are hauled out and built into walls or used in road construction. The land is then deeply plowed and the stones picked up again, this process being continued till all the stones are removed to a depth of ten or twelve inches. A good deal of such land proves very fertile and produces high class fruit.

After the land is cleared, it must be leveled with "Fresno" or other scrapers until the surface presents a uniform grade. This is very important, for otherwise the irrigation water will run through different parts of the rows at different rates of speed, and consequently sink to unequal depths, with the result that some trees get too much water while others do not get enough. On spots where hardpan is encountered, especially on knolls from which the soil is removed to fill up depressions, the conditions may be greatly improved by blasting and breaking up the hardpan in order that the water and roots may get through. The cost of blasting will vary with the thickness and depth of the hardpan. For instance, when a stratum six inches thick lies four feet below the surface, it will require two sticks or one pound of 25 per cent dynamite, four feet of fuse, and a cap. The cost of materials and labor will amount to about 25 cents per tree, the charges being placed only where the trees are to stand. If the ground is quite dry, as it should be, when the work is done the shattering effect will extend for about five feet in all directions. The chunks of hardpan which are loosened should be removed from the holes before the trees are planted.

CHAPTER X

PLANTING THE ORCHARD

AFTER the ground has been properly leveled, it should be put in the best of tilth by deep plowing and cultivating. It is a good plan to plow deeply in the fall and leave the land rough during the rains of winter. In spring, the volunteer crop of weeds and grass may be turned under and the land harrowed and dragged. This will leave the land smooth and in excellent condition for staking out the orchard.

ORCHARD PLANS

There are three objects to be considered in laying out the orchard: symmetry of appearance, economy of space, and facility for future care. On level land, of course, the first step is to set the trees in straight rows and at equal distances apart. There are various methods of disposing of the straight row, however, and these methods all have their advocates, and each one its advantages. The most important of these are the triangular, square, hexagonal, and quincunx.

In the triangular system, the trees are set in rows but the first tree in every second row is set not on the line but is moved in half the distance between trees. By this method more room is given the trees and a less number is planted to the acre than by the square method, but it is possible to cultivate and even irrigate three ways through the orchard. In laying out the orchard, the ground is first laid out in squares, after which a line is run diagonally across the field and a tree stake placed wherever this line passes through the corners or cuts the side of a square.

The square system is by far the most commonly used, and may be followed either for squares or oblong rectangles. The rows of trees intersect each other at right angles and cultivation may be carried on in two directions.

By the hexagonal system, the trees are set equidistant from each other. Six trees form a hexagon with a seventh in the center. By this means the ground is more economically divided and more trees are planted per acre at a given distance apart than by any other method.

By the quincunx system four trees constitute a square with a fifth in the center, thus doubling the number of rows. This method is chiefly used in planting with the idea of removing the center trees, which are usually of dwarf varieties, when those designed to be permanent shall have attained a considerable size. The orchard then assumes the square plan.

The quincunx system is rarely used in planting citrus orchards as it is not customary to use other and smaller varieties of fruit trees as temporary fillers in citrus orchards.

The following table gives the number of trees required to plant an acre at various distances apart according to each of the above four plans:

Number of Trees to the Acre [1]

Distance Apart	Quincunx	Hexagonal	Square	Triangular
35 × 35 feet	65	41	36	33
30 × 30 feet	83	55	48	44
25 × 25 feet	126	81	70	64
25 × 20 feet			87	79
24 × 24 feet	137	86	76	
22 × 22 feet	173	103	90	
20 × 20 feet	199	126	108	98
18 × 18 feet	247	142	134	122
20 × 15 feet			145	132

There is a good deal of variation throughout California in regard to the distances at which citrus trees are planted. The following are the usual distances which give the best results: kumquats, 12 × 12 feet; tangerines, 20 × 20 feet; Navel oranges, 22 × 22 feet; and Valencia oranges, lemons, and pomelos, 24 × 24 feet. Lemons sometimes bear well and produce a larger tonnage per acre when planted close in one direction. The old Eureka orchard at the Limoneira Ranch near Santa Paula, which is planted 26 × 15 feet, is a notable example of this.

Many citrus growers prefer to employ a surveyor to lay out the orchard and set the stakes which mark the points where the trees are to stand. While this is a good plan with large plantings, especially where the ground is rolling, it is not necessary in the case of five or ten acre blocks. A satisfactory way to lay out a small tract is by means of a strong wire as long as the tract is wide. This

[1] Adapted from Hume, Bailey, and Wickson.

should be carefully measured and a button soldered to the wire for each tree row. After the stakes are set along each side of the field marking the rows, the wire may be stretched between each pair and thus carried across the field, a stake being set at every point to be occupied by a tree.

Much of the land available for citrus planting is entirely too steep and broken to admit of any of the plans above mentioned. Such lands are often of great value on account of their freedom from frost. In such cases the rows are laid off on contours. By this means the irrigation furrows are run on a more uniform grade throughout their length, and the storm water problem is solved, since the water which accumulates in each row will be carried off separately to the side of the field and safely disposed of.

Where the general slope of the land is not more than 15 per cent, cultivation may be carried on at right angles to the irrigation furrows after a slight ridge has been established in the tree row. In order to facilitate orchard operations it is wise to arrange the trees in rows running up and down the hill.

On very steep hillsides it is necessary to build terraces and in such cases the trees are planted on the brink and cultivation and irrigation is limited to one side of the tree row. The terrace banks should be planted with some hardy plant which will displace weeds and prevent washing. In coast counties where the air is moist *Mesembryanthemum australis* (white flowered) or *M. roseum* (pink flowered) are recommended. In interior valleys perhaps *Lippia* may be used for this purpose.

Irrigation water is usually conducted in a pipe line along the crest of a ridge with contours or terraces diverging on either side at irregular intervals. Where the contours converge to within less than twenty feet the trees are omitted.

Contours may be easily laid out by the use of a twenty-five foot plank to which a carpenter's spirit-level is attached. One end is equipped with an adjustable leg or shoe upon which is marked off a scale to hundredths of a foot. By adjusting the length of the leg for the desired grade and pivoting on the other end, the shoe can be located on the next point of the grade by trial, the main plank being kept level as determined by the spirit-level. The grade established will depend a good deal upon the character of the soil and the nature of the slope, inasmuch as some soils tend to wash much more easily than others.

Time of planting. — As explained in a previous chapter, citrus trees have three more or less distinct periods of growth during the year. It is not wise to transplant the trees during one of these periods of growth. They may be planted at any time of year, but should be as nearly dormant as possible. The most convenient as well as the customary time of planting in California is between April 1 and June 15, preferably during the month of May or just after completion of the first growth and before the starting of the second.

ROOT-STOCKS

While there are at least seven possible root-stocks upon which citrus trees may be grown, there are only three which are used commercially in California at the present time, viz.: the sour or bitter, the sweet, and the pomelo. It is said that at present, practically every citrus tree in Europe is grown on the sour-stock. Perhaps we would be safe in saying that every tree in California would be as well off on sour-stock, yet there are a few people who still claim that, in certain situations, sweet-stock is best, at least for oranges. All lemons should be grown on sour-stock on account of its great resistance to brown-rot gumming. Sour-stock should be used for oranges and pomelos on low, heavy, or wet soils. On high, dry, well-drained soil sweet-stock is practically as good but apparently no better for oranges. Orange trees will make a quicker start into growth and begin to bear fruit a little earlier on sweet-stock, but after the trees are six or seven years old no one can tell any difference in the size or fruitfulness of the trees. The sour-stock has the advantage, therefore, in being more resistant to gum diseases and foot-rot of various kinds.

The use of pomelo stock is increasing somewhat, although it has not been widely experimented with. It is giving pronounced success where used for lemons on open gravelly soils in the interior valleys. Pomelo seedlings often give trouble in the seed-bed by gumming and by their peculiar habit of blooming and setting fruit when they are only two or three inches high.

In addition to the above three stocks there are several others which are entitled to mention for the reason that while they may be no longer used in propagation they are often met with in old orchards. The rough lemon is said to be hardy and to a certain extent drought-resistant, and is being experimented with. It will probably not gain favor, however, as it is very susceptible to brown-rot gumming.

Trifoliate stock is largely used in Florida, and in the citrus districts of Louisiana and Texas it is used almost exclusively for growing the Satsuma orange, which does very well on this stock. In California, however, trifoliate is but little used. There remain a few old orange and

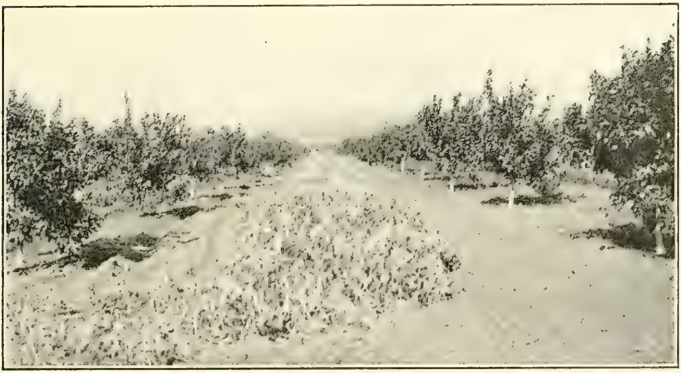

FIG. 45. — Cowpeas as an intercrop in young lemon orchard.

pomelo orchards upon it which are doing fairly well, but failures are more frequent than successes, and in very few cases does it appear to show any advantage over the sour or sweet. In some places Navel oranges sweeten earlier in the fall when grown on trifoliate stock. Perhaps the trifoliate comes nearest being a success when used on heavy soil in the Tulare district. Trifoliate is very objectionable for lemon trees and has been an absolute failure in every case recorded in California.

Chinese lemon, a form of citron, was once used to some extent but has long been abandoned entirely. It forced the tree into an extremely rapid growth which resulted in coarse fruit. It was short lived and quite susceptible to various root decays.

Ordinary lemon stock was sometimes used in the early days. Instead of growing seedlings and budding upon them, some of the early planters simply rooted cuttings of the variety desired and set them out in the orchard. A few of these old trees remain, but their record does not furnish a good recommendation for this stock, as the trees are nearly always more or less affected with root-rot. But aside from root-rot lemon roots have clearly shown their inferiority. The bud unions of certain lemon trees at the Limoneira Ranch became buried with soil and one or two roots put out from above the bud. Such trees showed a distinct depreciation in the amount and quality of fruit and vigor of foliage. Where only one large lemon root put out, the tree shows the effects on that side only, and this was the case even when the lemon root was apparently healthy and vigorous.

The question is sometimes asked as to whether the fruit of the orange will be deleteriously affected by the sap passing through a section of lemon wood as is the case when budded lemon trees are top-worked to oranges. A large number of instances of this have been reported on, and in no case does there seem to be any injury or reduction in quality of the oranges from having grown on lemon trunks.

Oranges are never grown from cuttings for the reason that orange cuttings cannot be induced to strike root.

There has been much difference of opinion and discussion of the point as to whether or not the hardiness of a cold resisting stock, such as the trifoliate, was transmitted to the scion. Published reports[1] indicate that such has been the case in Florida. In California such an effect, if present at all, is so slight as to be hardly worth recording. Rows of several varieties of trees on each of the different stocks have been grown for years at the Citrus Experiment Station at Riverside and have passed through two periods of excessive cold. After a very critical examination of the trees, the writer was forced to the conclusion that, in this case at least, there was practically no difference in the amount of injury from cold sustained by the trees on the different stocks.

DIGGING THE HOLES

Before the holes are dug, the notched planting-board should always be used in order to be able to set the tree in the hole in the exact position previously occupied by the stake. Large holes should be dug, two feet wide and one and a half feet deep. The bottom of the hole should be carefully inspected for stone or hardpan and should be well loosened up either with the spade or with a charge of explosive. If the trees come with bare roots, they should be handled with extreme care to prevent drying out.

It is customary to puddle the roots of trees when they are not balled. This puddling is done at the nursery and

[1] G. L. Taber, *Florida Farmer and Fruit-Grower*, 1901.

decreases to a small extent the susceptibility to injury from drying while handling in the field. The roots should be trimmed, all broken ends being cut off smooth, and the soil sifted in around the roots so as to leave no air holes. This soil should be moist and fine and must always be well tramped in order to bring the roots in firm contact with it. It is very important to set the trees at precisely the same height that they were in the nursery. After settling, citrus trees should always stand in the orchard at the same height that they did in the nursery. A citrus tree planted too deep or with the soil above the bud is doomed to failure.

Fig. 46. — Breaking a layer of hardpan by means of a stick of dynamite discharged in each tree hole.

When using the notched planting-board some planters prefer to set the guide pegs for several rows before the holes are dug, keeping the board at right angles to the tree row. A deep furrow is then plowed half way between the two rows of pegs. The holes are then dug in this furrow and after the trees are planted the water may be turned into the furrow. It is necessary of course to draw up a small mound of soil immediately about the tree to prevent the water from coming in contact with the bark.

When balled stock is planted, it is customary to allow the balls and sacking to remain. The strings are cut from about the crown and the tree planted, sack and all. It is also advisable to slit the sack at the bottom in order to allow irrigation water to enter more easily. Ordinary sacking decays in two months and the roots are not interfered with. In the case of the balls being composed of very stiff adobe soil, especially when planted in loose sandy soil, they should be soaked in water and loosened somewhat before planting. It is not advisable to attempt to stimulate the trees by putting fertilizer in the holes. Fertilizer may injure or even kill bare-rooted trees unless it is very thoroughly incorporated with the soil before the trees are planted.

Bare-rooted trees should be cut back when planted, the cut waxed over, and an entirely new head allowed to form. Balled trees may retain short stubs representing the main branches of the head, and a few leaves. Sun protectors are necessary to prevent sunburning of the trunk and should always be used, especially in hot interior valleys. Sun protectors may be made out of old sacking wrapped around the trunk or especially manufactured yucca tree protectors may be used. A number of thicknesses of old newspapers wrapped loosely around the trunk and tied with a string answers very well and has the advantage over yucca of being cheap as well as adjustable in length. Such tree protectors should be taken off once or twice during the first year in order to remove the water-sprouts from the trunk.

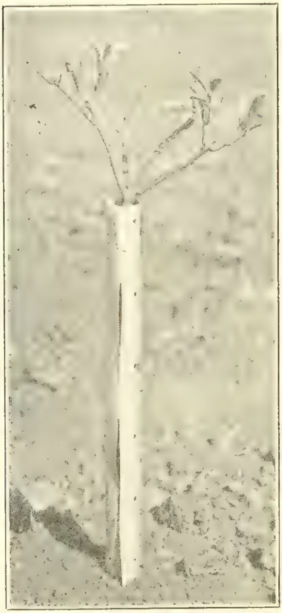

Fig. 47. — Newly set tree properly protected from the sun.

After the tree is well set and thoroughly tramped in, it should be watered immediately, the ground being thoroughly soaked. In order to save time, orchards are sometimes planted before the facilities for irrigating are completed. In this case the trees must be "tanked" or watered from a tank wagon. A basin is excavated about each tree, the soil being drawn against the trunk in the center to protect it from the water. After these basins are filled once or twice, the loose dry soil is returned to its place, in order to conserve the moisture, and the ground leveled off. If well attended to, tanked trees grow fully as well as those irrigated in the ordinary way. Whether they may be tanked to advantage the second year will depend on the cost of hauling the water. Usually the permanent system of irrigation should be ready by the second summer.

Wherever citrus trees are planted in new localities, where grain farming, rather than irrigated crops, have been the rule, a sharp lookout must be kept for ground squirrels and gophers. Both of these pestiferous rodents are apt to cause serious injury to newly planted citrus trees unless effectually prevented. Detailed directions for fighting gophers and ground squirrels are given in Chapter XXIV.

INTERCROPPING

The question often arises as to the advisability of growing intercalary crops between the trees in order to gain some revenue from the land while waiting for the trees to come into bearing. There are many cases where this has been done advantageously, although the intercropped citrus orchard is the exception rather than the rule. Such a practice is permissible only when the intercrop does not interfere with the best growth of the citrus trees. Citrus nursery stock is often grown between the rows of a young orchard where the soil is sandy and does not pack and bake as a result of the digging and tramping incident to balling the nursery trees. Vegetables, such as tomatoes, potatoes, peppers, lima beans, or black-eyed peas, may be grown to advantage. In interior valleys kaffir-corn and stock-beets make a satisfactory crop which may be used for hog feed. The corn-stalks are often convenient for wrapping the young trees in winter. A strip of alfalfa down the middles improves the soil, especially when the hay is cut and applied to the cultivated strip of land on either side of the tree rows. Such a strip of alfalfa should be reduced in width from year to year and plowed out entirely by the fifth year. Strawberries are very injurious to citrus orchards, especially on heavy soils, as they require such frequent irrigations that great injury from gum disease often results. In any event the young orchard should never be rented to tenant farmers to get all they can out of the land without reference to the good of the trees.

THE COST OF PLANTING

It is very difficult to estimate the cost of bringing a citrus orchard to bearing on account of the very great variation in existing conditions. Tait [1] gives an average estimate for a ten acre orange orchard in the Pomona district which gives a fair idea of the costs for the first five years.

Cost of Planting and Caring for Ten Acre Orange Orchard for Five Years

Ten acres of orange land	$1500
Water right, or stock in Water Co.	1300
Preparing and grading land	200
1000 trees at $1 each	1000
Planting trees at 7½ cts. each	75
Irrigating system	175
Irrigation and cultivation, five years	1500
Taxes and incidentals, five years	250
Fertilizer, three years	250
Total for 10 acres, 5 years	$6250

Since 1911 the cost of some items has increased, especially clearing and grading, as the land still available in this district is often encumbered with bowlders and brush. The cost of water has also increased. See page 359.

[1] C. E. Tait — "U. S. D. A., Office of Exp. Stations," Bull. 236, 1911.

COST OF NEW PLANTING, 1911, BY SAN DIEGO FRUIT CO.[1]

ORCHARD No.—	ACRES	NUMBER OF TREES	COST	SURVEY	WATER	LABOR	FERTILIZER	TOTAL
9	$2\frac{1}{2}$	158	$126.05	$5.00	$8.75	$16.21	$5.62	$161.63
31	$2\frac{1}{2}$	237	177.60	5.00	8.75	34.21	9.37	234.93
32	$4\frac{1}{2}$	351	278.25	10.00	15.75	58.90	13.12	376.02
33	6	491	370.72	35.00	21.00	133.57	18.75	579.04
78	9	712	580.31	12.50	31.50	207.63	26.25	858.19
80	15	1,072	953.91	19.00	52.50	346.18	39.46	1,411.05
83	8	591	443.25	5.00	28.00	149.88	22.50	648.63
85	4	262	209.60	2.50	14.00	52.44	9.84	288.38
106	$1\frac{1}{2}$	103	77.25	——	5.25	11.64	3.75	97.89
108	10	770	630.50	——	13.50	259.67	29.06	932.73
111	13	1,199	910.21	25.50	45.50	301.38	45.00	1,327.59
Total . .	76	5,946	4,757.65	119.50	244.50	1,571.71	222.72	6,916.08

Average cost of planting per acre	$91
Add grading and preparing land	35
Total	126

This will vary as the number of trees vary. This report shows average of 78 trees per acre. Frequently there are 90 trees planted per acre:

First year's care	$38.50
Second year's care	42.50
Third year's care	57.50
Fourth year's care	95.00
Fifth year's care	115.00
	348.50
	126.00
	474.50

In the case of Navel oranges, the orchard should yield a scattering of fruit the third year and a considerable amount the fourth and fifth years. Valencia oranges are later in coming into bearing.

[1] Speech of Senator J. D. Works, "Congressional Record," July 24, 1913.

STATEMENT NO. 1

Cost of bringing 163 acres of lemon grove into bearing, trees planted in 1905 by the Riverside Trust Co. (Ltd.) [1]

Year ended Sept. 30, 1905:		
Land and water, 163 acres, at $450 per acre		$73,350.00
Plowing and leveling	$1,017.36	
Fluming	4,310.31	
12,608 trees, at $1	12,608.00	
Planting	957.04	
Cultivation and irrigation	107.53	
Fertilizing	71.40	
Water dues	87.17	
Total	19,158.81	
Management	113.80	
		19,272.61
Year ended Sept. 30, 1906:		
Cultivation and irrigation	1,238.72	
Fertilizing	1,361.79	
Water dues	804.65	
Taxes	369.92	
Other expenses	953.75	
Total	4,728.83	
Management	788.03	
		5,516.86
Year ended Sept. 30, 1907:		
Cultivation and irrigation	1,548.05	
Fertilizing	734.64	
Water dues	1,036.41	
Taxes	794.40	
Other expenses	536.78	
Total	4,650.28	
Management	1,777.29	
		6,427.57
Carry forward		$104,567.04

[1] J. D. Works, *loc. cit.*

Brought forward		$104,567.04
Year ended Sept. 30, 1908:		
Cultivation and irrigation	$1,967.99	
Pruning	205.15	
Fertilizing	2,522.25	
Water dues	978.00	
Taxes	773.51	
Other expenses	309.42	
Total	6,756.32	
Management	1,670.91	
		8,427.23
Year ended Sept. 30, 1909:		
Cultivation and irrigation	2,493.20	
Pruning lemons	125.35	
Fumigation (90 acres)	1,423.19	
Fertilizing	411.18	
Water dues	1,556.70	
Taxes	1,042.52	
Other expenses	509.55	
Total	7,561.69	
Management	2,521.43	
		10,083.12
Total		$123,077.39
Less crop returns 1908	1,069.50	
Less crop returns 1909	4,431.06	
		5,500.56
Total		$117,576.83
Average, $721.33 per acre.		

These figures should be considered in connection with those given on pages 360 to 362. These tables present typical actual expense accounts while the figures given in Chapter XX represent the averages of very large numbers of ranches or packing-houses as the case may be. The consideration of averages alone often leads to incorrect conclusions, particularly with agricultural operations where the personal factor enters so largely into the account.

Statement No. 2

Cost of 163 acres of lemon groves, by the Riverside Fruit Co. (Ltd.)

Cost of land and water, at $450 per acre . . .		$73,350.00
First year:		
Proportion of cost of equipment, building, stock, tools, machinery, etc., at $82 per acre . . .		13,366.00
Cost of planting, care, etc.		19,272.61
Second year, cost of care, etc.		5,516.86
Third year, cost of care, etc.		6,427.57
Fourth year, cost of care, etc.		8,427.23
Fifth year, cost of care, etc.		10,083.12
Total		136,443.39
Less:		
Crop returns, fourth year	$1,069.50	
Crop returns, fifth year	4,431.06	
		5,500.56
Total		$130,942.83
Average, $803.33 per acre.		

Statement No. 3

Cost as per statement No. 2		$130,942.83
Interest at 6 per cent per annum:		
Five years on $86,716	$26,014.80	
Four and one-half years on $19,272.61	5,203.60	
Three and one-half years on $5,516.86	1,158.50	
Two and one-half years on $6,427.57	964.10	
One and one-half years on $7,357.73	662.20	
Six months on $5,652.06	169.56	
		34,172.76
Total		165,115.59
Average, $1,012.96 per acre.		

CHAPTER XI

CULTIVATION, FERTILIZATION, AND COVER-CROPS

THE operations incident to the care and management of orchard soils constitute a very important part of the work of producing citrus fruits. Upon the intelligence used in the handling of the soil will depend to a large extent the degree of success finally achieved.

Tilling the soil (1) improves its physical condition by loosening it and extending the rooting area; (2) aids in saving moisture by enlarging the water-holding capacity and by checking surface evaporation; (3) augments chemical action by making inert plant food available; and (4) admits air to the soil. This last function of tillage is very important because plant roots must have air in order to grow, and air in considerable quantities is also essential for the life of all the beneficial bacteria upon which we depend for the making available of inert plant food in the soil and for the acquisition of nitrogen from the atmosphere.

PLOWING

The tillage of citrus orchards consists of two kinds of operations known as plowing and cultivating. The land, in most cases, should be plowed thoroughly once a year, preferably in March or April, which is the time the winter cover-crop is turned under.

This plowing should be completed before the trees come into full bloom, as the unavoidable cutting of many roots at such a time is apt to interfere with the setting of the fruit. A mold-board plow is usually the best tool, and for plowing close up under the branches a special plow with

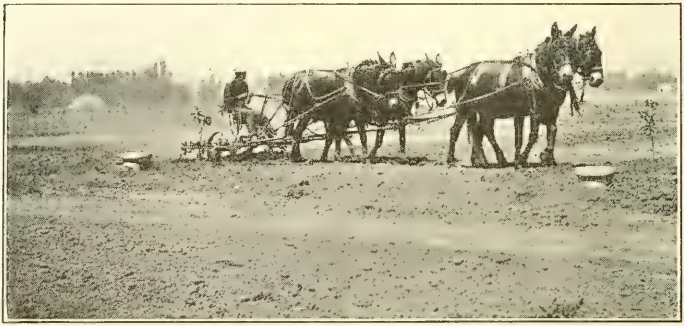

Fig. 48. — Cultivating newly set orange trees with eight chisel cultivator.

one handle is very convenient. The disk plow is very satisfactory in some soils and especially in orchards of small trees. The proper depth to plow is usually about eight or nine inches. It is unwise to plow at the same depth every year, for this is apt to encourage the formation of what is known as a plow-sole or hard layer which in time becomes impenetrable to water and air. Such a plow-sole may be largely avoided by plowing seven inches deep one year and nine or ten inches the next. Plow-sole once established may be broken up by running a subsoil plow fifteen inches deep, once down the center of the middles between the tree rows and again at right angles. Such treatment will cut a good many roots of course, but only those which extend beyond their legitimate feeding

Fig. 49. — Cloddy condition due to land being worked while too wet.

ground. Such subsoiling should be followed immediately by copious irrigation.

When the cover-crop is tall, a heavy iron chain suspended between plow beam and single-tree will serve to hold the mass of vegetation down until caught by the soil and a much more satisfactory covering of the crop will result. The disk harrow should follow the plow, crushing down the loose soil and bringing it into close contact with the mass of green vegetation. This will result in a more uniform incorporation of the crop with the soil. In California there need be no fear of souring the soil by turning under a rank, green crop, for the large amount of lime present in the soil quickly neutralizes any acid which may form.

Plowing cannot be carried on as rapidly as cultivation and it is often very difficult to complete the spring plowing before the land gets too hard and dry to plow without much extra labor and the turning up of tremendous clods which are a nuisance the rest of the season. In such cases it is a good plan to run over the entire acreage first with a disk harrow, going in both directions, chopping up the cover-crop, and creating a light mulch on the surface which will retard evaporation and hold the land in good condition to plow for a longer time. By the use of the orchard tractor also a larger area of land may be plowed in a given time.

In order to keep the ground level it is necessary to plow toward the trees one year and away from them the next.

CULTIVATION

Citrus trees are grown on irrigated lands, and as irrigation and cultivation go together, it follows that upon proper cultivation depends much of the success of the orchard. If water is applied and the land left without cultivation, the surface soil bakes hard, cracks open, the moisture escapes, and the trees suffer. It is the custom to cultivate after each irrigation just as soon as the ground is dry enough to stir without puddling. The irrigation furrows are obliterated by the cultivator and

Fig. 50. — Ground under trees may be worked with ease by means of an orchard tractor.

the surface four inches thoroughly stirred. In many cases it is advisable to follow the first cultivation with a second at the end of two weeks. In the case of square plantings the second cultivation should be carried on at right angles to the first. Cultivation should be deeper on heavy than on light soils for the reason that it requires a somewhat thicker mulch to prevent the loss of moisture from heavy soils. In the event that the weather is very hot and dry immediately after cultivation it may not be necessary to cultivate again before the next irrigation, for the reason that the mulch is more effective when very dry. When cultivation is followed by a period of cool, foggy weather, the capillary connections may be re-formed and much loss of moisture result unless a second cultivation be given. The object of cultivation is to create and maintain an effective soil mulch and the soil stirring process should be carried just far enough to achieve this object. Cultivation is an expensive operation and much money is wasted by the system of continuous stirring of the soil as practiced by some growers.

Disk cultivators are satisfactory in adobe and silt soils and especially among small trees, but it is not well to depend upon disk implements exclusively. An occasional cultivation with narrow chisel teeth will bring about better aëration and prevent the soil from packing.

All tillage implements used in citrus orchards should be provided with carefully made shields which protect the low hanging fruit and prevent it from being knocked and scarred by striking sharp projections of the implements as they pass close under the branches.

Orchard soils may be very seriously injured by cultivation at the wrong time, that is, when too wet or too dry. Immediately after irrigation there is a period of variable length when the soil is too wet to stir. If cultivated when too wet, the physical condition will be ruined. Soil is too wet to cultivate when it is muddy or scours off the plow with a slick, wet appearance. An adobe soil is injured more than a sandy soil by stirring when too wet. It may take a year or more to restore the physical condition ruined by injudicious cultivation. Ordinary or medium soils should be ready to cultivate about five or six days

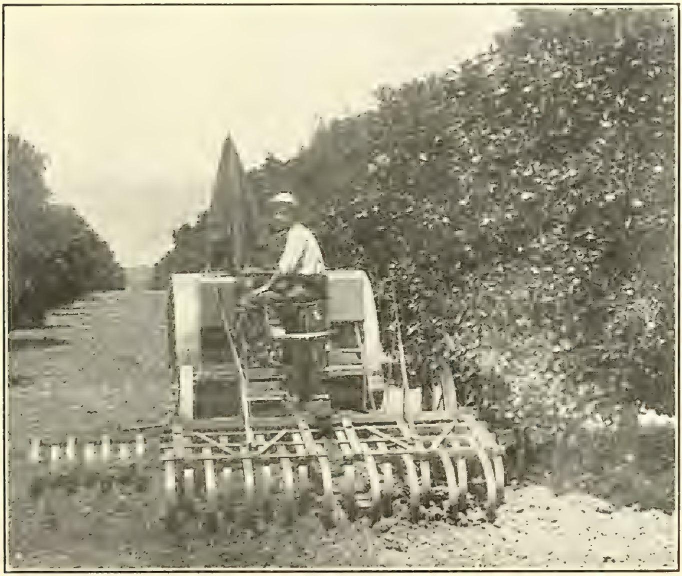

Fig. 51. — Orchard tractor doing the work of eight mules in a hot desert valley.

after irrigation, and they remain in good condition for about a week, after which they become too dry. If not stirred at the right time, the soil will bake hard and be very difficult to handle. If extra mules are then put on the cultivator, the soil will be turned up in large clods which will bake into brick-like masses which will be in the way for a year or more.

It is often very difficult to cultivate the entire acreage at the proper time on account of the lack of men and teams. In too many cases one-fourth the ground is stirred while too wet, one-half when the soil is just right, and one-fourth after the soil has become too dry. The remedy for this is to either increase the equipment of men and mules or to have recourse to the orchard tractor, which makes it possible to cover a much larger area in the same time. This difficulty is not serious with those growers who irrigate from local wells. They are in a position to irrigate a small piece of land at a time and follow the irrigation with cultivation after the proper interval.

In old bearing orchards the trees cover most of the ground and hardly more than a strip in the middles in each direction can be cultivated with teams or tractors. It then becomes necessary to do a considerable amount of hand work. The ground under the trees should be thoroughly worked over once a year, preferably in the spring just after the winter rains are over. Either a light spading fork or a short-handled mattock may be used. Workmen should be cautioned not to strike the trunks of the trees or the crown roots, as wounds made in this way are very apt to become infected with brown-rot gum-disease. The irrigating furrow nearest the trunk should pass just beneath the outer branches and the soil immediately about the trunk will not be wet during summer — hence the necessity of hand hoeing to furnish a mulch and prevent the soil about the crown from baking as hard as a pavement.

MULCHING

The great difficulty of handling heavy and intractable adobe soils or soils which acquire an adamantine hardness when dry has led some growers to substitute a mulch of straw or other humus forming material, for the soil mulch, and discontinue cultivation of the middles with

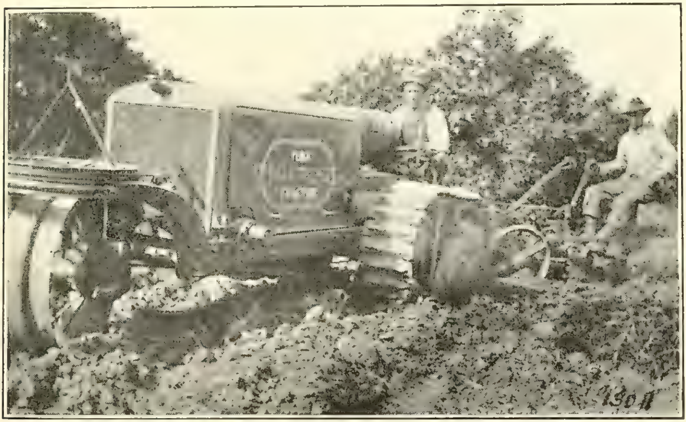

FIG. 52. — Heavy plowing with an orchard tractor of the caterpillar type.

teams. Permanent basins are made around each tree of a diameter approximating the extreme spread of the branches. One permanent irrigating furrow extends down either side of the tree row and connects with each basin. A permanent strip of alfalfa occupies all of the available space of the middle. The alfalfa is mowed five or six times each season and thrown into the basin under the trees before it is dry enough to shatter. This material accumulates during summer and, after acting as an effective mulch, rots down during the winter rains and may be worked into the soil with hand hoes each spring before the new crop of mulching material is available. The alfalfa is sown broadcast and is irrigated by flooding between slight ridges which bound the strip. In California this system is still in the experimental stage, although modifications of it have long been used in other countries.

ORCHARD TRACTORS

The availability in California of large quantities of cheap fuel oils has made possible a great increase in the use of orchard tractors. There are a number of these machines now on the market, some of which have proven economical and satisfactory. While the mule is by far the most flexible motor for small jobs and for work on broken ground such as contour plantings, the tractor is gradually displacing the mule on large tracts of level land. A grower who keeps sixteen head of mules worth $2400 may retain four for light work and with the money from the sale of the others get a machine which will do the work of the original sixteen. The engineering of such a machine appeals much more strongly to the average farm boy than hitching, unhitching, and feeding the mules morning, noon, and night! The tractor also is immune to the high heat of the interior valleys, which is often embarrassing to work-stock. With a tractor it is possible to till a larger proportion of the orchard area at the right time.

The work in citrus orchards demands a low down, light, short-turning gas tractor either of the three wheel or caterpillar type. The machine should not exceed five feet in height and should be provided with steel hood or limb protector. Extra strong tillage implements must be used with tractors, as otherwise serious breakage may result when stones or stumps are struck. An ordinarily good orchard tractor should plow about twelve acres of orchard a day at a cost, including an ample allowance for interest and depreciation, of not over $12.

FERTILIZATION

Perhaps no subject connected with citrus fruit culture is hedged about with as much uncertainty as that of fertilization of the soil. California soils are usually very rich in available plant-food, and in many cases fertilization is not needed for the first few years. The average orchard, however, will begin to fail after five or six years of production unless fertilization of the soil is resorted to. How much and what kinds of fertilizer to apply are questions which are extremely difficult to answer specifically, and it is usually necessary for each grower to experiment on his own land in order to gain an idea of the best course to follow in his particular case. No one should be disappointed if results fail to appear quickly, for with citrus trees on rich land it often requires a number of years before any measurable differences due to experimental fertilization can be observed.

There is a very widespread idea among persons not well grounded in the principles of agriculture, that the logical procedure is to take samples of the soil to a chemist for analysis, and to lay out a well calculated program according to his report. Such a course is not often practicable, however, for the reason that while the chemist may show the exact amount of plant-food in the soil, he has as yet no way of measuring the amount of plant-food which trees on a given soil may be capable of taking up. And

FIG. 53. — Substituting baled lima bean straw for manure in lemon orchard near Whittier, California.

there are still other difficulties, such as the trouble experienced in obtaining a sample which fairly represents a considerable area of land, and the variation in the composition and physical make-up of the soil on the same farm and often in the same field. Of course chemical analyses are valuable guides in the case of unusual soils, as when alkali is suspected or when some one of the necessary elements is markedly deficient. But the claims of some people, that the proper formula should be made up by adding a little of "this" to make the fruit set, and a little of "that" to increase the sugar content, and a little of "the other" to improve the color, are very largely without foundation of scientific evidence.

A ton of fresh oranges and lemons removes the following amounts of plant-food from the soil:

	Nitrogen	Phosphoric Acid	Potash
Oranges	3.88 lb.	1.06 lb.	4.22 lb.
Lemons	3.04 lb.	1.16 lb.	5.08 lb.

Citrus growers, as a rule, do not limit themselves to replacing the amount of plant-food removed from the land, but commonly apply as fertilizer many times this amount of plant-food.

A study of soil analyses teaches us that when the average California soil begins to fail from heavy production nitrogen is most likely to be the first crop limiter and after nitrogen phosphoric acid, and after that potash. Most important of all, however, is the physical condition of the soil, for all of these elements may be present in excessive amounts; and yet if the physical condition of the soil is not favorable to a vigorous and healthy root action, the plant-food present cannot be used. By proper physical condition is meant that state in which the soil will absorb water quickly and hold it long as well as admit air to considerable depths.

A Type of Fertilization Practice in Southern California for Old Bearing Trees which are Too Close to Permit Cover-crop

Variety	Kind of Fertilizer	Lb. per Tree	How Applied	Date of Application
Navels	Bone meal	7	Drilled in	Oct., 1912
Lemons	Bone meal	6	Drilled in	2.5% N
Tangerines	Bone meal	8	Drilled in	22% P_2O_5
Navels	Sodium nitrate	2	Hand spread	Mch., 1913
Lemons	Sodium nitrate	2	Hand spread	Buds just
Tangerines	Sodium nitrate	2	Hand spread	starting
Navels	Tankage	12	Drilled in	Apr., 1913
Lemons	Tankage	12	Drilled in	8.35% N
Tangerines	Tankage	15	Drilled in	7.65% P_2O_5
Navels	Stable manure	5 cu. ft.	Disked in	Aug., 1913
Lemons	Stable manure	5 cu. ft.	Disked in	
Tangerines	Stable manure	5 cu. ft.	Disked in	
	Same as for 1912			Oct., 1913

HUMUS

Humus is a dark colored highly complex organic compound which is formed by the decay of vegetable matter in the soil. Humus is present in relatively small amounts in California soils, because on account of their greater ventilation and higher temperatures the humus is oxidized or burned out of the soil more rapidly and does not accumulate to the extent it does in the soils of humid and cold climates. The chief reason why humus is so important is found in the fact that it is relatively insoluble under good field conditions and does not leach away, but remains to form the food of nitrogen-forming bacteria which convert it by degrees into nitric acid, which, while one of their waste products, yet is the essential form of nitrogen for the food of citrus trees. Humus also has tremendous water-holding capacity and its presence enables the soil to take up water like a sponge. Humus has the tendency to make close compact soils more open and porous, and at the same time sandy soils are made more retentive of water.

It happens also that the average humus of arid soils contains about three times as much nitrogen as that of humid soils, and therefore it is especially important to maintain the humous content of arid soils. On account of the fact that the humus in California soils is so intimately associated with nitrogen formation, we are warranted in saying that where the humus and moisture conditions of a soil are kept at the optimum, the question of nitrogen fertilization becomes of less importance, especially where heavy crops of leguminous green manure are practicable.

The humous content of soils may be kept high by the application of vegetable matter in various forms. Stable manure, bean straw, alfalfa hay, trash and sweepings of many sorts, leaves, kelp, cover-crops, weeds, prunings, citrus fruit culls — all these are used to supply decaying organic matter to the soil. When the humus is too low, the soil, if sandy, loses water too rapidly; if heavy, it becomes cloddy, dead, inert, and bakes quickly after irrigation. Such a soil is hard to cultivate, forms a plow-sole quickly, and it becomes more and more difficult to get the water to sink in rapidly. The trees make small growth, and as the tops become thin, numerous water sprouts push out from the trunk. The fruit is small and appears to be more susceptible to splitting and sunburn. Too much humus (a condition very rare in arid countries) causes too great a vegetative growth at the expense of fruit wood, while the fruit tends to grow large,

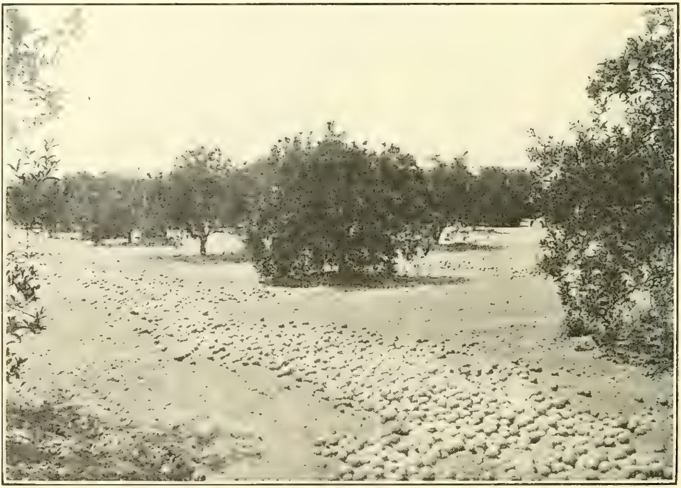

Fig. 54. — Cull oranges used as a humus-forming fertilizer.

coarse, thick-skinned, and poor flavored. The optimum amount of humus for citrus trees in California has not been determined with any degree of certainty. No doubt it varies with the distance from the coast, being higher in the hot, interior valleys. It is suggested that manure, or its equivalent in other vegetable matter, to the depth of two inches over the entire surface of the land once a year would not be too heavy an application on the type of soils common around Redlands and Riverside, although somewhat smaller amounts should answer for soils nearer the coast.

As a matter of practice it is very difficult to secure anything like adequate supplies of humus-forming materials. Although enormous amounts of manure are bought at high prices in the cities and shipped to the citrus ranches by rail, only a small percentage of the orchards are manured every year. In order to make up the deficiency, the growing of green manure crops has been largely resorted to.

GREEN MANURE CROPS OR COVER-CROPS

Cover-crops in the citrus orchard have many advantages and few disadvantages.

Advantages —

1. They increase the fertility of soil by the addition of humus which acts as a liberator of mineral nutrients;
2. Increase the water-holding capacity;
3. Make the land easier to work by improving physical condition;
4. Encourage an increase in number of soil bacteria;
5. Add nitrogen directly to the soil from the air when such crops are leguminous;
6. Puncture the plow-sole with roots which decay and leave openings for the admission of air and water;
7. Bring plant-food up from below and leave it near the surface;

8. Prevent excessive erosion on steep hillsides;
9. May decrease the amount of brown-rot.

Disadvantages —

1. They may necessitate irrigation at times not good for citrus trees.
2. Heavy root-pruning of trees incident to turning under cover-crop is not advisable while trees are blooming and setting fruit.
3. They may increase cottony-mold in case the cover-crop used is a host for this fungus.

A large number of different crops have been experimented with, but the ideal plant for this purpose has not yet been found. Some of the plants in use are, in the order of their importance, common vetch, Canada field peas, bur clover, fenugreek, hairy vetch, sour clover, alfalfa, buckwheat, and cowpeas; the last named crop being grown only in summer.

Common vetch, *Vicia sativa*, is by far the most commonly grown crop. It has large seeds which germinate well, and grows throughout the winter. It has the disadvantage of maturing rather late in spring and is in some cases a host for the cottony-mold fungus. In recent years it has been seriously injured and in many cases destroyed by a species of aphid. For these reasons the use of common vetch is on the decline.

Recent experiments have shown that purple vetch, *Vicia atropurpurea*, is better than common vetch and it is to be hoped that an adequate supply of seed will soon be available.

After an irrigation in the first half of September, the soil is well cultivated and fifty to one hundred pounds per acre of vetch seed is either deeply drilled in both directions or sown broadcast, after which the irrigation furrows which are to remain all winter are immediately laid off as close together as possible.

If planted in October or later, the plants do not get sufficiently well started before cold weather to make much growth during the winter. In northern California, under irrigation, vetch should be sown about the first of October. It will then make a sufficient growth to be turned under in February or March.

In the citrus districts of northern California vetch is used to a small extent only, as the volunteer crop of bur clover is often very satisfactory. In many places a common weed, *malva*, comes volunteer and growing to a height of three or four feet produces a large tonnage of green stuff. This plant is not a legume, but makes up in quantity what it lacks in quality. Other weeds which sometimes make good cover-crops are *erodium*, known as "filaree" and a *chenopodium*.

In southern California a winter cover-crop of some kind is the rule on all except the very stiff adobe soils near the coast. Such soils are injured in texture by lying without cultivation all winter, and consequently manure is used to the exclusion of a cover-crop, and the cultivators are kept moving all winter.

The question is often asked whether it is not advisable to inoculate seed to be sown on land that has not previously grown that crop. In California, it has been found that the bacteria necessary to nodule formation on the more common leguminous crops are present in most soils.

The first seeding may not, however, be as abundantly inoculated as desired, and in some sections the bacteria essential to certain crops seem to be entirely lacking. In such case the land should be inoculated by drilling in with the seed a small quantity of fresh soil taken from some field which has grown the particular crop satisfactorily.

A few growers who have sufficient water grow a summer crop of cowpeas in addition to the winter crop. This of course is advisable where practicable, but on account of the higher price of summer water and the need of most soils for frequent stirring, the practice is considerably limited. In the northern part of the Sacramento Valley, where water is cheap, the practice of planting the orchards permanently to alfalfa is on the increase. As yet this can only be regarded as an experiment and should not be adopted on a large scale at the present time.

SUMMARY

In summing up this discussion of soil management it may be said that optimum production depends upon a number of factors working together. As a chain is only as strong as its weakest link, so the size of the crop cannot rise above the one factor which is farthest from the optimum. The effort of every grower should be to discover the "crop limiter" in his particular grove. First he should provide plenty of water to dissolve the plant food and carry it into the plant. Then he should increase the humous content to the point where his soil is actually "alive" with bacteria working to fix for him the free nitrogen of the air and make available the tremendous stores of inert plant-food in the soil minerals. This should be done by the application of manure or straw and the growing of leguminous cover-crops. The soil should be deeply plowed and cultivated in order to encourage the roots to go down after the plant-food which in arid soils is available at unusual depths. The arid soil farmer has a great advantage in this regard, and this advantage should not be thrown away by shallow irrigation and cultivation.

After all this is done it is time to consider the kinds and amounts of commercial fertilizers to apply. This will be found a puzzling question and one which must be largely determined by each individual grower for himself. He should first experiment by trying out each plant-food element alone. A few rows should receive nitrate of soda, a few phosphoric acid, and a few sulphate of potash, with check rows receiving nothing alternating with the fertilized rows. It will require a number of years' patient effort perhaps before results will be evident. Having found the element or elements to which his trees respond, his next step is to determine the optimum amount of such fertilizers which it is profitable to use at the price he has to pay for them.

Meanwhile the grower should apply to the remainder of his acreage, not included in the experiment, a fair amount of fertilizer as determined by the amount of nutrients removed in the crop, modified to some extent perhaps by the former results and experience of other growers in the immediate neighborhood.

While fertilization is a very important part of the process of producing citrus fruits, too great or too quick results should not be expected. A few extra pounds of fertilizer should not be expected to overcome the injury done by neglect or carelessness in irrigation, cultivation, or pruning. There is an old Roman proverb which applies especially well to citrus fruit raising. It is somewhat as follows:

"The footprints of the owner make the best fertilizer."

CHAPTER XII

IRRIGATION

In all parts of the arid Southwest citrus fruits require irrigation. In many localities in California, especially where the rainfall is heavy, deciduous fruits, such as

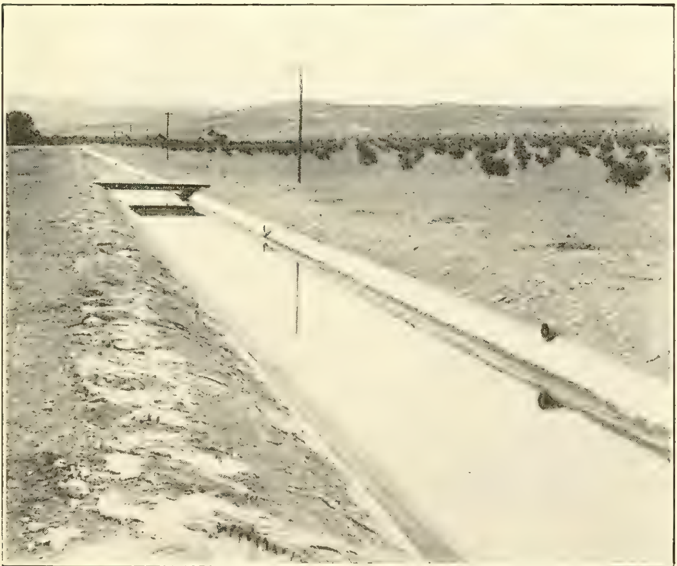

Fig. 55. — Canal lined with cement. Transformation of desert hills into orange groves.

prunes, peaches, walnuts, grapes, and almonds, are grown very successfully without irrigation. The very deep rich soils not only encourage deep rooting, but they constitute a reservoir for the winter rainfall which is, or should be, carefully conserved for the use of the trees by frequent surface cultivation during summer. Citrus fruits, however, being evergreen, transpire large amounts of water at all seasons of the year; and while in the more favored locations the trees may remain alive, they should not be expected to bear commercial crops without irrigation water in addition to the rainfall.

AMOUNT OF WATER NEEDED

The amount of water needed will depend upon the amount of rainfall, the character of the soil, the climatic conditions, and the age and kind of trees. Heavy clay or adobe soils are usually difficult to saturate, but once well soaked they retain the water well, and a less amount is needed on such soils than on open gravelly soils through which the water passes more readily. Near the coast, where the air is moist, trees require somewhat less water than in interior valleys where it is more windy and the air is hot and very dry in summer. The draught on the tree for water varies with four factors: the temperature, relative humidity, velocity of wind, and the amount and intensity of the sunlight. The observers of the United States Weather Bureau record all of these factors, but apparently no systematic attempt has been made to correlate them. The porous-cup atmometer automatically correlates all of these factors, the record indicating in cubic centimeters of water evaporated per day, the total demand of the air on the plant for water. The writer kept duplicate atmometer records for one year at Whittier and Riverside, California, for the purpose of measuring this difference in the climate of the two places. Whittier is in Los Angeles County, about fifteen miles from the coast, and situated on the foothills facing the sea. Riverside is about thirty-five miles due east of Whittier and on the opposite side of the hills.

Atmometer Records June 1, 1911, to May 31, 1912

	Whittier	Riverside
1911, June	686.0 cc.	1,302.1 cc.
July	779.1	1,301.0
August	934.8	1,244.3
September	852.7	1,421.7
October	989.7	1,249.7
November	1,544.0	1,541.4
December	1,279.3	1,371.3
1912, January	1,319.5	1,211.1
February	1,025.0	1,019.8
March	654.6 [1]	620.4
April	464.8	1,017.9
May	707.2	1,643.4
Total	11,236.7	14,944.1
Average daily	30.7	40.9

[1] Estimated from incomplete records.

These figures show that the draught of the air for water is about 33 per cent greater at Riverside than at Whittier, and this fact considered in connection with the

FIG. 56. — Preparing the ground for furrow irrigation. (From U. S. D. A., Farmers' Bul. No. 404.)

more porous character of the Riverside soils explains why a larger quantity of irrigation water is needed.

Of course it goes without saying that old bearing trees require much more water than young trees, and it is essential for permanent success that the right to sufficient water for old trees be secured in the beginning and jealously guarded until it is all needed. As a basis for estimating the capacity of wells and streams, the available flow during the driest years on record should be taken. The rainfall is variable and it is not unusual for several dry years to occur in succession. At such times the underground stores of water are greatly depleted and the trees are apt to suffer.

Inasmuch as the average yield in pounds of mature lemon trees is considerably greater than that of orange trees, it follows that they require more water, and this is borne out by the experience of the growers.

From what has been said it is clear that no definite rule can be laid down as to the exact amount of water needed under different conditions. For the sake of comparison, however, it may be stated in a general way that water to a depth of from thirty-five to forty-five inches, including both irrigation and rainfall, should be allowed bearing citrus trees. Full bearing orchards on retentive soils near the coast should be provided with about one and one-fourth ordinary miner's inches to each ten acres, while the same trees in the hot interior valleys and especially on gravelly soils should have not less than three ordinary miner's inches to ten acres.

The miner's inch in California has two values. The ordinary one adopted by custom is a stream flowing freely through an opening one inch square under a pressure head of four inches on the center of the opening. This flow is equivalent to one-fiftieth of a cubic foot per second or nine gallons per minute. The miner's inch as defined by the statute of 1901 and known as the "Statute Inch" is equivalent to a stream flowing freely through an opening one inch square under a pressure head of six inches on the center of the opening. This flow is equivalent to one-fortieth of a cubic foot per second or eleven and one-fourth gallons per minute. All contracts for water should specify the miner's inch to be used.

SOURCES AND COST OF WATER

Water for citrus orchards is secured by diversion from flowing streams, by pumping from reservoirs in underground gravel beds, and from artesian wells. The best water rights are old and well established claims to stated quantities of water from streams which are fed the year round by melting snows of high mountains. The right to a water supply pumped from wells is good provided the land to be irrigated overlies the underground reservoir, the owner of such land having an equal right with other overlying land owners. In cases where the surface of the ground immediately over the reservoir is not suited to cultivation the water may be transported for use upon any land within the same natural drainage area. The right to transport water from one natural drainage area into another for irrigation purposes is questionable.

Where a great many wells are put down in the same neighborhood they are apt to interfere with each other, and the general level of the underground water may be drawn down to such an extent that the pumps may have to be lowered and engines of greater power installed to lift the water to the surface. Artesian wells often cease to flow under such conditions. In cases where a series of dry years brings about a marked diminution in the supply of the underground water, the lands immediately overlying the water-bearing gravels have first right to the water; and in case these lands are not cultivated, then the distant lands enjoy prior rights in the order in which the water for them was appropriated.

The cost of water is extremely variable, running from almost nothing to as high as fifty or sixty dollars an acre a year. With the development of cheap electric energy and the internal combustion engine, water may now be economically lifted to great heights. One large company near Corona, by the use of what is known as a "boosting plant" run by an internal combustion engine, lifts water to a height of 750 feet for the irrigation of lemon orchards.

The average cost of water used in citrus orchards in California is about twenty dollars an acre a year.

METHODS OF DISTRIBUTION

In the early days water was distributed to the high places throughout the orchards through open ditches and viaducts. These were very unsatisfactory because they filled up with grass, weeds, and silt and had to be cleaned out quite often. Not only was this expensive, but a great deal of water was lost by seepage. These ditches were replaced by wooden flumes, which answered well until they rotted out. They have been gradually replaced by concrete pipe-lines, which are now almost universally used in the citrus orchards of California. If well made of one part of cement to four parts of clean, sharp sand this pipe is permanent and has proved highly satisfactory wherever the pressure is not over ten feet. It is laid about fifteen inches below the surface or deep enough to be out of the way of the subsoil plow. The joints are carefully cemented to prevent leakage and the entrance

Fig. 57. — Irrigating stands in operation.

of roots. Where the pressure is greater than ten feet, steel pipe must be used. Concrete pipe twelve inches in diameter costs about thirty-five cents a foot, laid.

The pipe-lines are laid across the rows and at the end of each row a standpipe is placed over the line in such a way that the water will rise to a certain height and overflow back into the line. Each standpipe is furnished with delivery spouts controlled by close-fitting metal gates. The overflow provides for an even pressure on the delivery spouts at all times.

Where the check system is used the water is delivered at the highest corner in a large head and conveyed to different parts of the orchard through temporary earth ditches.

TIME OF APPLICATION

Citrus trees should never be allowed to suffer for water. Olive trees, aside from dropping the fruit, are not permanently injured, but citrus trees receive a setback which it often takes years to overcome. The soil should be watched and water applied before the trees show any signs of distress such as curling of the leaves or dropping of the fruit. It is very important that the grower keep in close personal touch with the condition of the soil to the depth of four or five feet. The only way to find out the condition of the soil is by digging holes at various places or by using the King soil sampler.

Where growers take the water from a company serving a large area, they usually irrigate in rotation about once a month during the summer and less often during the rainy season. This system is objected to on the ground that there is not an incentive to use water economically. While the trees are small and the supply of water is greater than necessary there is a tendency to try to make amends for poor cultivation by over irrigation.

Experienced growers are able to determine when a soil needs water by simply feeling it in the hands. Beginners, however, should make physical tests of the water content occasionally. Such a test is very simple and may be performed by any one. Samples may be taken to a depth of four feet, keeping the soil from each foot separate. These samples are weighed immediately, and again after having been exposed to the hot sun for the greater part of a day. The difference in weight will represent the moisture content. It is considered that six per cent by weight of free moisture is sufficient, in sandy loam soils, to keep the trees in good condition.

"Dr. Loughridge in his experiments at Riverside in June, 1905, found an average of 3.5 per cent in the upper two feet and an average of 6.16 per cent below this level in an orchard which had not been irrigated since October of the preceding year. It had received, however, a winter rainfull of about sixteen inches. On examination it was found that the bulk of the roots lay between the first and fourth foot. These trees in June seemed to be merely holding their own. When irrigated, July 7, they began to make new growth. A few days after the water was applied, the percentage of free water in the upper four feet of soil rose to 9.64 per cent. The results of these tests seemed to indicate that the percentage by weight of free moisture should range between 5 and 10 per cent in average orchard loams."[1]

The temperature of the water oftentimes has an important relation to the health and productivity of the trees. Hilgard[2] has the following to say in regard to this: "To those who are located in or near the foothills and are apt to receive their irrigation water at a tem-

[1] Fortier, U. S. Dept. Agr., Farmers' Bul. No. 404, p. 24.
[2] *Rpt. Calif. Exp. Sta.*, 1897–98, p. 54.

Fig. 58. — Zigzag furrows wet the ground between the trees.

perature not far above that at which it left the high Sierras, this is a very serious consideration. Many a time there have come to the Station complaints of an unaccountable dropping of fruit, or injury to field crops, which, when investigated, were directly traceable to the use of cold irrigation water, at a time when the trees and crops were in full growth. As the same ditch may at different times supply him warm or cold water, according to the use made of it before it reaches the lower level, the irrigator should use, if not a thermometer, at least his hand and a good slice of common sense, to determine whether or not he is running a risk of injury by applying it directly to his land."

METHODS OF APPLICATION

In orchard irrigation it is necessary that the water be evenly divided between all the units of space both horizontal and vertical. It is desirable that the water be retained in the soil until taken up by the roots of the trees. Part of the water may escape through leaching into the sub-drainage, and part will evaporate from the surface. It should be the aim of the irrigator to reduce the loss through these avenues as much as possible. Sub-irrigation through some kind of system of pipes would seem to be ideal, but has been found to be impracticable, on account of the plugging of the openings in the pipe by tree roots in their natural growth toward the moisture in the undrained pipes.

Overhead irrigation is being experimented with on a small scale by various growers, and in some cases gives promise of success. Mr. David Overholtzer of Covina is irrigating nine acres of twenty-two-year-old Valencia oranges by this method with apparent success. He lifts his water 147 feet or more from a well in the orchard with a Pomona deep well pump and a 40 H. P. gas engine. A centrifugal pump keeps the pressure on the line at about forty pounds. The supply pipes run down the center

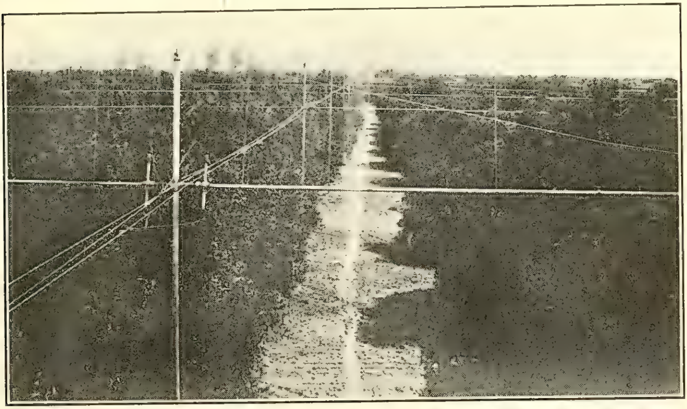

Fig. 59. — Overhead irrigation system in old orange orchard near Covina, California.

of the orchard and from them radiate the delivery pipes, one over every other middle at an elevation of 16 feet. The patent brass nozzles, $\frac{37}{100}$ inch diameter, are placed four feet apart, and the streams of water are thrown laterally about twenty feet. The entire orchard is irrigated at once and the delivery pipes are all rotated from one windlass in the pump-house. The equivalent of one inch of rain is applied in about twelve hours.

The two chief methods of application are by basins and furrows. Furrows are best for heavy soils, but basins are often necessary on sandy or gravelly soils across which it is impracticable to transfer the water except in very large heads. In loose sandy soils, water percolates with such rapidity near the head ditch that a large part is lost by passing far below the roots and possibly into sand and gravel strata, through which it flows away. In one orchard measured by Loughridge the water had percolated to a depth of twenty-six feet at a distance of thirty feet from the head ditch. As it is doubtful if water at a depth of more than five feet below the root systems will be of any benefit to the trees, it is evident that a large part of this water was wasted. For these reasons it is advisable to use the basin system on all loose sandy soils. By the use of a ridger, the loose earth is thrown up into ridges midway between the rows in two directions at right angles to each other. This divides up the ground into a number of squares with a tree in the center of each. A ditch is then run from the supply line at the head down every alternate row by splitting the ridge in this row. The water is then admitted in a head of 40 or 50 miner's inches and run through to the lower two basins. After these are full, the water is admitted to the two above, and so on till the double row is completed.

By far the larger part of citrus irrigation in California is done by the furrow method. The orchard is divided into sections and head lines of concrete pipe with stands run across the orchard from 300 to 500 feet apart. The distance between these is known as a "run." The length of these runs is governed by the size of the orchard and the kind of soil. Where the soil is open and water sinks readily through it, 300 or 400 foot runs should be used, otherwise much water is lost by deep percolation on the upper part of the tract. On very sandy or gravelly soil having a slight slope, the proper length of furrows is 200 feet, while on heavier soils with considerable grade, the length may be increased to 500 or even to 700 feet. The grade of the furrows varies widely from one per cent or less to ten per cent or more. The steeper the grade, the more likelihood of washing and consequently the smaller the stream of water used. On ordinary soils, a three or four per cent grade is preferred. Where the grade is more than ten per cent the furrows should be run on the contour.

The number of furrows used between each tree row depends on the age of the trees, the distance between rows, the depth of the furrows, and the character of the soil. During recent years the general trend of orchard practice is toward deep rather than shallow furrows, a depth of eight inches being frequently used. The furrowing implement ordinarily used consists of a sulky frame to which are attached two or three wide shovel plows. Sometimes a subsoil plow is run in the bottom of the middle furrow and again at right angles in the center of the middles in order to insure deep percolation of the water.

As the trees grow and occupy most of the space, it becomes difficult to run the furrows close to the trees, and consequently there is a large space left in the row between the trees which is not wet. This trouble is met by cross-furrowing. While this occasions a large amount of hoe work in reopening the furrows where they cross, it is absolutely necessary when large wide-spreading trees are irrigated by the furrow method. Cross-furrowing is also used with newly-set trees when the cost of water is such as to require the most economical use.

Fig. 60. — The King soil sampler is very useful for determining the downward progress of irrigation water.

After the irrigator has walked along the row of stands and opened enough jets to consume the head of water, one to each furrow, he proceeds to the lower end and awaits the arrival of the water. As soon as two or three runs are through, he walks across the lower end and takes note of the progress of the water in each furrow by number. Returning to the upper end, he cuts down the flow in those furrows which are "through" and increases the flow in the others. This process is repeated several times until just enough water is admitted to each furrow to run through but not waste at the lower end. All the while he must devote some time to locating and plugging gopher and mole holes, which are apt to intercept some streams, and to keeping a watch for "dams," which are accumulations of floating leaves which force the water to rise and break over from one furrow into another, thus causing serious trouble. After once well regulated, the water should not require much attention, and is allowed to run till the ground is soaked to a depth of four feet as ascertained by digging or pushing down the shovel handle. After being turned off, the water in the soil will usually percolate a foot or two farther, thus wetting the required five feet. In case the water will not soak down on account of the presence of a hard layer such as plow-sole or hardpan, this condition should be remedied at once. This may be done either by blasting the soil in the case of hardpan or by using a sub-soil plow as described above in the case of ordinary plow-sole.

CHAPTER XIII

PRUNING AND TOP-WORKING

THERE is probably no horticultural operation about which more dogmatic advice has been given than pruning. Among practical citrus growers there is much diversity of opinion, and this is due in most cases to the attempt to master all the details without previously obtaining a true conception of the principles involved.

We hear little of the " Let Nature have her way " sentiment in these days of scientific horticulture. While our old sweet seedlings may have developed into fairly satisfactory trees with but little attention, the highly artificial Eurekas and Navels which we grow to-day are different. They should no more be expected to take care of themselves than should a highly bred Jersey cow turned out on the range be expected to give her normal flow of milk.

It is difficult to give definite detailed directions for the pruning of citrus trees because trees are like children, every one different and presenting a set of individual problems.

In pruning citrus trees, the chief object sought may be stated as follows: to develop such shape and size of tree and strength of limb as will permit the bearing of optimum crops of maximum quality without damage to the framework of the tree; which at the same time must be consistent with convenient and economical cultivation, fumigation, and harvesting.

The first requirement in achieving the above object is to head the tree correctly, and in the case of balled stock this is done in the nursery row.

The usual height at which citrus trees are headed is about thirty-three inches, although there is some variation

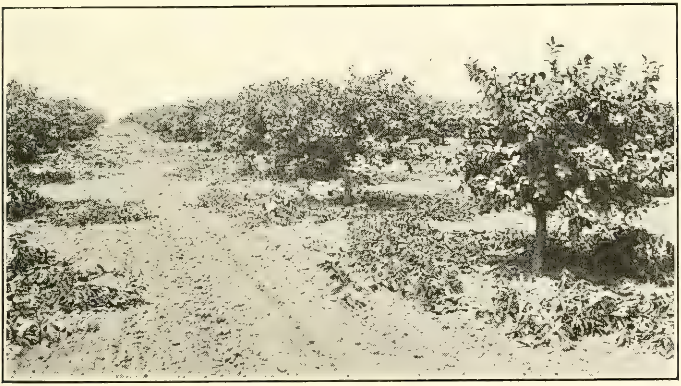

Fig. 61. — A well pruned Eureka lemon orchard photographed August 10th.

from this, and two or three inches higher or lower will not make any material difference. It is not wise to pinch out the bud and head the tree as soon as the shoot reaches the required height. It should be allowed to grow at least six inches taller and then cut back to the desired height. This will result in harder and stronger wood at the top, where the main branches which constitute the framework of the tree are to grow. This cutting back will force into growth a number of buds all along the trunk. Five or six of these should be selected for the main branches and they should not only be distributed on all sides but also over the upper thirteen inches. When two limbs join the trunk at the same height, they are apt to split the trunk under the load of fruit in later years. Whenever two branches grow out from one bud, one of them should always be removed. Every shoot which puts out from the lower twenty inches should be removed. It is customary to allow the big

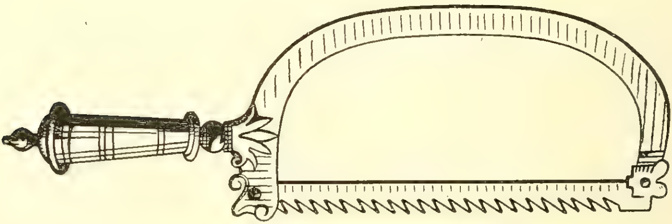

Fig. 62. — Prototype of California pruning saw. From Volckamer's "Hesperides," 1708.

broad leaves which grow on the main trunk to remain until the trees are dug for sale. The main branches may grow out a foot or so in length, but are usually cut back to six-inch stubs when the trees are dug.

When trees are dug with bare roots, the entire top is cut off, leaving the trunk as a straight cane. The work of heading the tree must then be done in the orchard. In some places, it has become a common practice to make vertical slits in the trunks of young orchard trees with a sharp knife. In some cases, a V-shaped blade is used which lifts out a small strip of bark, the idea being to release an imaginary pressure on the bark and allow the tree to grow faster. There is no scientific basis for such a practice, and while there is usually no particular harm done, it is unlikely that any real advantage results. On the other hand, trees freshly scored in this way are very much more susceptible to injury by frost. In the freeze of January, 1913, thousands of young trees were lost for no other reason than that they had recently been scored on the southwest side; and as a result of the cold followed

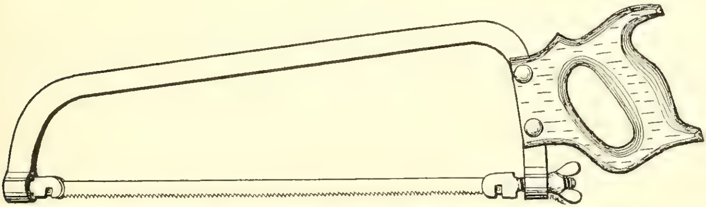

FIG. 63. — California pruning saw. Used throughout the Southwest.

by sunshine the entire cylinder of bark came away from the trunk.

From the time the young trees are planted in orchard form the methods of pruning oranges and lemons diverge, and it is best to discuss them separately.

PRUNING ORANGES

It has long been the custom to prune orange trees very little or none at all beyond the removing of water-sprouts and dead brush. The tree resulting from this system is a dense, bushy ball of foliage, growing close down to the ground, with the fruit distributed over the surface on the ends of the outer limbs and twigs, and the inside an impervious thicket of dead brush or a closely shaded open space if the brush has been removed. While such trees are very beautiful to the eye and produce fairly satisfactory results, they fall far short of the ideal in orange pruning.

Navel oranges of true standard type usually need little pruning during the first two years beyond removing watersprouts. If the Navels are from poorly selected buds, a good many will throw up strong, rude branches which are often more or less thorny, and which tend to monopolize the tree and sap the strength of the more modest growth. All such shoots should be cut off early in their career exactly where they began. The best branches of a first-class Navel tree naturally become more or less pendant and gradually upon such horizontal branches upward growing shoots arise. These shoots are dimorphic in character, and every pruner should learn to distinguish between them. One form, commonly known as sucker growth, is large and rapid growing, reminding one of a young shoot of asparagus. The leaves are large and often resemble pomelo leaves. Long thorns are common, although a sucker may occasionally lack thorns entirely. Suckers often grow two or three feet in length before branching or making one of the characteristic nodes which mark a resting period.

The other type of growth, commonly known as fruiting brush, is more modest. It is thick set, fine stemmed, and with smaller but well formed dark green leaves. This type of growth will branch often and form frequent nodes and many flower buds. The character of a shoot is not necessarily determined by its place of origin, for fruiting shoots often arise from the trunk or main branches and have access to large food supply and yet do not develop into suckers. They may be exceedingly vigorous and erect with very large leaves, and yet terminate at six inches in a flower bud and mature a large, more or less coarse skinned orange. Suckers usually arise from branches of some size. When they appear low down on the trunk they are usually called water-sprouts, although there is no clear distinction between the two.

A sucker left alone will, after a few years of riotous living, quiet down and produce fine brush and fruit. The first fruit produced will be more or less coarse and inferior, but the quality will gradually improve from year to year. Many experienced growers believe that suckers will never produce fruit fully equal in quality to that borne by other parts of the tree. Some growers also claim that the presence of a large sucker in a Navel tree will gradually bring about a deterioration in the quality of fruit borne on older parts of the tree as regards shape, color, and texture, and a diminution of the quantity as well. This question has been a common bone of contention at Farmers' Institutes and Fruit Growers' meetings in California for years, and there is as yet no accurate scientific data upon which to base a conclusion.

Of certain things we are sure, however. Suckers do produce poor fruit for several years. When suckers arise from a horizontal limb, they are apt to acquire great leverage when in fruit and often twist and split the parent limb. When suckers arise from upright branches they are usually poorly attached and are apt to split off with the weight of fruit. Suckers destroy the symmetry of the tree and reflect discredit upon the orchardist. When a sucker is cut back, its nature will not be changed at once, for it will branch and give rise to several suckers where one was before. For these reasons it is clear that as far as the Navel orange is concerned, the best practice is to allow the tree to increase in size slowly and develop its top out of the fruiting type of growth.

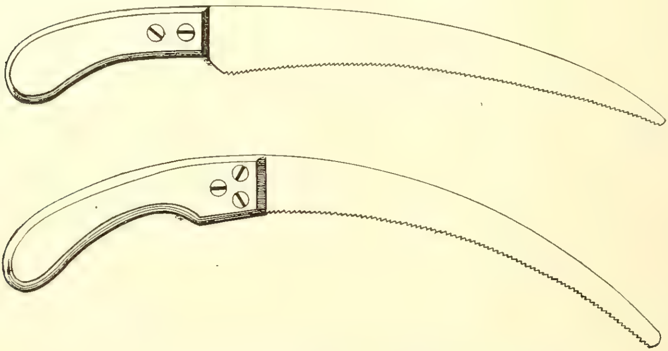

Fig. 64. — A good type of pruning saw above. Poor type below.

The two types of wood above discussed are not always clearly differentiated, and intermediate forms are often met with. Such forms are often puzzling to the amateur pruner, whose best policy is to allow them to remain temporarily and watch future tendencies. In every case where the growth is clearly a sucker, and experienced pruners find little difficulty in distinguishing them, they should be vigorously suppressed.

It is very important to keep a careful watch for bud-sports, especially in old Navel trees which have been propagated from carelessly selected buds. The same sport will sometimes appear many times on different trees in the same orchard, as explained in Chapter VII. Some growers confuse sporting branches with the dimorphic branches discussed above, while in reality the phenomena are quite distinct. Sporting involves a change in the germ-plasm of the cells, while the dimorphic differences mentioned do not. Sports may be removed while the branches are

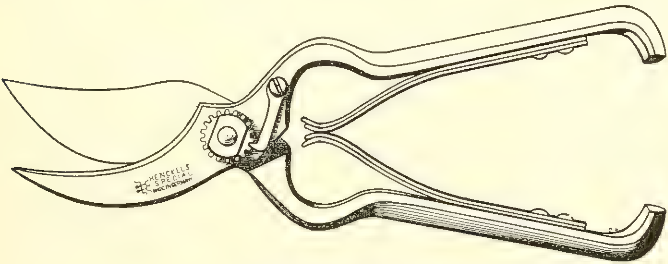

FIG. 65. — One of the best types of pruning shears.

still small and the orchard thus kept true to type by pruning. Occasionally a tree may be encountered which apparently has ever-sporting tendencies. This is due to the fact that the mutation occurred in the trunk early in the history of the tree, or even on the tree from which the original bud was taken, and the mutative cells have multiplied and become distributed through various parts of the tree. It requires very drastic pruning to cure such a tree of its bad habits, and it is often advisable to pull it out and plant a new tree in its place.

It is well for the pruner to bear in mind, however, that while the great majority of sports are objectionable, some of our improved varieties have originated as sports, and it is therefore wise to critically examine the fruit of every sport discovered before destroying it.

Valencia oranges grow in quite a different way. They are not so much given to erratic growth, but their fruiting wood is much more rapid growing than that of the Navel, and is apt the second or third year after planting to produce a number of bare canes three or four feet long which, branching at the apex, become overloaded with fruit and break down. It is well to pinch these shoots and force them to branch before they grow too long. This should result in a stronger framework and render propping unnecessary in future years.

Fig. 66. — Vigorous fruiting brush growing in the place of suckers.

As orange trees come into full bearing, the weight of fruit bends the lower branches down to the ground, with the result that uprights form upon them. All the uprights which are of the fruiting type of growth should be allowed to remain. They may be depended upon to produce a large proportion of the crop. Finally, however, the extremity of the lower mother branch becomes weakened with much fruiting, and, bending low under the young growth, becomes smothered. It should then be cut back to vigorous growth or removed altogether.

In order that the short fruiting brush along the larger limbs shall produce a greater quantity of fancy inside fruit, it must have light. The top and sides of the tree are apt to get too thick and keep the center too dark. To prevent this, the wall of foliage should be opened up occasionally by taking out bodily a few small branches from various places in the walls and top. These holes will let in sunlight, which shifts as the sun moves across the sky. This is much better than outraging the tree by cutting out the entire top at one time.

It is necessary to go over all bearing trees once in two years to remove all interfering and crossed limbs, as well as dead brush, and to thin the tops somewhat. The trees should also be examined several times each year, and any water-sprouts appearing on the trunk or main branches removed.

PRUNING LEMONS

Young lemon trees should be cut back severely from the beginning. They should be curbed in their riotous growth and forced to increase in size slowly and by the addition of the more or less crooked, much branched fruiting type of wood. The tendency of the lemon, and especially the

Fig. 67. — This extra vigorous orange shoot terminated at six inches with a fruit, showing that excess of food did not change it into a sucker.

Eureka variety, is to throw out long branches which fruit at the ends. These bend over and are not only in the way of cultivation but are whipped about by the winds and often break with the weight of fruit. The main object should be to shorten back and strengthen the scaffold or main limbs in order that they may carry their load nearer the center of the tree and be stocky and stiff enough to withstand strong winds without swaying and thorn stabbing the fruit. This result is not always easy to attain. The tendency of lemon trees is to grow rapidly upward while most of the fruit is borne on more or less crooked horizontal branches. According to the Baronio system, which is now practically abandoned, the trees were absolutely limited to horizontal growth after they had reached a height of about five feet. The vital trouble with this system was that it did not recognize that on deep, rich soil a lemon tree could not produce to its full capacity when limited to five feet in height. The tendency now is toward higher trees. With lemons at a high price it pays to climb after them, provided, of course, that the number borne near the ground is not reduced by the presence of the high tops. It is the writer's belief that in deep, rich soil the economic limit of bearing surface of the lemon tree is not below ten feet.

It is the custom of some growers to arbitrarily decide upon a certain height and then shear the tops to this line, making the trees appear from above as flat as a floor. This shearing process results in the brush quickly becoming too thick. It is much better to select those branches which reach above the line and cut them off at their junction

FIG. 68. — A sixty-acre three-year-old Valencia orchard top-worked to lemons. The paper bags protect the buds from rose beetles.

with the mother branch. If a vigorous upward growing shoot is cut back for a part of its length, it will put out several shoots which continue the growth. When building up a young tree, this is necessary, in order to make the main branches more stocky, but it must always be followed by a thinning out of the resulting shoots.

The following five statements are in the nature of maxims and should form the basis of any rational system of lemon pruning. They are accepted by the majority of lemon growers:

a. Lemon sap flows more freely in vertical branches, hence vertical branches grow at the expense of lateral ones.

b. A lateral crooked branch is much more fruitful than a straight upright one.

c. Fruitfulness and high quality are the results of a slow but steady circulation of the sap.

d. The finest quality fruit is borne on small fruiting brush on the interior of the tree and the sap supply of such brush should be protected from thieving suckers.

e. The wider the angle the stronger the limb. Crotches with acute angles often split down.

Fig. 69. — Fifteen months' growth on stocks shown in Fig. 68.

Lemon trees may be pruned at any time of the year, but it is customary to defer removing large limbs till the time when there is the least amount of fruit on the trees. This usually is in the late spring. Some of the larger ranchers employ pruners, for the mature trees, who work the year round. They confine their work to thinning out the fruiting brush, removing interfering and broken branches and suckers from the trunks. In addition to this a special group of pruners go over the trees each spring and autumn and cut out the superabundant growth of vegetative shoots in the tops.

When it is necessary to cut off large limbs containing some good fruit, it is wise to pick this fruit from the limbs at once. If this is not done, the leaves (being separated from the roots) will draw on the water contained in the juice of the lemons and dry them out very quickly.

DISPOSITION OF PRUNINGS

If prunings are to be hauled out and burned, they should be removed to some distance. Citrus trees are extremely susceptible to injury from the heat of fires. However, in a country such as California where humus-forming materials are scarce, it is very wasteful to burn prunings. They should by all means be chopped up fine and plowed into the soil. On several of the larger ranches power cutters run by gasoline engines are drawn through the orchards, the prunings being chopped up and allowed to lie where they fall till succeeding cultivations gradually work them into the soil. On other ranches the prunings are cut up with hand shears.

PRUNING FROSTED TREES

When citrus trees are injured by frost, it is wise to defer pruning several weeks or until it is perfectly clear just how far back the wood has been killed. After the line of demarcation between living and dead wood becomes apparent, no time should be lost in taking the necessary steps toward reconstructing the top in the best way with the least possible loss of time.

The problems involved in mending and reforming the tops of frosted citrus trees fall naturally into two classes: those having to do with very young trees and those concerned with large mature trees.

Reheading Young Trees

When a one- or two-year-old tree has been killed to a point near the ground it should first be determined in each individual case whether the dead wood extends below the bud union. If there remains enough live wood above the union to grow a strong shoot, such a shoot may be allowed to grow and become the trunk of the new tree, all other shoots being suppressed. If on the other hand the trunk is killed below the union, it will be necessary to set a new bud. The opportunity is thus presented of reconsidering the relative profits to be derived from oranges, lemons, or pomelos. In case the root is sweet orange the bud may be set immediately, provided there is sufficient room to do so without excavating the soil, for in no case should a bud be set below the soil. In case the trees have been killed to the ground it is well to select the most vigorous sprout and bud into this two or three inches above the ground. If the root is sour orange or pomelo, it is best to place the bud six or eight inches from the ground on a strong sprout. This will result in a somewhat hardier tree and one more resistant to gum-disease.

In all cases in which a new trunk must be grown on trees already planted in orchard form, it is necessary of course to stake the trees and tie them every few inches, taking care to disbud often and remove all sprouts from the root, eventually heading the tree at the desired height. A stake larger than the customary building lath is advisable in order to prevent injury by passing teams and tillage tools.

When the tops of young trees are partly frozen it will be found, especially with lemons, that the more rapid growing upright shoots have been killed, while the fine fruiting brush has been spared. Instead of cutting back all these injured shoots in proportion to the injury, it is much better, especially with lemons, to take out most of the very strong upright canes entirely. If they are merely cut back and allowed to remain, each one will throw up several shoots, which in turn must be cut back, the final result being a broom-like growth with far too many shoots. The proper pinching and thinning of such a multiplicity of shoots will involve much more labor than the commercial orchardist can afford. It is better, therefore, to remove most of the upright vegetative shoots entirely and rely on new shoots from the horizontal wood to enlarge the framework of the top. All water-sprouts arising from the trunk and around the crotches should be vigorously suppressed. It is a good plan to whitewash the exposed trunks in order to prevent sunburning of the bark.

It often happens that the bark of the trunks of young trees will be split by the frost and will dry out, resulting in a strip of dead bark on the southwest side. This condition is not necessarily serious, provided there remains a strip of live healthy bark of sufficient width to provide a flow of sap to the top. The living bark will gradually increase in width and extend over the dead areas, in time covering them entirely. In order to prevent the entrance of wood-decaying fungi it is well to paint the dead areas with white lead, asphaltum paint, or bordeaux paste. Bandaging is often resorted to in order to prevent the injured bark from drying away from the wood. Experience has shown that this is of little value unless it is done immediately or within a few hours after the injury. On a large acreage it is impracticable.

Reheading Mature Trees

Orange trees are much more resistant to frost than lemon trees. Over certain large areas the freeze of January, 1913, ruined the fruit and completely defoliated the trees without killing back the wood to any appreciable extent. In such a case the trees need no extra pruning, although while the leaves are absent a good opportunity presents itself to remove conflicting branches and thin the brush with greater ease and efficiency than is possible when the trees are covered with leaves.

Where the wood is killed back to any extent, however, too many shoots are apt to start from the live wood and many suckers appear about the crotches. Theoretically the shoots should be thinned out, leaving only what is needed. Those left will be stronger and bear more fruit than if such a large number were allowed to struggle for life. Practically, however, such a course would require more labor than is available and large growers will have to adopt the next best course, namely, that of cutting out all the dead wood and thinning the new growth by taking out bodily a certain number of branches.

Where lemon trees have been killed back severely, it is best to withhold or decrease the fertilizer during the succeeding year in order that a more moderate growth may take place. Frozen trees have been thrown out of balance. They have the same amount of root as before,

Fig. 70. — Three-year-old Navel head on top-worked sweet seedling.

which is now pouring sap into a much reduced top. The result is bound to be a tremendous new growth breaking out all over the trunk and branches. At best a great deal of labor will be required to properly sucker the trees. If additional stimulation is brought about by the application of quick-acting fertilizers, this trouble will be increased. Wise lemon growers prefer to build the new head out of the more moderate growth of fruiting wood rather than out of water-sprouts. It is not necessary or always advisable to root prune frosted trees, but if hardpan or plow-sole exist, it may be broken up with a subsoil plow at this

FIG. 71. — Pruning a frosted lemon orchard.

time with less injury to the trees from cutting large roots. The number of roots which may be cut with impunity will of course depend upon the amount the tops of the trees have been killed back.

It seems reasonably certain that no injury to the tree can result from any of the materials passing from the frozen oranges back into the tree. An examination of those oranges which have been too badly frozen to be fit for shipment shows that most of them have been only partially killed; consequently they are presumably respiring carbon dioxide. This loss of energy would be saved if the oranges were removed from the tree rather than allowed to hang all summer. There is no experimental evidence, however, to show whether this loss is sufficient to warrant the cost of early removal by hand. In case the fruit is picked off the trees it may safely be plowed under, thus adding humus and some plant-food to the soil. There is no danger of the soil becoming acid as a result of this practice, for in some orchards cull lemons and oranges are regularly used in large quantities as a manure with only beneficial results.

TOP-WORKING OLD TREES

It often becomes desirable to change an orchard from one variety to another by top-working. Any variety of citrus tree may be top-worked to any other variety, although some combinations succeed better than others. It is thought that Valencia oranges do not always do well when worked on lemon. Satsuma, as a rule, should not be worked on sour orange.

There is no particular difficulty in regard to this process except that it interferes with the production of the orchard and much time is lost during the transition from one variety to another.

Top-working may be accomplished in any one of three ways:

1. By cutting off the entire top and budding directly into the trunk or large limb stubs.

2. By cutting the top back to large stubs and allowing strong shoots to grow, and later budding into these shoots.

3. By cutting back the top to small stubs and budding directly into these.

This last method entails so much labor and trouble in keeping water-sprouts down that it is little used except for highly prized dooryard trees.

Some growers cut the entire tops off as soon as the buds have taken; others leave a few branches to draw the sap by the buds. "Safety branches," as they are called, prevent the buds from being "drowned out" and should be left when top-working is done in late spring or summer. Some growers cut away a few limbs a few months before budding in order to cause the old bark to slip better. The thick heavy bark of old limbs or trunks should be scraped down thin immediately surrounding the bud at the time it is set. Large buds should be used and in many cases they take better if the bit of wood which is severed with the bud is removed, thus bringing together larger areas of cambium.

After the buds have begun to grow, great care should be taken not to allow any sprouts from the old wood to grow up and crowd them out. In some cases, as when lemon is worked on orange, it is easy to tell stock from scion, but when two varieties of lemon or orange are worked together, it soon becomes very difficult to tell which is stock and which is scion. On account of this difficulty, and for other reasons, the top-working of old orchards is practiced to a much smaller extent now than formerly.

When an old orchard is top-worked, the trunks should be protected by whitewash or sacking, for sunburn will be almost sure to result from the exposure of the bark.

PRUNING TOOLS

The operation of pruning involves the making of wounds; and since these wounds heal over quickest when the cut is smooth and even, it follows that any tools which crush or tear the bark are objectionable. For all small branches and twigs, a strong sharp knife is ideal. It is a fact, however, that for economy's sake, some form of hand shears with one blade and a guard are universally used in commercial orchards. For larger branches the two-handled lopping shears are most convenient. For removing large limbs, a saw is necessary, but the pruning saw with teeth on both edges should be avoided, as it is too difficult to use without damaging the tree. By far the best saw for use in a citrus orchard is that known as the "California" pruning saw (Fig. 63) with reversible and detachable blade. The blade of this saw may be turned in any direction, and it is especially convenient for work in close places. It is very important to keep all pruning tools sharp. A half dozen extra saw blades should enable the pruner to keep a sharp, well-set saw in hand at all times.

A satisfactory outfit for the citrus tree pruner may be enumerated as follows:

1. A short, light stepladder.
2. One pair strong leather gloves.
3. One pair hand shears (Henckel's special No. 9 preferred).
4. One California pruning saw (six extra blades).
5. One B. & H. special pruning saw.
6. One pair lopping shears with riveted wooden handles.
7. Bucket of paint with brush for dressing large wounds.

WOUNDS AND DRESSINGS

All large limbs should be sawed off close to the trunk or mother limb in such a way that new bark will grow over the cut surface from all directions. This takes place most readily when the cut surface is parallel to the mother limb. Stubs are a source of danger to the tree and reflect discredit upon the orchardist. When a sucker is cut off and even a very short stub left, other suckers will put out from the same point until there is formed what is known as a "sucker-nest." This is very objectionable, and when such "sucker-nests" are found in old trees they should be removed cleanly with one cut of the saw, going well into the wood in order to stop any further growth of suckers from that point.

It requires several years for a large wound to heal over entirely, and during this time it is susceptible to infection by various fungi which cause the wood to decay. The fine checks in the wood which form as the wound dries, are ideal lodging places for the spores of decay-producing organisms. Decay often slowly works its way back into the trunk and causes hollow center. Decayed wood in the heart of a tree weakens it and brings on a diseased condition. Fortunately it is a simple matter to prevent this by disinfecting the wounds and applying some dressing which will protect the exposed wood while it is healing over.

In the case of pruning-wounds where small limbs are removed it hardly pays to go to the expense of disinfecting the wounds before the dressing is applied. In tree surgery, however, where large cavities are chiseled out and where large limbs are removed, it is well to apply a coat of liquid creosote to sterilize the wound and after this has dried the waterproof dressing may be used.

The matter of complete covering is of the utmost importance. Wound dressings should exclude the air and render the cut surface impervious to water. As infection may take place through a very small opening, time and labor are entirely wasted unless the wounds are completely covered.

A large number of substances which vary widely as to cost and convenience of application are used for dressing wounds. As a rule those which require heating before application are not to be recommended, because it is too much trouble to carry a portable fire in the orchard, and the hot sun in summer is apt to cause them to melt and leave the wound. Out of a large number of formulæ three have been selected for mention here. No. 1 is satisfactory for small jobs in yards and gardens, but is much more expensive than No. 2, which should be used in all large orchards:

No. 1.	Alcohol	6 oz.
	Turpentine	1 oz.
	Tallow	2 oz.
	Rosin	1 lb.

Heat the tallow and rosin together, cool slightly, and add alcohol. Then stir in the turpentine. This may be used cold.

No. 2. Asphaltum paint. Heat the asphaltum till thoroughly melted and, after removing to a safe distance from fire, dilute with benzine to make a mixture which when cold is of the consistency of thick paint. As the asphaltum varies greatly in density, no definite proportion of benzine to asphaltum can be stated. Asphaltum tree paint may be bought in cans already mixed, but is much more expensive in this form.

When on account of gum-disease, wind breakage, top-working, or other reasons the trunks of old trees are exposed to the sun, they should be protected with a coat of tree whitewash or bordeaux paste or No. 3.

No. 3.

$$a. \begin{cases} \text{1 lb. copper sulfate or bluestone} \\ \text{3 qt. water} \end{cases}$$

$$b. \begin{cases} \text{2 lb. quick lime} \\ \text{3 qt. water} \end{cases}$$

Solutions *a* and *b* should be prepared separately before being mixed together.

Tar is often recommended as a wound dressing, but coal or gas tar should be avoided, as it usually contains compounds which are injurious to the bark of citrus trees. Most of these injurious compounds are volatile and may be driven off by boiling the tar, but even the boiled tar has no advantage over the asphaltum paint.

Small cuts heal over quickly and are usually so numerous that it would hardly pay to apply the dressing. Ordinarily cuts less than one inch in diameter are not dressed unless they are conveniently situated.

Often in old neglected orchards trees will be found in which decay has worked its way back into the wood of the trunks. The proper treatment of such cases involves tree surgery, the methods of which have been well described and illustrated by J. F. Collins in the United States

Department of Agriculture Yearbook for 1913, pages 163 to 190. It is necessary of course to remove all of the decayed and discolored wood by means of suitable tools such as chisels and scrapers. After the cavity has been carefully cleaned out it should be sterilized with creosote and then given a coat of asphaltum paint. The cavity may then be filled with cement (1 part of cement to 3 of sand). It is necessary to undercut the cavity somewhat after the fashion of a dentist preparing a cavity in a tooth, in order that the block of cement may be held in place. Sometimes nails are driven in large cavities for the same purpose. After the cement has hardened the whole job should be painted over and thoroughly waterproofed. It is wise to inspect such work at least once a year and repaint if not entirely waterproof.

If properly treated, such cavities will heal over in a few years and the tree will be saved and greatly strengthened.

It is a common thing for the main branches of old lemon trees which have been improperly headed to split down under the load of fruit. Such branches may be saved for many years of usefulness by bolting. Auger holes should be bored directly through the trunk and large iron bolts with washers used. It is important in such cases also to carefully disinfect the wounds made, and dip the bolts and washers in bordeaux paste before inserting. On account of prevalence of the gum-disease organisms and the ease of inoculation disinfection is especially important. The cracks in the trunk should be filled with bordeaux paste before they are drawn together. The bolt heads and the exterior of the cracks should be given a coat of asphaltum when the work is complete.

CHAPTER XIV

FROST AND ORCHARD HEATING

Perhaps no phase of citriculture has advanced with more rapid strides during the last few years than orchard heating. For hundreds of years in certain parts of Europe some protection to vineyards and gardens has been secured in a crude way by smudging. The modern science of orchard heating as practiced to-day, however, has been developed within the past fifteen or twenty years. Moreover this subject is of such vital interest to every citrus grower that it is considered well worth while to discuss the matter more or less in detail.

HISTORICAL COLD PERIODS

In Blodget's "Climatology," published in 1857, we find mention of a cold period as early as 1748 which caused considerable damage to the tropical fruits of the South. Other cold periods occured in Florida in 1766, 1780, 1800, 1835, 1852, 1876, 1886; and in 1894–95, the memorable double freeze occurred which almost wiped out the citrus orchards of Florida and changed the geography of the citrus industry there. Cold periods may therefore be expected to recur at intervals of about twenty years.

In California the available records do not extend so far back. In 1882 a severe freeze was experienced, a minimum of 21° F. being registered at Fresno. Ice was formed in Los Angeles, and the surrounding hills were covered with snow. Other cold periods occurred in 1888, 1891, 1895, 1899, 1911, and 1913. Frosts occur in California at average intervals of five or six years. Fortunately California has not so far experienced a frost approaching in severity the one which visited northern Florida in 1894–95. It should be pointed out, however, that the great damage in Florida was not due so much to the severity of the frost as it was to the peculiar relations of the two cold periods. The first denuded the trees of foliage and fruit and was followed by a period of warm weather. When the new growth was pushing vigorously and the tender shoots were about four inches long, the second freeze came and killed the trees to the ground.

The freeze of January, 1913, was the most damaging in the history of California, and in the southern part of the state the temperature was lower than had been known for a period of sixty years. Heavy frosts occurred on January 4, 5, 6, 7, and 8. Strong winds preceding the frosts came from the north and northwest rather than, as usually happens, from the northeast. The wind began to blow shortly after noon on January 4, and continued until 3 A.M. on January 6. Instead of the usual draught through Cajon Pass at an elevation of 3823 feet, the winds came directly over the Sierra Madre Range, whose elevations exceed 6000 feet. During the midday hours on the 4th, 5th, and 6th, the temperature did not rise much above 50° F. and in some places did not reach 50° F. Apparently the whole mass of air, to an elevation of several thousand feet, was at a low temperature. The wind was extremely dry.

During this freeze the fruit was subjected to temperatures below freezing for four successive periods, averaging four hours for the first, thirteen hours for the second, thirteen hours for the third, and nine hours for the fourth. In all, during a total period of 72 hours, during which, under normal conditions, the trees would have received a supply of heat approximately represented by 1500 hour-degrees, starting from a temperature of 40° F., they only received 220 hour-degrees. There were 170 hour-degrees below freezing, and of these 50 were below 25° F.

Minimum temperatures of 13° were recorded at Escondido; 16° at Chino; 17° at Pomona; 18° at Redlands; 21° at Riverside and Pasadena; and 25° at San Diego.

This cold period destroyed at least ten million dollars' worth of fruit, to say nothing of the damage to the trees. Yet the industry recovered very quickly, and in 1913–14 the normal amount of fruit was marketed. During this trying period the practical value of orchard heating was clearly demonstrated. Orange growers who were properly equipped saved their crops, and lemon growers also saved their crops and trees and in some cases marketed sufficient fruit the following summer at very high prices to pay the entire cost of their heating equipment several times over.

With deciduous fruits, the damage is done by late spring frosts which occur after the trees have blossomed. It is only necessary therefore to be prepared for orchard heating during a few weeks in March and April. With citrus fruits, however, it is very different. The fruit hangs on the trees all winter, and it is necessary to be prepared to heat the orchards at any time between November 15 and March 15 or for a period of four months.

FORECASTING FROSTS

There are several ways by which plants lose their heat. When two bodies at different temperatures are in contact, they tend to become alike in temperature by the direct conduction of heat from the particles of the warmer body to those of the cooler. Thus it is that the earth and living plants upon it, having become warmed by the sun, lose part of their heat to the atmosphere lying directly above them, through this process of conduction. This heat is conducted slowly upwards in the air. Air, however, is a poor absorber and conductor and would become warmed only very slowly were it not for another process of greater importance which soon begins to act.

Air, like all other gases, expands and becomes lighter upon heating. Therefore, the air at the surface of the earth which has become heated by conduction, rises, and its place is taken by the colder air from above. A kind of circulation is thus set up, somewhat resembling that in a vessel of water which is being heated.

In the horizontal movements of the air, which we call winds, the process of convection also comes into play. When a cold wind is blowing, as every one knows, the heat of exposed bodies will be rapidly carried away.

By still another means is the heat of the earth and trees lost to the air above. It is expended in the process of evaporating moisture from their surfaces. The heat thus lost is commonly said to have been changed into latent heat; it is really not heat at all in this latent condition, but is simply the energy needed to overcome the intermolecular attractions of the evaporating substance. Evaporation may be of considerable importance in lowering the temperature of vegetation, especially when the air is dry.

But the three processes just mentioned are by no means sufficient to account for the tremendous loss of heat which occurs on a quiet, clear night when freezing temperatures are most likely to occur. The fourth and much more important way by which heat is lost is by that peculiar process known as radiation. By this process the vibratory heat motion of a body is transferred in part to the ether, setting up in it waves which proceed outward along straight lines and in all directions, in the same manner that sound waves emitted by a vibratory tuning-fork proceed outward in all directions through the air. The surface of the earth is continually losing heat by radiation into space; but during the day it usually receives heat more rapidly from the sun than it loses it by radiation, and therefore it grows warmer. At night, however, when the sun's heat is cut off, the effect of loss of heat by radiation is not counterbalanced and the earth's temperature consequently falls. Radiation takes place more rapidly from the surface of plants than it does from the air about them, so that, on still nights, these surfaces are frequently cooled several degrees below the temperature of the surrounding air.

Factors influencing the Occurrence of Frost

Wind, relative humidity, and absence of clouds and dust, all influence the occurrence of frost. On still nights the air as it cools arranges itself in strata, the coldest and heaviest next the ground. Wind tends to mix the air and bring it all to the same temperature, which of course would mean an increase in the temperature of that next the ground which is in contact with the plants.

Atmospheric moisture lessens cold in two ways: first, it retards the escape of the day's heat by radiation at night; second, the latent heat of the vapor becomes sensible heat when the condensation of the vapor takes place. The indirect influence of the water vapor in the air, in checking radiation from the earth, is a powerful conservator of heat.

When moist air is cooled, it will finally reach a temperature of saturation which is known as the "dew point," when no more water vapor can be held at that temperature. When cooled further, water will be deposited as liquid drops (dew) if the temperature is above freezing point, or as ice crystals (frost) if below the freezing point. Now, when water vapor is changed into liquid form, a large amount of heat is liberated — the same amount which is required to change the same quantity of water into vapor. This liberated heat becomes available to warm the air. It is said that the precipitation of one quart of dew will liberate enough heat to raise the temperature of 1000 cubic feet of air 25° F.[1]

Clouds also have a marked influence in preventing the escape of heat from the earth; they reflect or radiate back to the earth the heat which escapes from it. There-

[1] W. H. Hammon, "Protecting Orchards Against Frost," Bul. No. 70, California State Board of Horticulture, 1896.

fore, frosts, as a rule, do not occur on cloudy nights, and the clouding up of the sky during the evening may often prevent expected frost. Dust and smoke suspended in the air act in much the same way as clouds.

The conditions favorable for a freeze may then be summarized as follows:

1. A clear sky; thus furnishing no check to loss of heat from the earth and trees by radiation.

2. Dry air; because cooling by radiation will then continue to a much lower temperature before being checked by the heat liberated in condensation.

3. Still nights; because the air, not being mixed by the wind, arranges itself in layers according to its density, with the colder, heavier air beneath in contact with vegetation.

4. Very cold dry north winds which abate before dawn.

5. A comparatively smoke and dust free atmosphere.

Local Conditions affecting Frost

Practically every citrus district in California has its frosty and its frostless spots. Even on the same ranch the line is often clearly drawn between safe and dangerous ground. There are several reasons for this. In the first place it is well known that frost is less likely to occur at moderate elevations, or on low hillsides, than in low-lying valleys and depressions. This is caused by what is known as "inversion of temperatures." On a hillside or bench land with good slope, the air, as it cools and grows heavier, will flow quietly downward and collect in the low-lands, thus crowding the warmer air upward. This warm air floating on top spreads out to the hillside, to which it imparts a portion of its heat. And so a gentle but complex circulation is kept up which accounts for the warming of one spot or belt and the cooling of another. Often there are unknown local factors influencing this circulation which makes it very difficult to foretell on any given hillside just where the thermal belt will be. This is due no doubt to various unseen cross-currents caused by the irregularities of the mountains. Again, a valley is usually shaded for a longer period, both in the morning and afternoon, than all the uplands; therefore it goes into the night with a less store of heat with which to counteract freezing temperatures.

The type of frost just described is the normal kind experienced in California and is known locally as a "gravity frost." This type of cold weather is comparatively easy to combat with orchard heaters. Occasionally, however, the conditions are reversed, as was so well exemplified in the "blizzard" of January, 1913. During this period the cold north wind sweeping directly down from over the mountain tops, 6000 feet in height, caused the trees on the uplands or thermal belts to suffer more severely than those planted on lower land, as were the orchards of Orange County.

Conditions indicating Frost in California[1]

The condition preceding frost in California is indicated by the passage of a low barometer area from Idaho south-

[1] Adapted from A. G. McAdie's "Frost Fighting," U. S. Weather Bureau, Nos. 29 and 219.

ward across Utah, thence westward into southern Nevada, and finally southward into southern California. For the most part, frosts are due to the movement of cold air from the northeast. Frosts also occur when a low area over southern California moves rapidly southeast and is followed by a high wind from northern California. Conversely, when the air moves from the sea inland, there is little danger from frost.

The topography of southern California favors drainage of the air from the mountains seaward at certain hours, and a return movement of the surface air inland at certain hours. Thus conditions are highly favorable for the formation of air streams, which reverse their direction at least twice in each 24-hour period.

In general, the lower air flows to the southwest during the night and early morning, and to the northeast during the afternoon. During the winter months, when areas of high pressure pass over the Great Basin, the surface air apparently moves south, crossing the northern flank of the Sierra Madre and descending with some momentum into the Great Valley. The wind movement is particularly marked in the vicinity of mountain passes.

During these so-called "northers," the temperature rises and the humidity falls. The existence of a low pressure area south of the Colorado seems to intensify this condition. Heavy frosts occur, as a rule, after a period of high north winds, and are traceable to the displacement of the warm air in the valley by cooler, very dry air. This dry air permits very rapid radiation, and when the wind lulls, which is apt to occur after sunset, the drop in temperature is very rapid.

HOW PLANTS ARE INJURED BY COLD

In the U. S. Department of Agriculture Yearbook for 1895, B. T. Galloway describes what takes place when plant tissues freeze, very concisely as follows:

"All the phenomena involved in the freezing of succulent and other plants depends on the condition of the protoplasm or living matter in the plant cell. If the temperature is sufficiently low to cause a chemical disorganization of the living substance, the part of the plant where this takes place dies. If, on the other hand, no actual disorganization of the cell contents occurs, the affected parts may recover. It is hardly necessary here to enter upon a discussion of the various phenomena. Suffice it to say that under the influence of cold the water in the cells escapes, and may be frozen either in the spaces between the cells or on the surface of the leaf, stem, or whatever the part may be. As the temperature rises this frozen water may again be taken up by the cells, and in such cases little or no injury results. If for any reason, however, the cells are not able to regain the

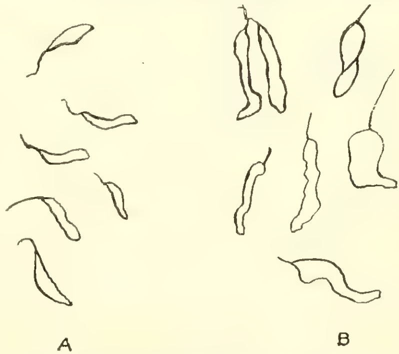

FIG. 72. — *A*, normal vesicles of lemon; *B*, enlarged vesicles from frosted fruit, six months after injury. (Nat. size.)

water withdrawn by the cold, injury or even death may result. In many cases the rapidity with which the ice is thawed has a marked effect on the ability of the cells to regain their normal condition. If the thaw is gradual, the water is furnished no faster than the cells can absorb it, and equilibrium is therefore soon restored, the chemical processes which were checked during the freeze are resumed, and the plant soon regains its normal condition. With a rapid thaw, however, the cells are not able to take up the water as fast as it is furnished, and as a result chemical decomposition sets in and death follows. Death in this case is essentially the same as that which results from drought. The cell loses water to such an extent that it is not again able to become turgid, and as a result it finally withers and dies."

That the above is equally true in the case of citrus fruits has been shown by Bioletti.[1] "Frozen and unfrozen oranges from the same tree were received — with the request to determine whether the cells of the frozen oranges had burst and whether this was the cause of the rapid drying up of the frozen fruit. Microscopic examination showed no difference in the cells of the two kinds. Pieces of the flesh of both kinds were placed in a water solution containing 33 per cent of cane sugar, and other pieces in distilled water. The next day the cells of both kinds in the sugar solution had shrunk equally, while the cells of those in distilled water had swollen equally; indicating that there were no breaks in the cell walls of the frozen oranges."

The condition of the plant, whether in a period of

[1] *California Agr. Exp. Sta. Rpt.*, 1897–98, p. 184.

succulent growth or in a dormant state at the time of low temperature, has an important bearing upon the limit of desiccation of the individual cell, dormant plants being able to withstand lower temperatures than those growing rapidly.

The moisture from the cells of frozen oranges either evaporates through the rind or passes out through the stem and is transpired by the leaves. The tissues of frosted fruit usually bear small white specks of hesperidin, evidently formed by chemical changes. The surface ordinarily shows very little indication of injury, although the inside tissues may be dry and shrunken. While frozen citrus fruits may occasionally be bitter in taste, no injury has ever been known to follow their use even when eaten in large quantities.

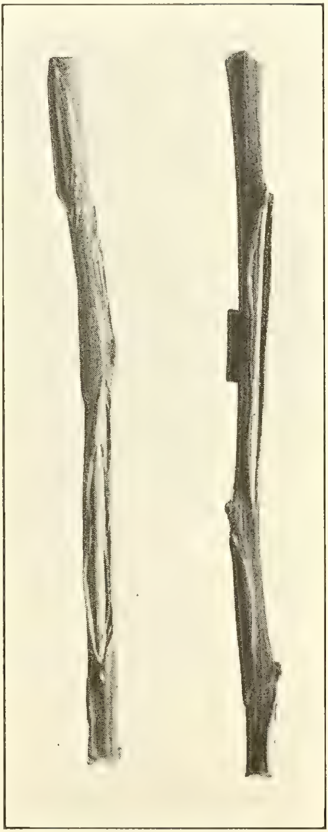

Fig. 73. — Bark on fruiting brush of lemon split by frost.

Leaves of citrus trees which have been frosted at first curl up; they may remain upon the tree and recover to a certain extent, or fall off after a few days. Defoliation may occur without serious injury to the smaller branches. The injury to branches naturally depends upon the degree of dormancy and the diameter of the branch; the twigs and smaller branches may be cut back seriously by frost without any appreciable injury to the larger parts. A very common form of frost injury to young trees is the splitting of the bark along the trunk and lower branches; the cracks are often noticeable a day or so after the frost, and if badly injured, the edges continue to roll back, exposing the bark and wood to the weather.

The amount of cold a citrus tree will endure without injury will depend upon: (1) the kind of tree; (2) the degree of dormancy of the tree; (3) the length of time the cold lasts; and (4) the kind of weather following the cold. Citrus trees resist frost in the following order, beginning with the hardiest: trifoliate, sour or Seville orange, Satsuma mandarin orange, kumquat, sweet orange (such as the Navel), pomelo, citron, lemon, and lime. In general it may be said that oranges, if fairly dormant, will endure a temperature of 25° or 26° F. for an hour or so without injury. Below 25°, the fruit begins to freeze, first that on the outside of the tree and near the ground, and later the inside fruit. At 20 to 22° F., the twigs begin to die back and the leaves fall, while a temperature of 17° or 18° for four or five hours, unless the trees are quite dormant, will kill them back to branches two or three inches in diameter. Lemons are much more tender, the fruit being injured at 26 to 28°. The limes are very tender, being killed back considerably at 28 to 30°. It must be understood that these figures are approximate only, a large number of variations being noted in many localities.

PREVENTION OF FROST INJURY

Very many schemes have been evolved from time to time for protecting orchards from frost. Let us briefly consider a few of the most important.

1. *By selection of frostless or nearly frostless locations.* — This plan is practicable for the few who are so fortunate as to possess frostless sites. The great majority of citrus orchards, however, are so situated as to be subjected to occasional low temperatures. It was pointed out in Chapter II that the best commercial oranges were produced, not in tropical climates, but very near the frost line. It is to be expected, therefore, that as the citrus plantings crowd close to the variable and uncertain frost line, that the frost problem will always be with us.

2. *By planting resistant varieties or grafting on resistant root-stocks.* — As a rule, oranges are planted in the colder spots and lemons in the warmer, but as has been pointed out, in time of blizzards the lines established by gravity-frosts are blotted out and all the orchards may experience low temperatures. Much has been written in Florida about the extra hardiness gained through the use of the trifoliate root-stock. Whatever may have been the experience in Florida, experiments have shown that in California nothing is to be gained by the use of this stock. At the Citrus Experiment Station at Riverside there is a duplicate root-stock experiment, one part of which is on high ground and the other on low. These trees have been examined critically after the severe frosts,

and all who have seen them agree that the trifoliate root does not augment the hardiness of the scion grown upon it.

3. *By breeding new frost resistant forms of citrus.* — Directly after the Florida freeze of 1894–95, Messrs. Webber and Swingle began experiments in breeding more hardy citrus fruit. This was accomplished by hybridizing the various edible forms with the trifoliate orange, and the citranges described in Chapter IV were thus produced. As yet, however, none of these hardy forms have proven of commercial value, they being used only for domestic purposes. Breeding new fruits is a very slow process, and time alone can tell what the final results may be. For the present, they offer no opportunity to the commercial grower.

4. *By the use of various mechanical devices designed to conserve heat by checking radiation.* — Much good may be accomplished by the use of screens of various sorts in conserving latent heat. Such methods are well adapted to young trees during gravity-frosts. When the blizzard comes, however, chilling the earth and trees and blowing the heat out to sea, there is but little latent heat left in the plants to conserve, and such methods are entirely inadequate.

The lath screens used over seed beds as described in Chapter V not only temper the rays of the sun, but serve as a protection from ordinary frosts as well.

Such screens have been tried over large commercial groves but proved too expensive and cumbersome. Sheds over bearing groves have been abandoned in California.

Newly planted trees are much more susceptible to frosts than old trees, and it is a very common practice to protect them during the first two winters by tying them up in cornstalks or tulles.

Cloth screens have been used to some extent over both nursery stock and old groves. The netting cloth which is used over tobacco fields in Connecticut has been tried and found to give some protection, although just how much is not yet definitely determined. Sheets of burlap or tent

Fig. 74. — Three-year-old trees protected with cornstalks.

cloth may be used to advantage in protecting specially tender or valuable trees in dooryard and garden. When the cold is severe, a lighted lantern may be set under the tent.

In northern Florida it is a common practice to make a mound of earth around young trees to protect the bud union and prevent the necessity of having to rebud the trees. Under California conditions this is dangerous on account of the prevalence of the gum-disease organism in the soil. If trees are mounded in California, the trunks should be first painted with bordeaux paste and then tied with cornstalks in such a way as to prevent the earth coming in contact with the bark of the trunk.

5. *By raising the dew-point by the addition of water vapor to the air.* — This is accomplished in various ways

FIG. 75. — Screens of tobacco cloth as a frost protection.

such as burning large quantities of wet straw, distributing steam among the trees, filling the air with spray such as by overhead irrigation, and by ordinary irrigation. Burning wet straw has been found of no avail for two reasons. There is not enough straw available in a country where every scrap of organic matter is needed for increasing the humus content of the soil. In the second place the air is so dry in California that it is often too big an undertaking to attempt to raise the dew-point, especially when the air movement carries the moist air away as fast as produced.

Experiments have actually been made in piping steam from large boilers and allowing it to escape through small holes in pipes distributed in the orchards. This proved an entire failure, as too large a proportion of the heat was lost through the smokestacks of the boilers.

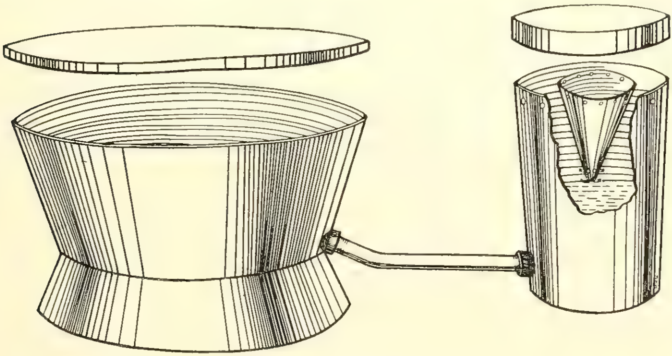

FIG. 76. — Big Six.

Overhead irrigation has been tried both from horizontal pipes and from sprinklers at the top of tall masts. This resulted in the formation of large masses of ice on the trees, and had to be discontinued. There was also much trouble from the freezing and bursting of the distributing pipes.

Ordinary irrigation has been found to raise the temperature from two to four degrees above that of adjacent nonirrigated areas. For light frosts this is of considerable value, but is open to the following objection. Most citrus growers receive irrigation water in rotation every 30 days, consequently but few growers would have water available at the critical time. Those who pump their water do not as a rule have pumps of sufficient capacity to cover their entire acreage at one time.

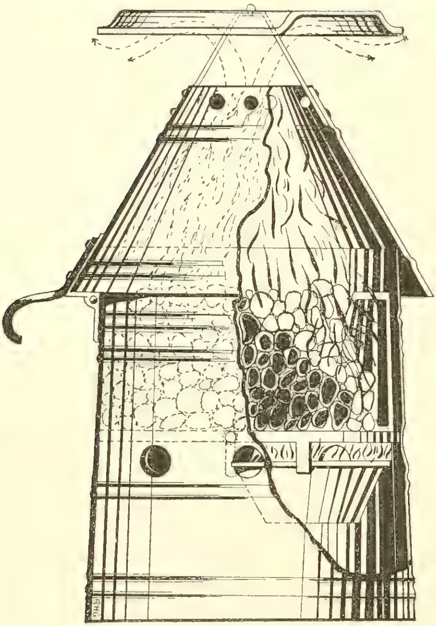

Fig. 77. — Eichoff Coal Burner.

Certain growers at Riverside once made an experiment of heating the irrigation water by passing it through a boiler. This was finally abandoned as too much heat was wasted through the smokestack.

6. *By mixing the air by creating artificial wind.* — This has been accomplished in California in two ways. By drawing a wagon about through the orchard bearing a huge rotary fan driven by a gas engine; and by building large bonfires at certain points which create a slight draught. Both methods have been abandoned as inadequate in the event of a sharp frost.

7. *By causing frozen plants to thaw out slowly.* — If all frosted fruit could be picked before it had thawed out and placed in storage where it could thaw gradually, a large proportion might be saved. Unfortunately, there is no

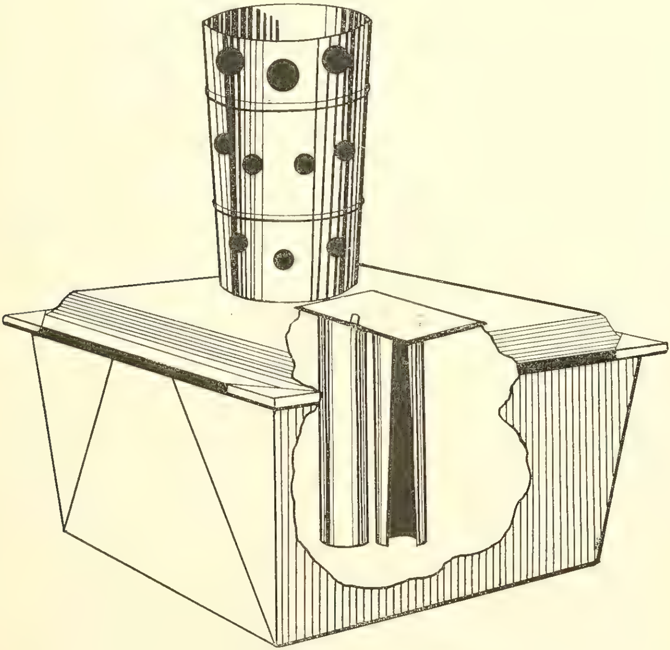

FIG. 78. — Hamilton Down Draught.

time to pick it, and there are no houses big enough to hold it. Some growers build fires of wet straw and manure on the windward side of the orchards and attempt to keep a blanket of smoke over the orchard all of the morning succeeding the frost for the purpose of keeping the trees shaded and allowing them to thaw slowly. In some cases this has apparently been quite successful.

8. *By the direct addition of heat to the plants and the air surrounding them.* — This has been accomplished by burning wood fires in the orchards, by burning coal in wire baskets, by burning smudge fuel (shavings and tar), by suspending electric heaters in each tree, and by burning crude oil or low-grade distillate in some form of sheet iron receptacle. Coal is too scarce and expensive at ten dollars a ton when compared with oil at two cents a gallon. Smudge fuel is unsatisfactory on account of the smoke and the scarcity of the material. Electric heaters are clean and efficient but too expensive to install. There is not sufficient electric current available to heat more than an extremely small proportion of the orchards.

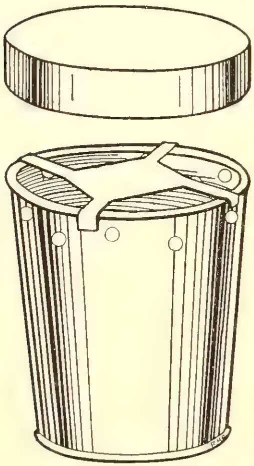

Fig. 79. — Bolton.

Several experiments were carried on with small electric heaters hung in the trees of the National Orange Company's Ranch in southern California during the winter of 1912–13. About one horse power of electric energy was used per tree during the cold period. A thermometer, the bulb of which was embedded in an orange on the exterior of a heated tree, showed a temperature 7° F. higher than a similarly placed instrument on an unheated tree. The fruit on the inside of an unheated tree would probably have shown a much higher temperature. In a letter from H. B. Chase, who conducted the experiments, it is stated that the temperature of the air in the orchard showed no appreciable increase, but the trees and fruit came through in much better shape than the trees which were not heated. The only conclusion to be drawn from this is that all of the heat given off by the electric heater is radiant heat which passes through the air without heating it and is absorbed by the limbs, foliage, and fruit. The great advantage of such a heater over the oil or coal heater at once becomes evident. With the electric heater the heat given off practically all gets to the place where it is needed, while with the other forms of heat generators which are placed in the rows between the trees, the heat given off (largely convectional heat) is carried up above the trees to a great extent and therefore lost.

Fig. 80. — Coe.

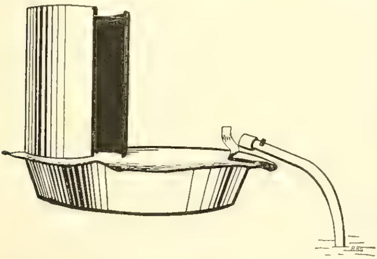

Fig. 81. — Pomona Pipe-Line Heater.

Electric heating on a large scale is apparently out of the question because of the lack of sufficient current to serve the orchards as a whole. It would seem a pity, however, if a few conveniently located orchards might not be able to take advantage of idle dynamos during early morning hours when street cars and factories are not running.

With the development of enormous quantities of very cheap oil in California, the oil burning orchard heater has proved itself eminently practicable and is now almost universally used throughout the citrus districts.

ORCHARD HEATING WITH OIL

In the early nineties, when the oil production of southern California was rapidly increasing, Charles Froude introduced the first oil heater. This heater was later improved by J. P. Bolton of Fresno, California, formerly U. S. Weather Bureau Observer at that place. The frosts of December, 1895, in southern California brought about a greatly increased interest in frost prevention devices. In this month the Riverside Horticultural Club in cooperation with the U. S. Weather Bureau, made a number of tests of smudging devices, heaters, and vaporizers, and published the results of the experiments. It was decided then that coal burned in wire baskets, as described by Edward Copley,[1] was the most satisfactory method. Since this time, however, on account of the tremendous development of oil wells in and near the citrus districts, oil as a fuel has become cheaper and more popular from year to year.

[1] *Riverside Press and Horticulturist*, April, 1896.

Requirements of Orchard Heaters

The ideal oil heater should provide good combustion and be as nearly smoke free as possible. It should be substantial yet simple in construction and of ample capacity. The rate of combustion should be easily controlled and it is an advantage to have the parts nest well for storage. The covers must effectually prevent rainwater from entering. Ease of handling, filling, lighting, extinguishing, and efficiency of radiation are all important. The cost should be low, usually not above $1 each.

The combustion should be good, not only to obtain as many heat units as possible from a given quantity of oil, but to lessen the amount of soot given off. The old idea of smudging was to give off as much smoke or smudge as possible in order to reduce loss of heat by radiation from the earth. While this may have been satisfactory to deciduous fruit growers when used at blossoming time, it is a positive detriment to bearing citrus orchards. The soot collects on the mature fruit and necessitates rather expensive special washing. While smoke in an orchard does conserve some heat, citrus growers would be glad to furnish a little more fuel to make up the loss by radiation if they could dispense with the soot-laden smoke. Most manufacturers advertise smokeless heaters, but few of them as yet approach smokelessness, and at the present time none of the cheaper oil burners are entirely satisfactory in this regard, although marked progress has been made toward this end.

Good combustion is also important when low grade oils carrying a large amount of asphaltum are used. Many heaters will not burn out clean with such oil. A cake of gummy material is left in the bottom of the heater which is very difficult to remove, and soon the capacity of the heater is much reduced.

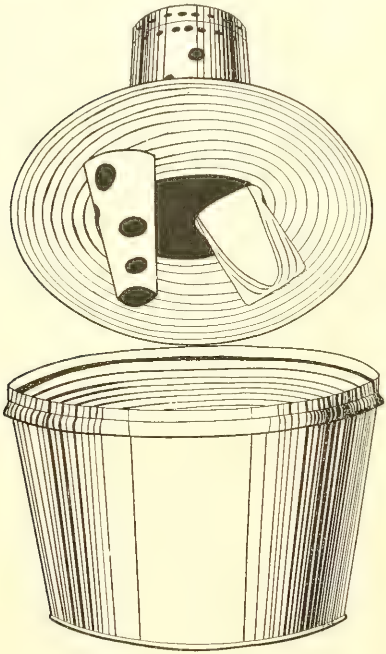

Fig. 82. — Dunn.

Heaters should be as simple as possible, for all classes of laborers will be required to operate them in the cold, dark nights. The less joints, valves, and attachments a heater has the better.

Ample capacity is important. One gallon heaters have been largely discarded in favor of the three and five gallon sizes. The capacity should be sufficient for a heater to burn at least eight hours without refilling. If small heaters are used, a large number will be required, and this increases the labor of handling and operating.

It is important that heaters be fitted with some device for controlling the rate of combustion. This not only permits conservation of fuel, but adds a great element of safety inasmuch as the oil saved in the early part of the night may be sorely needed at some critical time in the early morning.

Some heaters when burning low are apt to accumulate gas and explode, throwing oil over the trees and injuring them and lessening the safety of the operators.

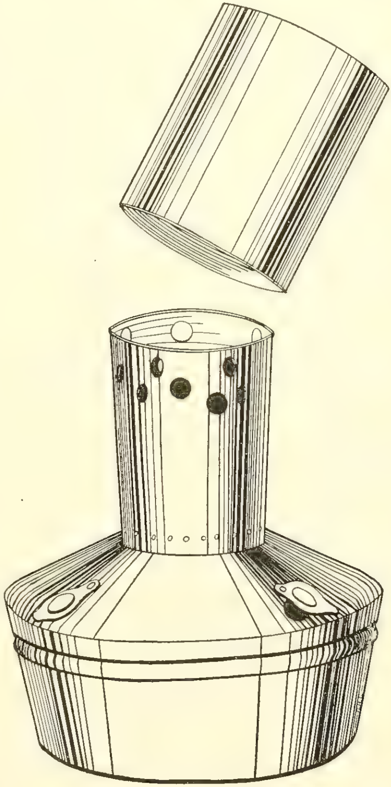

Fig. 83. — Canco.

The heating equipment of citrus orchards remains in position all winter, which is the rainy season in California. If not well protected from rain, water will find its way into the oil and sink to the bottom. When the oil is lighted this water turns to steam and causes the heaters to boil over. This results in a temporary bonfire which soon burns out and leaves the trees unprotected.

The greater the proportion of radiated, and the less convectional heat given off by any heater the greater its efficiency. This important principle is often overlooked while considering points apparently more practical. The Indians of Peru are said to have used for centuries, in protecting their crops from "gravity" spring frosts, a heavy clay pot in which charcoal is burned. By this means they secured radiated heat almost exclusively.

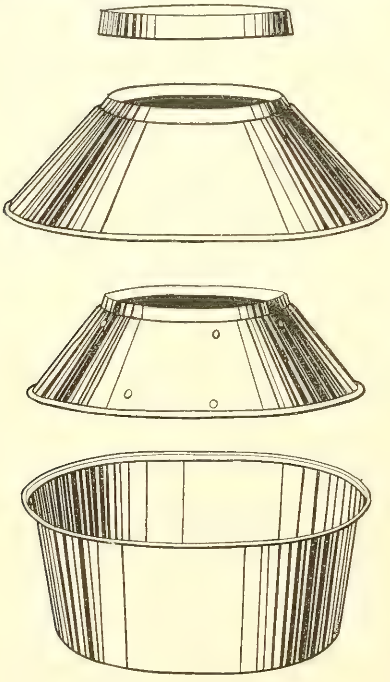

Fig. 84. — Rayo.

From a consideration of the above requirements it will be seen that the development of a thoroughly practical and efficient oil heater is not an easy matter. Four or five of the requirements may be combined without much difficulty, but some are more or less conflicting. It is especially difficult to combine perfect combustion and control of combustion with simplicity and cheapness.

Types of Oil Heaters

During the years 1911 to 1914 there was a tremendous amount of experimentation in developing types of heaters to meet the requirements of citrus growers. Almost every one, from the local blacksmith to the Standard Oil Company, seemed to have a new idea and was sure that he could produce the attachment or device which would put him ahead of everybody else. As a result, a very large number of different heaters were turned out and the patent attorneys had their hands full. Still the improvement in heaters goes merrily on. We cannot undertake a detailed description of all these different heaters, as lack of space forbids, and no doubt they will all be changed more or less during the next few years. The accompanying sketches

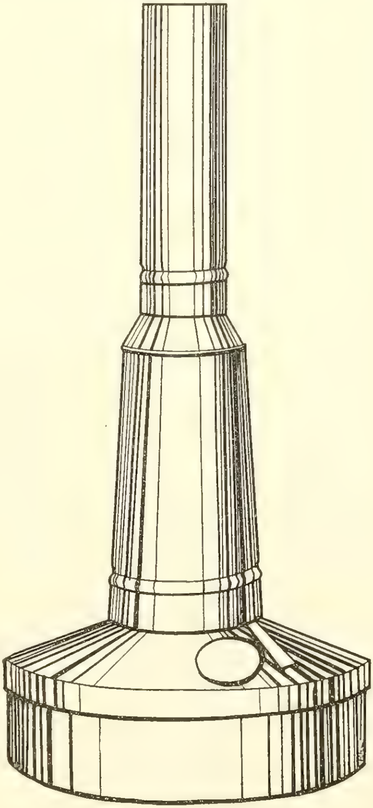

Fig. 85. — Hislop.

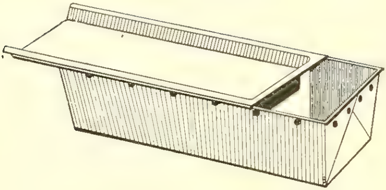

Fig. 86. — Hamilton Reservoir.

and pictures of heaters installed in orchards will suffice to give a general idea of the leading types at this time.

At present these heaters may be grouped into three general classes: (*a*) simple reservoir heaters; (*b*) automatic reservoir heaters; (*c*) pipe-line heaters. Simple reservoir heaters are the kind ordinarily used which burn from a free surface and are adapted to low-grade oil. Automatic reservoir heaters have a patent burner separate and several feet distant from the tank. The high-grade oil used is fed by a small iron pipe which passes through the almost smokeless flame, the oil being volatilized as it is fed. The burner is inclosed in a sheet iron pipe or drum, which acts as a radiator. This type has great possibilities, but is rather expensive and cumbersome.

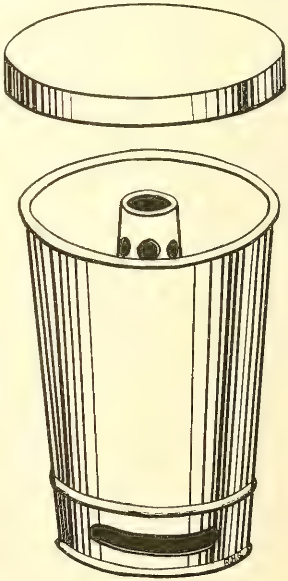

Fig. 87. — Troutman.

Pipe-line heaters are fed through pipes from a large tank set above the orchard. There are several forms, some of which burn the oil by dropping it slowly into a superheated cast iron bowl. Others require the orchard to be piped with compressed air as well as oil, and the oil is finely atomized in the burner and driven with some force into the drum, where it burns. The great objection to these forms is the expense of piping the orchard, yet there is much in their favor. The rate of combustion of all the heaters in the orchard may be controlled by operating one valve at the tank, and much of the annual expense of handling and loss from deterioration of reservoir heaters is eliminated.

Installation of Heaters

The number of heaters required to the acre varies of course with the size and variety of trees and the degree of cold to be encountered. A fairly common equipment consists of one three gallon heater to a tree, which is usually about ninety to the acre. These should be reënforced by an extra row around the windward side of the orchard. With such an equipment it should be possible to raise the temperature from seven to ten degrees for from seven to ten hours, depending on wind and other factors. Some growers use double this number and light only every alternate heater during the early part of the night,

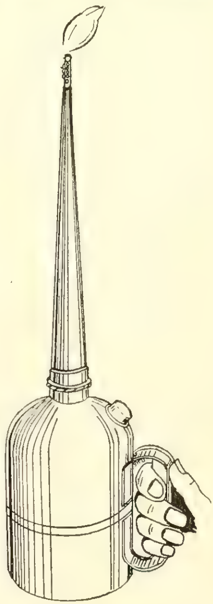

Fig. 88. — Adamson Torch.

holding the others as a reserve to be lighted only in case of emergency.

It has been found much better to have many small fires than a few large ones, as large fires tend to create convectional currents which carry much of the heat far above the tops of the trees. There is also danger of injuring the trees with large fires. As stated above, one heater per tree has been found to be the best plan.

The heaters are placed on the ground midway between the trees and in line with the trees in one direction. If placed in the center of the square made by four trees, they will be in the way of the wagons which haul the fruit out and the oil and manure into the orchards.

Properties of Fuel Oils

Petroleum when first taken from the wells is rich in gases and lighter substances such as benzine, gasoline, and kerosene. Besides these, it also contains such basic substances as asphaltum and paraffine. The crude oils of the Eastern states have chiefly a paraffine base, while nearly all Pacific Coast oils have an asphaltum base. The fuel oils on the market are residuals, the gasoline and other lighter oils for which there is a large demand having been removed in the refining process. What is known as crude oil is not petroleum as it comes from the wells, but a refinery residuum containing some of the heavy oils, a variable amount of asphaltum, together with some sulfur and a little water.

The types of oil commonly used are the so-called crude oil, smudge oil, slop distillate, and stove distillate. A particular grade of oil is usually recommended for each type of heater. A good grade of oil fairly free from asphaltum, such as 26 gravity slop distillate for instance, costs about two cents per gallon in carload lots delivered on siding in southern California citrus districts. The cars vary in capacity from 6000 gallons minimum to 12,000

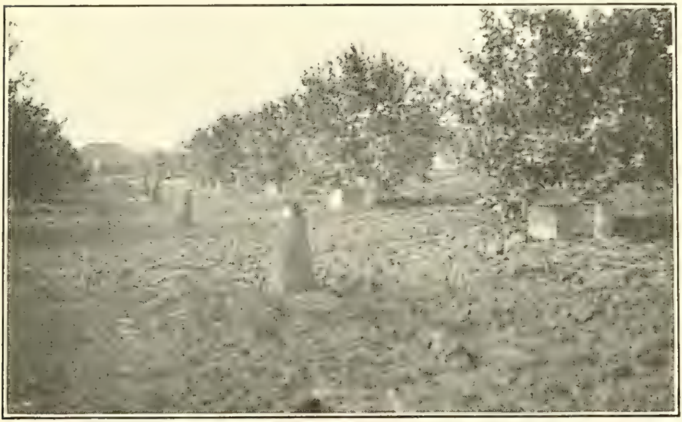

Fig. 89. — Coal burning orchard heaters. Fuel stored in boxes under trees.

gallons maximum. One great advantage in this oil as a fuel is its availability in very large quantities. During the blizzard of January, 1913, trainloads were ordered by telephone one day, and the oil was dispatched in trains having right-of-way, and was delivered, and in some instances was actually gotten into the heaters and fired before daylight next morning.

The density of the fuel oils varies from 14 degrees

Baumé to 35 degrees or more. Specific gravity varies from .850 or less to as heavy as .975. The heating value is usually stated in British Thermal Units, and varies from 17,500 to 19,100 B. T. U. a pound.

Fig. 90. — Orchard heaters ready for lighting.

Lighter oils are preferred when they are to be pumped or delivered through pipe-lines for the reason that in cold weather heavy oils become thick and sluggish like molasses and are very difficult to handle in small pipes.

Storage for Oil

As freezing temperatures often occur several nights in succession, it is highly desirable to have an adequate means of storing the oil on the ranch near the trees. Storage capacity should be provided for at least five fillings of all the heaters on the ranch.

Cement cisterns have been used to some extent for oil storage, but are often unsatisfactory. At present, galvanized circular iron tanks, similar to those used by the oil companies, are chiefly used.

Oil storage tanks should be located if possible on a side

Fig. 91. — Orchard heaters in old Valencia grove.

hill in order that they may be filled by gravity from above, and the oil delivered by gravity to the distributing wagons below.

On a number of the larger ranches it has been found expedient to install small tanks in various parts of the orchards and connect them with the large elevated tanks by a system of pipe-lines. The Arlington Heights Fruit

Company at Riverside has a main steel storage tank of 500,000 gallons capacity connected with a 6-inch pipe-line five and one-half miles long, which serves ten smaller tanks each of 12,000 gallons capacity. At intervals through the orchard there are "gooseneck" stand pipes from which the wagons may be filled. The Limoneira orchard at Santa Paula is equipped with two steel tanks holding 210,000 gallons each and two cement cisterns holding 100,000 gallons each. This 500-acre orchard has five miles of 3- and 4-inch pipe-line and four miles of telephone line with a dozen or more telephones located in various parts of the orchard. Thirty-five tank wagons and trucks are used to distribute the oil to the heaters.

Oil Heating Operations

For delivery of oil to the heaters, tank wagons of four or five hundred gallons capacity should be used. Heavier wagons are difficult to handle in cultivated or freshly irrigated soil. The tank is provided at the rear with a large valve or molasses gate, and men following the wagon fill the heaters by means of five-gallon buckets or ordinary oil cans with the tops cut off and provided with handles. Filling heaters by means of a trailing hose was tried, but has now been abandoned. One group of men go ahead of the tank wagon and remove the covers from the heaters, and others follow and replace the covers.

Many kinds of lighting devices have been tried, but the Adamson lighter shown in Fig. 78 has come into almost universal use. This is merely an oil can in the spout of which a roll of wire gauze and asbestos wicking has been loosely fitted. After lighting the wick and inverting the can over an open heater a few drops of gasoline or high-grade stove distillate will pass through the flame and fall burning into the heater. By use of this device heaters may be lighted almost instantly. It is a peculiar fact that new heaters are very difficult to light the first time. This difficulty is easily obviated by crowding a

Fig. 92. — Placement of orchard heaters. Extra fuel under trees.

loose wad of tow or excelsior into the mouth of the down-draught tube or by hanging a small asbestos wick on the side. This precaution will usually not be necessary after a little soot has accumulated in the heater.

It is the custom to begin firing lemons when the temperature at three feet from the ground reaches 30° F. A safe plan is to watch the young leaves on the lower part of the trees and begin firing as soon as they show transparent spots indicating that they are freezing.

Oranges may be allowed to go several degrees lower because they do not carry blossoms and tender young fruit in winter as the lemon does. It has been found that it is much easier to hold the temperature at 32° than it is to raise it to 32° again once it has fallen lower.

Fig. 93. — The perforated stack gives good combustion but may admit rain-water.

Many growers make a practice of lighting only every alternate pot at first, holding the others in reserve to be lighted later if needed. In case heavy firing and refilling becomes necessary it sometimes is confusing for the workmen to tell at a glance which heaters were lighted first. This difficulty may be obviated by painting a ring with white paint on every alternate pot in the rows. It also saves about one-third of the labor of lighting alternate pots to work diagonally through the orchard when the trees are planted in squares.

It often happens that the temperature will not go below 32 degrees before four or five o'clock in the morning, and it will be necessary to fire only a few hours. This usually pays well, however, for the blossoms and young fruit which are on the trees during winter mature in late summer when the prices are highest. As soon as the sun rises or the wind begins to blow the temperature rises and the heaters may be extinguished and the oil conserved for future needs.

Heaters may be extinguished by replacing the covers. Occasionally on very cold nights it may be necessary to refill the heater during firing operations. This is accomplished by placing the cover on for a few moments until the fire is out and then refilling and relighting.

During the winter 1912–13 one orchardist fired his lemon orchard on twenty-nine nights and saved enough fruit to pay for his heating equipment and all the expense of firing.

Care of Heaters

The depreciation of orchard heaters is heavy, especially with the cheaper forms. Being exposed to winter rains, they rust badly unless well cared for. It is usual to charge off from 15 to 25 per cent depreciation for each year of service. In the spring when danger of frost is past the heaters are emptied into the tank wagons, the oil being returned to the storage tanks. Each heater is then dipped in asphaltum paint made by melting asphaltum and diluting it with one gallon of stove distillate to ten pounds of asphaltum. Some growers even repaint the heaters in the orchard after a siege of firing has burned the paint off. It is extremely wasteful to store the heaters over summer in a rusty condition. In storing the heaters it will be found that those whose parts nest well are much more economical of space. At present some growers store the oil-filled pots under the trees in order to save expense of handling. This is satisfactory provided they are well painted. One trouble has been that careless laborers while hoeing under the trees are apt to strike the pots with hoes and cut small holes through which the oil leaks, soaking the soil and killing the trees.

Cost of Oil Heating

While the cost of heating varies widely and is in some cases high, there is no doubt in the minds of those who have the most experience that orchard heating pays well, especially for lemons.

Two typical actual expense accounts are given below, one for a small grove and one for a large ranch. In both cases the figures are for 1912–13.

Richardson Brothers' Lemon Orchard, Duarte, California.[1] Fourteen Acres — 1000 Trees

Equipment	
500 Hamilton heaters, 3 gal.	$200.00
700 Bolton heaters, 2 gal.	154.00
Tank wagon, 463 gal. capacity	48.00
Cement cistern, 8500 gal. capacity	125.00
Oil buckets 3, lighters 2	6.25
Four thermometers and automatic alarm	40.00
Total for equipment	$573.25
Oil and labor	
Oil for 16 nights, 16,195 gallons	$437.26
Labor bill for same	201.50
Total expense for operation	$638.76

[1] *California Cultivator*, Feb. 27, 1913, p. 260.

LIMONEIRA ORCHARD COMPANY, SANTA PAULA, CALIFORNIA.
FIVE HUNDRED ACRES[1]

50,000 oil heaters (including a thousand of last year's pots)	$50,000.00
2 steel storage tanks, capacity 210,000 gallons each	4,885.89
2 cement reservoirs, capacity 100,000 gallons each	3,000.00
5 miles of 3-inch and 4-inch pipe-line	6,375.03
35 tank wagons and trucks	4,315.00
150 spout pails for filling pots	300.00
200 torches	200.00
50 thermometers	150.00
4 miles of telephone system	750.00
350,000 gallons of oil in orchard at $2\frac{1}{2}$ cents	8,750.00
500,000 gallons of oil in storage at $2\frac{1}{8}$ cents	12,500.00
Total	$91,225.92

Reduced to the basis of one acre, the investment is:

100 heaters	$100.00
Storage space for 1,240 gallons of oil	15.77
Pipe-line	12.75
One tank wagon to 14 acres — per acre	8.63
Pails — one to $3\frac{1}{2}$ acres — per acre	.60
Torches — one to $2\frac{1}{2}$ acres — per acre	.40
Thermometers — one to 10 acres — per acre	.30
Telephone	1.50
Oil in heaters — 700 gallons at $2\frac{1}{2}$ cents	17.50
Oil in storage — 100 gallons at $2\frac{1}{2}$ cents	25.00
Total	$182.45
Interest, deterioration, and maintenance:	
6 per cent interest on total investment —	$10.94
15 per cent deterioration on $100 worth of heaters	15.00
6 per cent deterioration on other equipment	2.40
Estimated handling, painting, and filling (no firing)	5.00
Total	$33.34

This outlay would seem at first glance to make the expense of growing lemons under such conditions pro-

[1] *The Monthly Bulletin*, California State Com. Hort., Vol. 3, No. 1, January, 1914.

hibitive, and yet J. D. Culbertson, the assistant manager of the ranch, states that all of this expense was met by the sale of the lemons saved and "fair interest in dividends was paid to stockholders out of this year's earnings!"

SEPARATION OF FROSTED FRUITS

The Board of Food and Drug Inspection of the U. S. Department of Agriculture made the following ruling in regard to frosted citrus fruits on January 24, 1913:

"Citrus fruit is injured in flavor by freezing and soon becomes dry and unfit for food. The damage is evidenced at first by a more or less bitter flavor, followed by a marked decrease in sugar, and especially in acid content. Fruit which has been materially damaged by freezing is inferior and decomposed within the meaning of the Food and Drugs Act.

"For the guidance of those engaged in shipping citrus fruit, it is announced that, pending further investigation, the following principles will be observed in enforcing the Food and Drugs Act:

"Citrus fruit will be deemed adulterated within the meaning of the Food and Drugs Act if the contents of any package found in interstate commerce contain fifteen per cent or more of citrus fruit which, on a transverse section through the center, shows a marked drying in twenty per cent or more of the exposed pulp."

There is much variation in the degree of frozen fruit on the same tree. The oranges on the tops of tall trees are usually less frozen than those near the ground. Fruit on the inside of the tree is less frozen than that on the outside. Thus when the fruit is picked after a damaging freeze the good and bad fruit will be mixed together. If

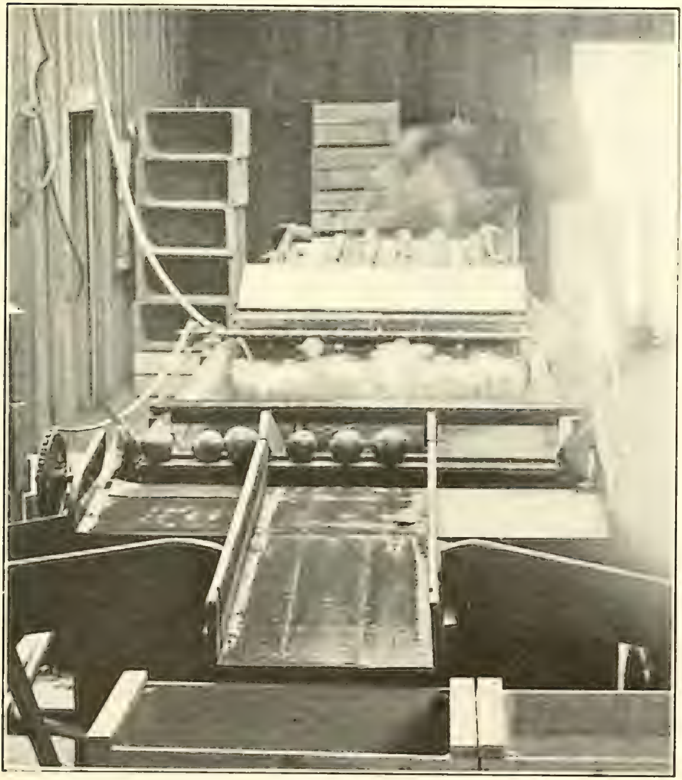

Fig. 94. — One type of water separator for frosted oranges.

the grower does not want to sell all his fruit at a great discount as frozen fruit, or run the risk of having trouble with Food and Drugs inspectors, he must separate the frozen from the uninjured fruit.

This is not as simple a matter as would at first appear for the reason that the fruit usually presents no outward indication of its interior condition.

Usually, after a few weeks, frozen fruit loses a considerable proportion of its moisture and grows lighter in weight. Upon this fact are based all methods of separating frozen from sound fruit. Normal oranges have a specific gravity of .82, but a few weeks after being frozen they dry out and become lighter. If oranges are dropped in a liquid the specific gravity of which is slightly lower than that of good fruit, the sound fruit will sink while the frozen fruit will float.

The first separations made on this principle were accomplished by using a mixture of kerosene and distillate oils. This proved very objectionable on account of the odor left on the fruit. D. C. Lefferts of Redlands invented a machine consisting of a large trough in which denatured alcohol of the proper specific gravity is placed to a depth of about thirty inches. The fruit is carried by conveyors and floated in the alcohol. A double conveyor sweeps the surface of the liquid and delivers the frozen fruit to one belt, while the returning conveyor drags on the bottom and delivers the sound fruit at another point. More or less difficulty was encountered by the alcohol increasing in specific gravity by the water absorbed and the inability of redistilling it on account of national laws governing distillation.

After the Lefferts machines had been used in many packing-houses for two years, Frank Chase of Riverside invented the water separator, which quickly displaced all other methods of separating oranges. This machine consists of an oblong tank through which water may be made to circulate at definite speeds by a small propeller. The oranges roll down an incline and drop into the moving water from a height of a foot or more. The light frosted oranges bob up to the surface quickly, while the sound, heavy fruit is slower to rise. Meanwhile the oranges have been carried along by the current, the sound fruit passing under, and being caught by a horizontal wire screen, while the light fruit is carried along above it. At the farther end of the tank the two grades are lifted by conveyors and delivered to separate bins. By adjusting the position of the screen and the rate of flow of the water any degree of separation desired may be secured. This device enables the grower to save whatever sound fruit may have been left, and he may ship it under his regular brands with some assurance. The frosted fruit, if not seriously injured, may be shipped under a special frost brand or it may be used as a fertilizer, or made into various by-products.

The water separator does not work satisfactorily with lemons for the reason that they are not round, and the depth to which they sink in the water will depend, to an extent, on the position in which they happen to strike the surface. For the separation of lemons the denatured alcohol bath is still used. A layer of lemons is placed in a large wire tray and submerged in the alcohol, which has a specific gravity of .82. The frosted lemons float and are removed by hand. Frequent tests with the hydrometer are necessary in order to keep the liquid at the proper density.

The question is often raised as to whether fruit which is only slightly frozen may not improve and fill up with juice again if left on the trees. The writer has observed this to take place to a limited extent both with lemons and Valencia oranges. It appears that the individual juice vesicles in any particular fruit vary in their resistance to freezing. Some reabsorb the water which has been drawn out of the cells in order to crystallize, while others fail to do so and collapse. A juice vesicle once collapsed apparently will not fill up with juice again, although the cells making up the walls may retain life. Those juice vesicles which do regain their turgidity, however, will grow larger than they otherwise would and to an extent will fill up the spaces left by the collapsed cells. When more than one-half the number of vesicles are destroyed, the gain in size of the others will hardly be sufficient to make the fruit marketable. See Fig. 72.

COÖPERATION IN FROST FIGHTING

The large citrus ranches are in a measure sufficient unto themselves when frost fighting is undertaken. On account of their size and the large number of men employed they are able to organize their forces effectively. The interests of small growers, however, who own three, five, or ten acres each will be best served through coöperation wherever their holdings lie close together. For some years a very successful organization of this kind has operated at Pomona. It is known as the Pomona Valley Orchard Protection Association and is composed of many small growers of the district who own in the aggregate about

3000 acres. Supplies are bought by wholesale, and the labor of firing is carried on by a specially organized force which is directed by one manager by telephone from a central station.

Thermometer stations are located at convenient points along the roads running through the orchards, and scouts mounted on motorcycles make the rounds of these stations on nights when danger from frost is imminent. The temperatures are reported to the manager at the central office; and when the temperatures fall dangerously low in any section, the owners of the orchards in that district are notified by telephone to prepare for lighting their heaters. As these temperature records are all charted and preserved, they constitute a fund of information in regard to air currents and cold spots which is of very great practical value in all future operations. The example set by this organization should be followed in other districts where many small orchards lie near together.

Fig. 95. — Thermometer station of Pomona Valley Orchard Protection Association.

In concluding this chapter we may say that whatever may have been the final verdict in regard to deciduous orchard heating in intermountain states, the heating of citrus orchards in California has proved a decided success, and new heaters are being installed as fast as the factories can turn them out. It is safe to say that citrus and especially lemon orchard heating in California has come to stay — at least as long as cheap fuel oil is available. Judging from the present increase in oil production in the state there would appear to be no warrant for any uneasiness in regard to the fuel supply for many years to come.

CHAPTER XV

PICKING AND PACKING ORANGES

California oranges are harvested throughout the year. Navel oranges are picked from November 1 to May 1. Occasionally Navel picking continues till June. Most seedlings and miscellaneous varieties such as Mediterranean Sweet, Paper Rind St. Michael, Ruby and Malta Blood, and Crafton are picked during May and early June. Valencias are harvested from June 1 to November 1 or later, thus overlapping the next Navel crop.

Oranges are picked with a great deal of care for the reason that carelessness will result in bruises and abrasions of the skin which admit the germs of decay. An orange with a perfectly sound skin is proof against decay and will normally live and respire (breathe) for several months, gradually losing water and carbon dioxide until it finally dries up, turns brown, and becomes as hard as a wooden ball. Oranges will not rot unless they become infected with microscopic plants which grow in the tissue, softening and breaking it down. All such premature decays (and there are many kinds) are preventable.

As before stated, the unbroken, healthy skin of the orange is proof against almost all such decays; but when the skin is abraded in any way, these germs are almost sure to get in, as the air is full of them, and most ordinary objects, such as gloves, bags, boxes, and the like, are always coated with them. The reader should remember that these germs or spores are practically ever present, and he has only to blow his breath across a moldy orange or lemon and observe the billions of minute "seeds" or spores floating in a cloud, to realize the enormous number produced. If some of this "mold dust" be examined under a microscope, each particle will be found to be a well-developed spore capable of reproducing the same decay whenever it may fall in a suitable place to grow.

Sometimes in dry weather a very slight scratch, which breaks the oil cells only, is cauterized over and healed without infection taking place, but this is not always the case and it rarely happens in damp weather.

When the fruit is hanging on the tree the rind is filled with water and the surface cells are turgid. They are very easily broken when in this condition, while after the fruit has been stored in the packing-house a few days and the rind dried out somewhat the fruit will endure a great deal more in the way of rough handling. This is the reason why it is wise to let the fruit cure on the packing-house floor for a few days before running it through the various machines.

The following are a few of the ways that abrasions may occur, and each of these should be carefully watched:

a. Clipper-cutting; careless pickers often allow the points of the clippers to extend beyond the stem and cut into or prick the skin.

b. Stem punctures; all stems must be cut off short and smooth, else they will be sure to puncture the skins of other oranges during handling.

c. Fingernail scratches; all pickers should be required to wear soft cotton gloves which are made especially for the purpose and sold for from 60 to 85 cents a dozen pairs.

d. Gravel scratches; sometimes a careless workman will throw an empty box from the distributing wagon in such a way that sand or gravel will be flirted into it. Before filling a field box it should always be inverted and the bottom tapped to dislodge any grain of sand present.

e. Nails in boxes; in many cases nails have been found protruding on the inside of field boxes, and their points rusted by pricking into perfectly good oranges.

f. Thorn scratched and dropt fruit; often with thorny varieties considerable care is needed to extricate interior fruit from the brush without scratching it. No fruit which is dropped should be picked up, as it is almost sure to decay.

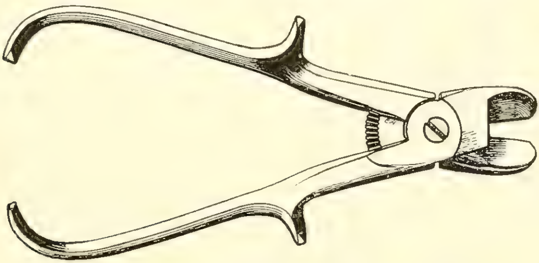

FIG. 96. — Tuttle fruit clippers with rounded points.

The clippers now used are a great improvement over the old styles. They have rounded points, and in certain types, cup-shaped blades. Most fruit should be double clipped, that is, the fruit is separated from the branch with one motion, and then held in a more convenient position while the stem is carefully cut off short and smooth. The green calyx or "button" should always be left on the fruit, for if it is pulled off, an opening is made for the entrance of decay germs.

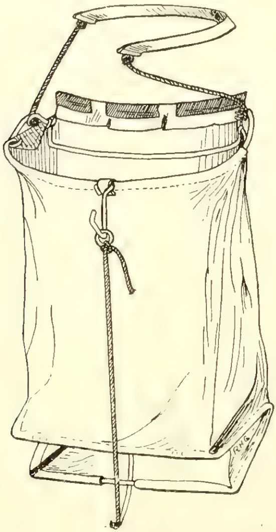

Fig. 97. — Dashboard picking bag.

Only cloth picking bags are used, of which there are five or more types. They are carried by a broad strap which passes over the shoulder, and the most approved types are adjustable in capacity and open at the bottom, allowing the fruit to be emptied into the lug-boxes gently and without bruising.

Many different types of ladders are used, the prevailing one having a third leg on hinges which is let down through the branches and rests on the ground near the base of the tree. Simple ladders which rest against the branches are not recommended, as they cause too much injury to the fine fruiting brush. Sometimes it is necessary to climb up into the crotches of the trees to reach inside fruit. This should be avoided as much as possible, as the heavy shoes of the pickers scar the bark and may carry the germs of gum-disease, especially when the surface of the soil is wet.

Some growers designate one man in each picking gang to do what climbing is necessary and require that man to wear a grain sack tied about each shoe in order to avoid bruising the bark of the trees. In moving ladders about great care should be taken to avoid injury to the fine fruiting brush which must be depended upon to bear succeeding crops.

The fruit after being picked is transferred to the lug-boxes which are never filled quite full. These lug-boxes are then stacked one on top of the other on the shady side of the trees to await the spring wagon which conveys them to the packing-house.

Fig. 98. — Covina picking bag.

It is often customary to pick the fruit from the lower branches first, leaving the high fruit till later in the season. There are two reasons for this. One is that frost is often more severe near the ground, and low-hanging fruit picked early is out of the way of frosts. Secondly, the brown rot fungus grows in the soil, and during wet spells comes to the surface and fruits. The spores are splashed by the rains up on the low-hanging fruit, causing decay. It should be pointed out that this fungus is different in its action from most other fungi in not needing an abrasion for entrance into a sound fruit. The spores are motile, and when there is a film of rainwater on the surface of the fruit these spores are capable of swimming into the stomates or natural breathing pores and causing decay. This fungus causes most trouble near the coast, and low-hanging fruit need not be picked early in the interior valleys on this account.

Occasionally oranges are picked according to size on orders from the packing-house which desires a preponderance of large or small sizes as the case may be to meet the requirements of some certain market. Sometimes, also, in the case of a very heavy crop, it is advisable to thin the fruit on the trees rather than to pick it clean the first time. This is done to ease the strain on the branches and permit the props to be removed.

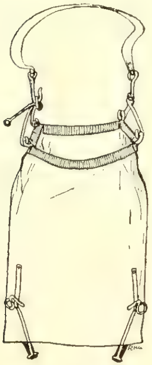

Fig. 99.—Woodward picking bag.

It has been customary to pay pickers by the day rather than by the box. Piece work encourages careless handling and an increase in the amount of decay.

The process known as "sweating," by which the color of oranges is changed from green to yellow, is illegitimate when employed for the purpose of deceiving the consumer as to the quality of the orange. Immature fruit may not be colored in the sweat-room and sold before it is fit to eat. There are cases, however, in which sweating is perfectly legitimate. Mature Valencia oranges often develop a green color during their second summer on the trees, and a light sweating to restore the former yellow color deceives no one, and is commonly practiced. In some locations also the fruit becomes sweet before it is fully yellow. The coloring of such fruit may be finished in the sweat-room, providing always that such treatment is restricted to fruit which is otherwise mature and in good condition to eat.

Very good prices are usually received for the earliest

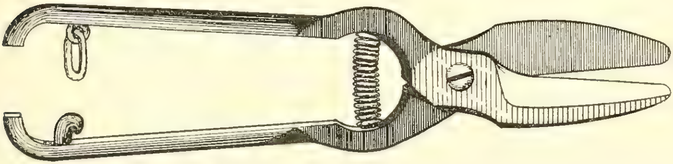

FIG. 100. — The Wiss clipper now being superseded by the Tuttle shown in Fig. 96.

Navel oranges sent to Eastern markets. This has resulted in recent years in considerable competition for the early markets and the shipment of much fruit which is immature and not satisfactory. Sometimes oranges are picked as early as the first week in October, while still perfectly green in color, colored by sweating and hurried to market. While some of this fruit brings high prices the result is disastrous for the much better fruit which follows. This unwise shipment of immature fruit resulted in so much loss and dissatisfaction among the growers of both California and Florida that the legislature of the state of Florida on June 13, 1913, passed an immature fruit law which has since been enforced with some good results. This law forbids the shipment of green fruit between September 1 and November 5 of each year which shows by test to

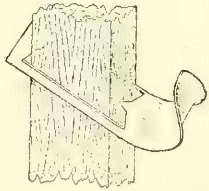

FIG. 101. — Metal attachment for propping limbs.

contain in the juice more than 1.3 per cent of acid. A simple and cheap method of making the acid test was worked out by the state chemist and placed at the disposal of all growers. Between September 1 and November 5 inspectors traveled through the state taking samples and making tests at the various packing-houses.

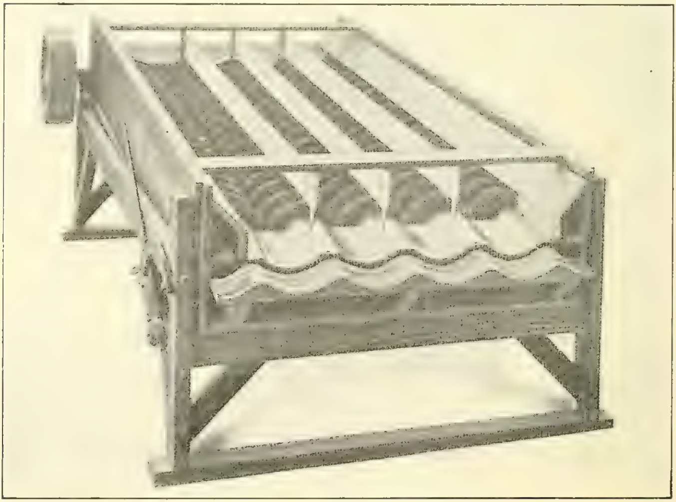

FIG. 102. — Worm brushes used for polishing oranges.

The simple field test was used, but in the case of dispute the remainder of the sample was sent to the state chemist for more accurate analysis.

Some time before the Florida law was passed the Federal Board of Food and Drugs Inspection took notice of the artificial coloring of immature oranges by sweating, and made the following ruling:

FOOD INSPECTION DECISION 133

The Coloring of Green Citrus Fruits

The attention of the Board of Food and Drug Inspection has been directed to the shipment in interstate commerce of green, immature citrus fruit, particularly oranges, which have been artificially colored by holding in a warm, moist atmosphere for a short period of time after removal from the tree. Evidence is adduced showing that such oranges do not change in sugar or acid content after removal from the tree. Evidence further shows that the same oranges remaining on the tree increase markedly in sugar content and decrease in acid content. Further, there is evidence to show that the consumption of such immature oranges, especially by children, is apt to be attended by serious disturbances of the digestive system.

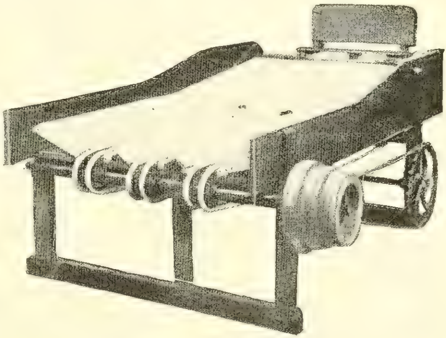

Fig. 103. — Rope feed hopper.

Under the Food and Drugs Act of June 30, 1906, an article of food is adulterated "if it be mixed, colored, powdered, coated, or stained in a manner whereby damage or inferiority is concealed." It is the opinion of the Board that oranges treated as mentioned above are colored in a manner whereby inferiority is concealed and are, therefore, adulterated.

The Board recognizes the fact that certain varieties of oranges attain maturity as to size, sweetness, and acidity before the color changes from green to yellow, and this decision is not intended to interfere with the marketing of such oranges.

H. W. Wiley,
F. L. Dunlap,
Geo. P. McCabe,
Board of Food and Drug Inspection.

Approved:
James Wilson,
Secretary of Agriculture,
Washington, D. C., March 28, 1911.

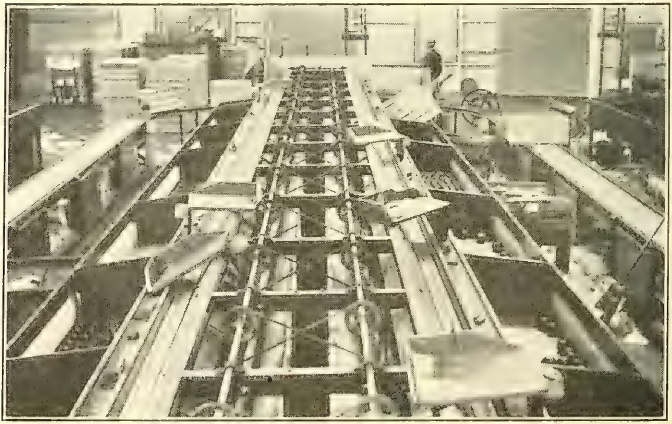

Fig. 104. — Orange sizing machine.

The enforcement of this ruling has done a certain amount of good, but it has not entirely put a stop to the irresponsible shipment of worthless fruit, for the reason that it applies only to fruit which has been artificially colored.[1]

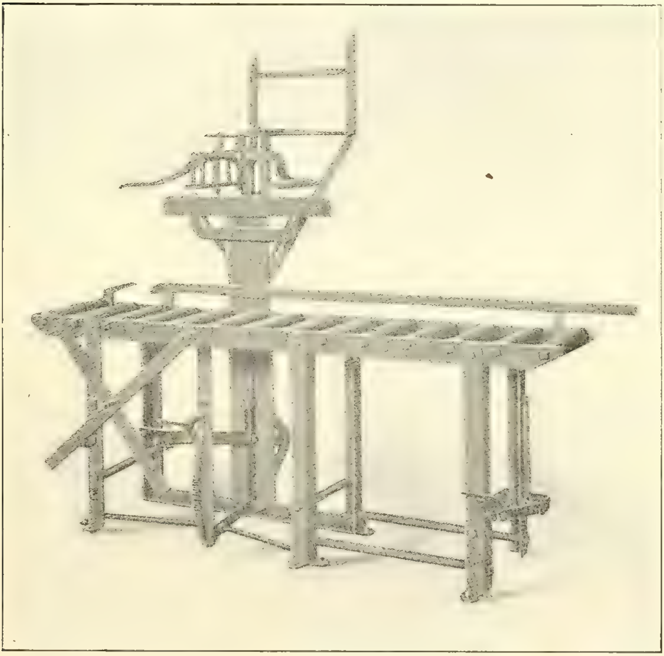

Fig. 105.—Box press and nailing machine.

[1] Where there is living vegetable tissue there is respiration, and carbon dioxide and water are given off. That the respiration of stored oranges takes place at the expense of sugar and acid and results in the gradual reduction in the amounts of these substances has been shown to be true by investigations carried on in the U. S. D. A. Bureau of Chemistry in 1905.

"During the storage (of Navel oranges) there was a slight loss in acid and in sugar. This is confirmatory of similar results

Navel oranges color earlier and become sweet earlier in central than in southern or northern California. The apparent advantage in sweetness of early oranges from southern San Joaquin Valley is not due so much to an early increase in total sugars as it is to an early increase in the ratio between sugar and acid. Colby[1] has shown that it is the early decrease in acid, together with the early coloring, which enables the growers in the San Joaquin Valley to market their oranges early.

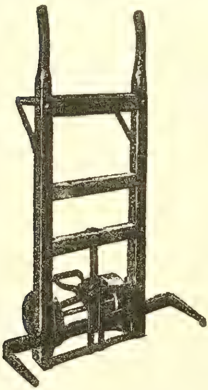

Fig. 106. — Citrus fruit truck.

Recently C. L. Alsberg, chief of the Bureau of Chemistry, U. S. D. A., suggested that as a result of investigations carried on, the northern district oranges may be considered to be immature when the juice does not contain soluble solids equal to or in excess of eight parts to each part of acid present, acid to be calcu-

with apples and peaches, and is probably due to the decomposition of acid and sugar in the respiration of the fruit." . . . "The loss of acid and sugar noted above is to be explained, as in the case of apples, by the consumption of these substances as a result of respiration of the fruit." — W. D. Bigelow and H. C. Gore, "Ripening of Oranges." Read before A. A. A. S. in New Orleans, 1905. Contribution from the Bureau of Chemistry, U. S. Dept. Agr. — Published in *Journal American Chemical Society*, Vol. 29, No. 5, 1907.

[1] G. E. Colby, "Comparative Examination of Shipping Navel Oranges from Northern, Middle, and Southern California," *California Agr. Exp. Sta. Rpt.*, 1898–1901, Part II, pp. 243–251.

lated as citric without water of crystallization. It was decided to base this figure upon the acid solids ratio in preference to the acid sugar ratio for the reason that the growers and packing-house foremen would be able to make the necessary analyses, which would be impossible in the case of sugars.

Since this valuable suggestion was made growers and shippers throughout the early districts have applied the test quite generally and are coöperating in limiting shipments to fruit which shows the 8–1 ratio. The effect of this has been very beneficial as shown by market reports.

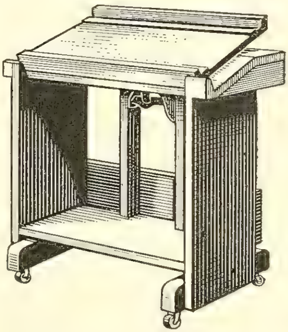

Fig. 107. — Packing stand.

Shippers of oranges will do well not to pick the fruit until it is in condition to be enjoyed on the tables of the growers themselves. If the orange industry in northern California is to grow to great proportions, it must do so on a basis of satisfactory fruit. Every orange sent to market should stimulate in the buyer a desire for more of the same kind.

The sweat-room. — The sweat-room is an air-tight, fireproof chamber usually built separate from the main part of the packing-house. Beneath a false floor are placed kerosene burning stoves of a type which does not give complete combustion. The hot gases and water vapor pass up through the floor and envelop the fruit. The temperature is controlled by ventilators in the roof and is kept for oranges at 100° F. for from three to five days, or until the oranges are properly colored. During this time the air in the sweat-room should be kept quite moist to prevent wilting and shriveling of the fruit. This will require close watching, as the air will dry out with some lots of fruit and tend to remain saturated with other lots. Pans of water may be set on the stoves, and occasionally it is necessary to wet down the fruit and the sides and floor of the room in addition. The fruit should be graded according to shade of color, the lightest being placed next the door, so that it may be removed earlier than the rest if desirable. The air should be a little less than saturated with moisture.

FIG. 108. — Box squeeze. Small size.

When the coloring of citrus fruit is forced too rapidly the buttons (stems) shrink away and drop off. This is very undesirable, as fruit without buttons is not supposed to keep as well and is discounted in the markets. When used to excess the same gases which color the fruit throw the buttons.

In very few places in California does the fruit come to the packing-house sufficiently clean to pack. In interior valleys it is covered with a layer of dust, and near the coast it is apt to show scale insects or the black smut (*Meliola camelliæ*) which is a fungous growth on the honey dew or excretions of scale insects. If fruit is simply dusty, it is run through a series of rapidly revolving dry roller brushes. In some cases it may have a spray of water directed upon it while in the brushes or it may pass in water between two series of submerged brushes. In the latter case a tank is necessary, and it is good policy to disinfect the wash water against brown rot infection. Wash water for oranges is usually disinfected by the

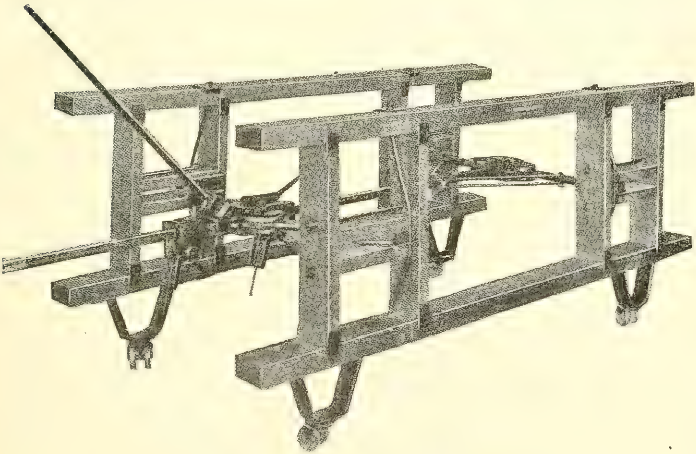

Fig. 109. — Car squeeze. Large size.

addition of one pound of permanganate of potash to 1000 gallons of water in the morning, and at noon $\frac{1}{2}$ pound is added to the same water. The water in the tank is changed each day.

After being washed the fruit is conveyed by belts to drying racks in the open or under cover, or is run through an air-blast dryer.

The fruit next passes on belts or roller ways before the graders who, considering color, shape, smoothness, and blemishes, sort the salable fruit into three grades, standard, choice, and fancy, placing each grade on a separate belt which conveys it to its respective automatic weighing machine where the proper proportion of each grade is credited to the grower. After the oranges pass the weighing machines their identity is merged in the general pool of the house.

The fruit next passes through the sizing machines, of which there are a great many different types, and each size is delivered to a separate bin. The bins are carefully padded on bottom and sides with cotton cloth, and have movable sides which provide for adjustment of capacity.

Box shooks are usually bought in Oregon or northern California, and the boxes are made in the basement of the packing-house. They are made either by hand or by an automatic box making machine. A standard box of California oranges is 12 by 12 by 26 inches outside measurement. It is divided in the middle by a partition. For purposes of computing freight charges it is estimated to weigh when packed 72 pounds.

On the end of each box is pasted a paper label, usually a five-color lithograph, showing some picture appropriate to the brand. Each packing-house or association has a series of brands copyrighted for its own use. In addition to this the finest quality fruit sold through the California Fruit Growers' Exchange bears the additional "Sunkist" label of the Exchange. The variety and size of the fruit and the packer's number is stenciled on the end of each box. Boxes which are liable to be sold in

New York State are now stenciled with the exact dimensions and cubical contents of the box.

Box shooks are made of Pacific Coast pine exclusively. The standard 8 slat orange box requires $5\frac{11}{100}$ feet of lumber and costs about $13\frac{1}{2}$ cents delivered. The standard lemon box contains $\frac{1}{4}$ foot more lumber and costs on an average $15\frac{3}{4}$ cents. The cheaper grades of tissue wrappers come from mills in Oregon and California, while the fine grades come from Hamburg, N. J. The paper is printed in Los Angeles from wide rolls on cylinder presses. The cost printed and delivered to the packing-houses for the 10×10, an average size, is about $17.50 a hundred thousand. A pound contains about 414 sheets. Box labels are procured from lithograph houses and are usually done in five colors. They cost about $3.00 per thousand. Special cement coated nails are used which cost in large lots about three cents a pound. Metal box strapping comes from New Jersey chiefly in 6500 foot reels and costs about $1.46 a thousand feet. From 18 to 24 inches of strapping is used on each box. Most of the larger packing-houses use beveling machines for the ends and partitions and box making machines for putting the boxes together.

Both women and men are employed as packers, women being most largely used. The empty box is placed on a packing stand which rests on rollers and has a revolving top. The hod holding tissue wrapping paper is placed over one end of the box. The packers stand beside the sizing bins, and wrapping each fruit in printed absorbent tissue paper, place it in the box with great dexterity and skill, averaging about sixty boxes a day. The fruit is placed in the box in its respective order of arrangement

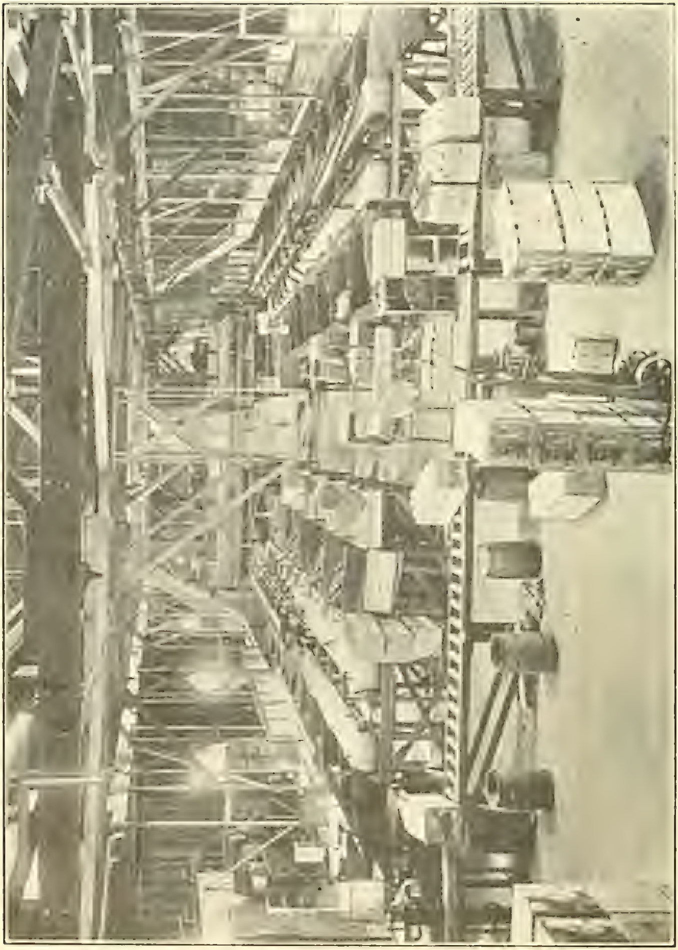

Fig. 110. — Interior view of the Pioneer Fruit Company's orange packing house at Lindsay, California.

according to the size. Each size of fruit has its own order of arrangement and the size is designated in the house and on the market not by the diameter of each orange, but by the number required to fill a box.[1]

ORANGES

SIZE	AVERAGE DIAMETER IN INCHES
64	$3\frac{5}{8}$
80	$3\frac{1}{2}$
96	$3\frac{3}{8}$
112	$3\frac{1}{4}$
126	$3\frac{1}{8}$
150	3
176	$2\frac{7}{8}$
200	$2\frac{3}{4}$
216	$2\frac{5}{8}$
250	$2\frac{1}{2}$
288	$2\frac{3}{8}$
324	$2\frac{1}{4}$
360	$2\frac{1}{8}$

A very high pack is customary, and after the covers are forced on and nailed the boxes are usually delivered by automatic carrier to the car or precooling room. One hundred field boxes will usually pack out about sixty packed boxes. The cars vary in capacity, depending on whether they are provided with collapsible ice bunkers. The standard car of oranges contains 384 boxes loaded two tiers on end and six rows wide and including sizes 96, 112, and 250, and not over 20 per cent of the 126 size. The remainder of the car may be divided among the 150, 176, and 216 sizes. Cars other than standard are discounted from 25 to 50 cents a box on the market according to the number of off sizes they contain.

[1] For further rules governing packing, see Chapter VIII.

The boxes are set with two inch air spaces running lengthways the car. Each tier of boxes is braced in position by a narrow strip running across the car and

Fig. 111. — Orange packers at work.

nailed to each box. As the tiers are set the slack throughout the car is taken up by a device known as a "car squeeze." A copy of the manifest card showing the number of different sizes and their location in the car is tacked on the inside wall near the door.

The freight is figured on an estimated weight of 72 lb. to the box, and is $1.15 a hundred pounds to points on the Missouri River and eastward. Icing charges are extra.

Precooling

The term "precooling" properly applied relates to the reduction in the temperature of any given lot of fruit before it is dispatched on its journey to market, in contradistinction to the usual method of reducing the temperature gradually in transit. It has been found by experiment that when warm fruit is loaded into cars with ice and started on its journey across the desert that before the fruit in the center of the boxes is thoroughly chilled, decay has set in. This decay is checked, but on unloading the fruit in the warm, humid climate of the East such decay spreads rapidly. With precooled fruit the decay has not been allowed to become so much advanced, and cars do not require such frequent re-icing. Precooling will not take the place of careful handling.

Inasmuch as citrus fruits, when carefully handled, keep excellently for long periods at ordinary temperatures, precooling is not as valuable with them as it is with other more tender and quickly perishable fruits. Several packing associations have adopted the practice of sending their fruit to market "under ventilation" or without ice, but it requires great care in picking, handling, and packing to be able to do this successfully.

The large precooling plants which chill a whole train load of thirty cars simultaneously by driving or circulating a blast of cold air through the cars, are owned by the railroad companies who desire that precooling be considered a function of the transportation companies. Some packing associations which had built small precooling plants of their own objected to the above point of view and fought their case in the courts for several years, finally winning their point before the U. S. Supreme Court in January, 1914. The Court ruled that $7.50, for each reicing, the rate set by the Interstate Commerce Commission, was reasonable and applicable to precooled shipments. The rate previously charged by the railroads for icing cars was $62.50 for the trip, regardless of whether much or little ice was needed. Inasmuch as precooled cars only require a comparatively small amount of ice *en route*, the saving to the growers by this decision amounts to about $30 a car.

About 55 per cent of the oranges shipped East go forward under ice. In very cold weather and especially for cars sent to the extreme North, it is advisable, before loading, to paper the inside of the car with several thicknesses of heavy building paper to prevent the fruit from being frozen *en route*.

The average haul for cars shipped east of the Mississippi River is 2585 miles and the average time between San Bernardino, where the Santa Fe overland citrus trains are made up, or Colton, where the Southern Pacific trains are made up, and New York is about fourteen days.

After many years of effort the citrus growers have gained from the railroads the right of diversion, which means that a car of oranges may be billed to Chicago, for instance, and when it arrives should the Chicago market be unfavorable it may be diverted to Cleveland or Buffalo or Boston or to any other place toward the East and within that traffic zone without additional charge.

There are two concerns in southern California which

FIG. 112. — A typical orange box label.

make a specialty of designing and constructing packing-houses and manufacturing special equipment. Most orange houses consist of a basement, where shook and other supplies are stored and where boxes are made, and a packing floor where fruit is handled from delivery wagon

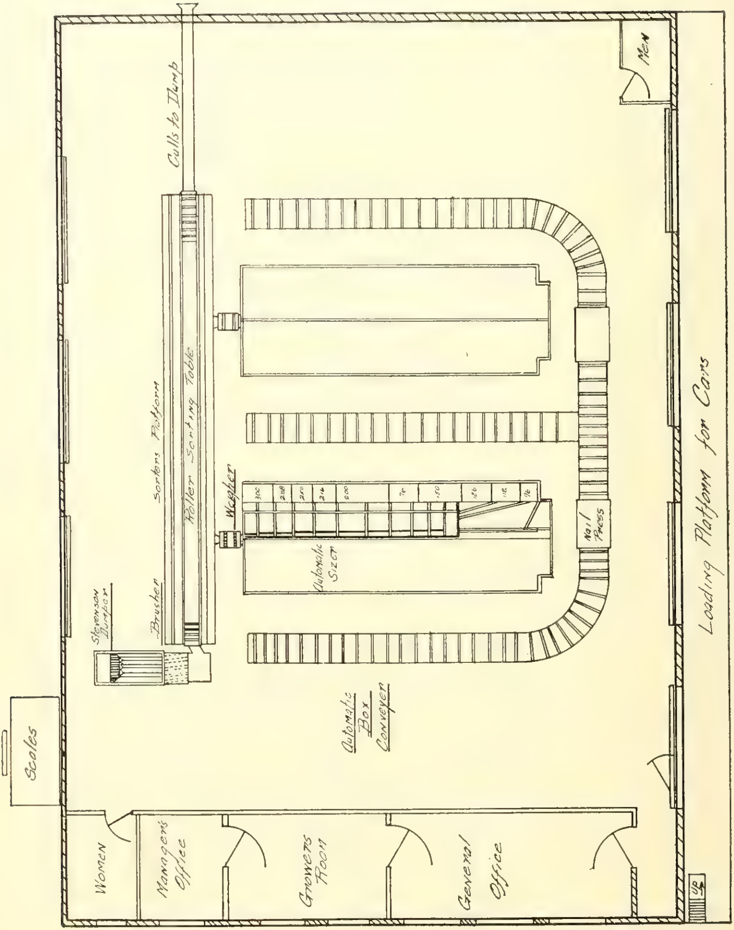

FIG. 113. — General arrangement of orange packing house.

to the car. The fire hazard is high and losses are rather frequent. Most of the houses belong to a local mutual insurance association which prorates and assures the losses as they occur.

There are at present about 200 packing-houses in active operation in California, besides a large number of sheds and old houses which operate only at infrequent intervals. The capacity of the houses varies from one to twenty cars a day.

The associations which are affiliated with the Exchange enjoy the privilege of buying ranch and packing-house supplies through the Fruit Growers' Supply Co. This is a non-profit coöperative organization through which the growers pool their orders at low cost. The Supply Company has an authorized capital of one million dollars and in 1914 did a business of $3,319,062.04 at an operating expense to the members of $\frac{3}{4}$ of one cent on each dollar of business transacted.

CHAPTER XVI

PICKING AND PACKING LEMONS

The picking and packing of lemons differs radically from that of oranges as described in the previous chapter. Lemons are usually picked from ten to twelve times a year, the heaviest pickings coming in March and April and the lightest in August and September. It is a peculiar and unfortunate fact that the heavy pickings come at a time of year when there is little demand for lemons and the lightest pickings come during the picnic and lemonade season,

Fig. 114. — Picking lemons.

when the demand is greatest. For this reason the proper storage of spring lemons becomes one of the important functions of the lemon packing-house.

The following typical example of an actual yield of a $9\frac{1}{4}$ acre mature lemon orchard of mixed Eurekas and Lisbons growing near Covina, Los Angeles County, gives a good comparison of the various pickings:

RECORD OF LEMON PICKINGS. SEASON 1910–11

Orchard of Mr. N. D. Mussey

POOL	DATE	LUG-BOXES	POUNDS
1	Sept. 19	76	3,698
2	Oct. 19	60	2,880
3	Nov. 17	289	13,852
4	Jan. 3	520	24,470
5	Feb. 1	832	39,415
6	Mar. 18	1,122	50,906
7	May 3	1,120	51,350
8	May 30	196	9,268
9	July 21	298	14,224
10	Aug. 30	52	2,506
	TOTAL	4,565	212,569

The method of picking lemons from the trees is much the same as with oranges except that the use of the ring and consequent searching about in the foliage among fruit of all sizes makes picking slower and more expensive. Especial care should be used to prevent dead twigs and other trash from falling into the picking sacks as the weight of the lemons against such objects in handling will cause scratches in the skin. In some sections special picking sacks with closed tops are used to prevent this. In this type of sack the fruit is introduced at the side near the top.

For hauling to the packing-house the growers generally use a factory-made wooden wagon with steel skeins

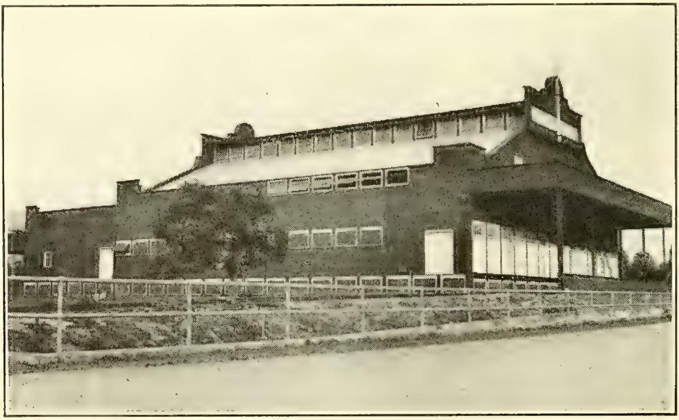

FIG. 115. — Two-story lemon packing house, Glendora, California.

on which they place a wide flat rack usually about 8 feet wide and 14 feet long. The racks are made locally and are set on the gears over bolster springs. It is not uncommon to see a string of three or more of these wagons hooked together and being drawn by the gas tractor which is used for cultivating the orchards.

Lemons differ from oranges also in being valued for their acid rather than for their sugar content. A green lemon therefore is better than a yellow "tree ripe" one provided it is fully sized and mature. For these reasons lemons are picked altogether according to size rather than color. The pickers carry wire rings which are slipped over each lemon, and every fruit which fails to pass through the ring is picked. In summer a ring $2\frac{1}{4}$ inches in diameter, inside measurement, is used; while in winter and spring a ring one-sixteenth of an inch larger is used, inasmuch as the fruit will be held longer and will undergo greater shrinkage.

On account of the demands of the markets mentioned above, there is a tendency to pick often in summer, carefully searching for every lemon which may be up to size. This fruit is quickly colored in the sweat-room and hurried to market while prices are high.

SWEATING AUTUMN LEMONS

The sweating of lemons is for the purpose of quickly changing the green color to a whitish yellow. While the practice of sweating oranges is sometimes abused, lemon sweating is always legitimate as it in no way deceives the buyer. In fact the mature but green lemon properly colored in the sweat-room and hurried to market is usually sourer, and therefore better, than the lemon which has been kept in storage for several months and has consumed a small portion of the acid in the process of respiration.

For best results, lemons should be fired intermittently. The air of the sweat-room should be kept saturated with moisture, and beads of water should be in evidence on the ceiling at all times. If the air is allowed to become dry, the lemons will quickly shrivel. The temperature should be kept at 90° F. or ten degrees lower than for oranges. So far it has been impossible to fully color green lemons in five days and retain the buttons, as the same quality of the gas mixture which changes the color causes the buttons to drop off. Inasmuch as sweated lemons are sold and consumed quickly, the loss of the buttons is not as serious a matter as would otherwise be the case.

STORAGE OF WINTER LEMONS

In the late winter and spring when it becomes advisable to hold the fruit for summer markets, the problem of the lemon packer is very different from that of early fall. Instead of sweating the fruit and thus accelerating the life processes as much as possible, he now wishes to retard to the greatest possible degree these same life processes. The fruit is therefore picked with very great care in order to prevent abrasions. On arriving at the packing-house the lemons are carefully washed in a brush washer. For disinfection against brown rot, one pound of bluestone is added to each 1000 gallons of wash water in the morning and one-half pound added to the same water at noon, the water being changed each morning. To prevent the bluestone from corroding metal tanks it is well to apply a thick coat of asphaltum paint to the inside of the tank.

The lemons are now separated into three grades according to color alone, known as green, silver, and tree-ripe; the silver being those fruits which are just beginning to lose the deep green color. Each of these grades is placed loosely in packing boxes and stacked up, a car in each stack, on the storage floor. Lemons are often kept in this way six or even eight months, but the fruit picked after April 1 is much shorter lived than that picked earlier. Lemons picked green will keep much longer than those allowed to turn yellow on the tree. These tree-ripes are kept separate and shipped first. Lemons will also keep much better near the coast than in the interior valleys, where much more expensive storage houses must be provided in order to control the humidity. The great problem is to give plenty of ventilation in damp weather in order to prevent decay and to reduce the

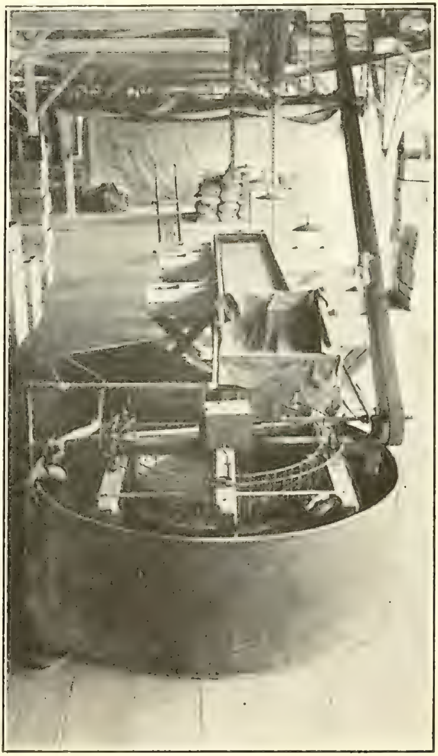

FIG. 116. — Lemon washing machine and sorting table.

ventilation, or withhold it entirely in warm dry weather to prevent the fruit from losing moisture and shriveling. The relative humidity of the air in the storage house should be held as near 80 per cent as possible, but this is very difficult to accomplish in interior valleys, where the humidity of the air varies from 90 per cent to as low as 10 per cent. In order to control the temperature and humidity each carload stack of lemons is inclosed in a heavy duck tent. These tents are usually made of 8 oz. special army duck, and are 10′ wide, 10′ high, and 20′ long. This size includes one carload of lemons. This tent is open at the bottom, and is open at the four corners, which are laced so that any part of the fruit may have ventilation, without interfering with fruit that it is not necessary to ventilate. These tents are also built in other sizes, which is sometimes necessary to fit the space in a packing-house, but this is the size that is most generally used. The tent is hung from the ceiling on a frame, there being eyelets in the top to fasten to frame. In some of the packing-houses in interior districts the tents have been abandoned and the fruit is stored in large basements, usually built of concrete, with outside shutters which provide for ventilation.

Unless the lemons have been very carefully handled from the orchard to the packing-house, a great deal of decay is almost sure to develop in storage. Lemons are always handled more carefully than oranges and the brush washer is about the only piece of machinery they are allowed to pass through. On account of the absence of machinery, a lemon packing house presents a very different aspect from an orange packing house.

When the fruit is taken from storage it is graded by hand into fancy, choice, and standard, each grade being placed one layer deep in broad flat trays. Stacks of these trays of fruit are weighed and the proportion of the different grades credited to the grower of the fruit. All through washing, storing, and grading each grower's fruit is accompanied by a ticket attached to the guide box. When each

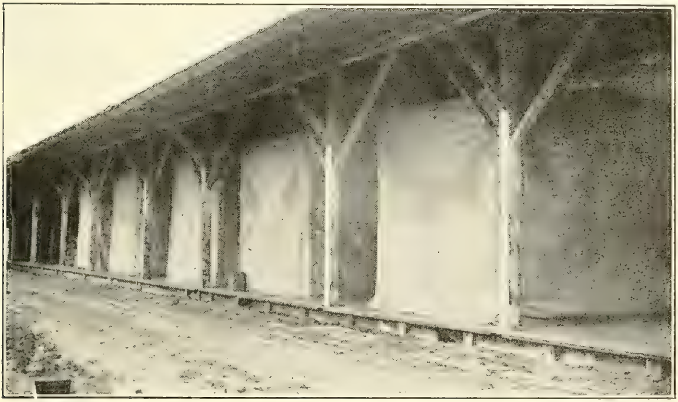

FIG. 117. — Lemon curing tents in packing-house near the coast.

of several hundred growers has four or five pickings in greens, silvers, and tree-ripes, all in storage at one time, the task of keeping account of each lot of fruit necessitates a well-organized system. In the packing-house lemon varieties are not kept separate, and the name of the variety is not stenciled on the end of the box as is customary with oranges.

Lemon packers use the same packing stand that is used for oranges, but instead of packing from bins containing fruit all of one size, they pack from the trays, sizing the fruit by eye and hand, the range of sizes in each grade running from 210 to 540 per box. Lemons sizing 300 to 360 to the box are in greatest demand on the markets, Southern markets preferring the smaller and Northern the larger sizes. In one or two of the newer lemon packing houses, sizing machines built especially for lemons have

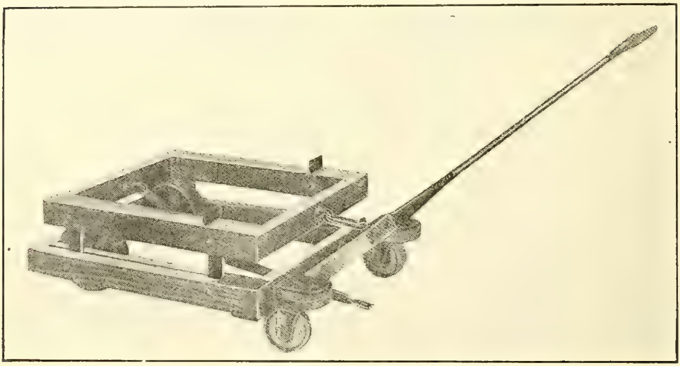

Fig. 118. — Truck for handling stacks of lemon trays.

been installed. These are operated very slowly in order to avoid injury to the fruit. Most packers still regard sizing machines for lemons with suspicion.

The standard lemon box has an outside measurement of 11 by $14\frac{1}{2}$ by 27 inches and is divided in the center by a partition. For the computation of freight charges a box of lemons is estimated to weigh 84 pounds. The standard car of lemons contains 312 boxes.

FIG. 119. — Packing lemons from sorting trays.

LEMONS

SIZE	AVERAGE DIAMETER IN INCHES
210	$2\frac{3}{4}$
240	$2\frac{5}{8}$
270	$2\frac{1}{2}$
300	$2\frac{3}{8}$
360	$2\frac{1}{4}$
420	$2\frac{1}{8}$
490	2
540	$1\frac{7}{8}$

Lemons were formerly shipped under ventilation from November to March, and under ice the remainder of the year. Some shippers who have learned to handle their fruit with extreme care have abandoned ice altogether to their great profit. In 1912–13 only 14 per cent of the lemons shipped were iced. The average haul to market is 2283 miles, being 304 miles less than the average haul for oranges. This difference is accounted for by the fact that a larger proportion of California lemons are marketed west of the Missouri River, thus avoiding, to a certain extent, the sharp competition with Italian lemons throughout the Atlantic seaboard.

The freight rate on lemons from California to New York, Chicago, and intermediate points has been fixed at $1.00 per hundredweight after a long and expensive contest in the courts, the lemon growers finally winning their contention.

PICKING POMELOS AND TANGERINES

Pomelos are picked from the middle of December to the following August and many growers keep some fruit for home use on the trees the year round. The total shipment of pomelos from California is not large, being about 200 cars per year. Ordinarily the fruit is stored in lug-boxes for a few days until the rind becomes soft and pliable. After this the fruit is packed in orange boxes and handled like oranges. Pomelos improve somewhat in flavor with storage and proper curing, and for best results, this fruit should be very carefully picked in February or March and held in storage precisely as are lemons until May, June, and July.

POMELOS

Size	Average Diameter in Inches
64	$3\frac{5}{8}$
80	$3\frac{1}{2}$
96	$3\frac{3}{8}$
126	$3\frac{1}{8}$
150	3

Large quantities of pomelos are grown in Florida, Cuba, Porto Rico, and the Isle of Pines, and these dominate the markets of the eastern United States. California pomelos are marketed mostly within the state and to some extent in the intermountain country and the Pacific Northwest. Only a few are sold in New York. On account of the state quarantine, Eastern pomelos cannot be brought into California for sale. At present a large portion of the California pomelos found on the markets are poor in quality. This is due to the fact that but little attention has been paid to pomelos and most growers tend to treat them in every respect like oranges. That the climatic and soil conditions in some parts of California are well suited for the production of a first-class pomelo is evidenced by the fact that a few skillful growers market their fruit in New York at very remunerative prices in competition with Eastern fruit.

Tangerines are the only variety of mandarin orange grown to any extent in California. They are picked, packed, and shipped in much the same fashion as oranges except that, being a fancy fruit and in limited demand, they are not shipped in car lots. It is customary to market tangerines gradually, including a dozen boxes or half-boxes in a car of oranges.

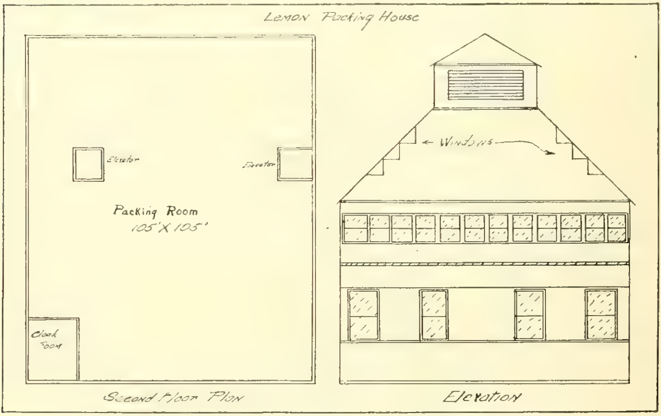

FIG. 120. — Lemon packing house. Compare with Fig. 113.

PACKING-HOUSES

There are hardly two packing-houses in California which have the same capacity, arrangement, or equipment. In general the orange house is small and is equipped with a great deal of machinery, while the lemon house is large and contains but little machinery. The fruit is received at one end from wagon scales and moves gradually through the house as it is washed, graded, sized, packed, and so on, until the packed boxes are loaded on the cars at the opposite end. Various types of mechanical conveyors are employed to save labor in handling the fruit and packed boxes.

FIG. 121. — Typical lemon box label.

Cleanliness is very important. No decaying fruit should be allowed in the house, as the spores given off tend to increase the amount of decay. All culls should be conveyed by belt from the grading table to some bin or outhouse entirely separate from the main packing-house and situated to leeward of it.

The comfort of employees should be provided for by rest rooms and lunch rooms. The main packing floor should be well lighted by glass skylights, for it has been found that the efficiency, comfort, and spirit of the employees are greatly improved by clean, airy, and well lighted work-rooms.

Fig. 122. — Combination box label.

Some packing associations confine their work to packing and shipping, while others take charge of all picking, pruning, and in some cases fumigating of the groves. In packing lemons, especially, it is a good plan for the packing-house manager to control the picking. The San Dimas Lemon Association, for instance, keeps account of the fruit picked by each crew of pickers, and as this fruit comes out of storage and is sorted over a careful account is kept of the percentage of each kind of decay. In this way a check is kept on the pickers, and if decay due to careless handling occurs it may be traced back and the blame placed where it belongs. Each foreman of a picking crew knowing that he is responsible for any decay which may develop in his lemons takes pains to instruct his men in the best methods of handling the fruit. At the end of each season a substantial prize is awarded the picking crew in whose fruit the least amount of decay has developed.

Pickers are drawn from many nationalities. Americans receive about $2 a day, while Japanese and Hindus are paid twenty cents an hour. A responsible picking foreman of considerable experience in handling lemons and men may receive $75 or more a month aside from a variable bonus at the end of the season.

CHAPTER XVII

BLEMISHES OF THE FRUIT AND THEIR PREVENTION

A LARGE increase in the production of citrus fruits will mean, if it means anything, a keener competition in the markets. In order to meet this increased competition, California growers and packers are being encouraged to adopt higher ideals in grading and packing. With more rigid grading the cull-heaps near many of the packing-houses assume large proportions. A conservative estimate places the direct loss from cull oranges alone, aside from frozen fruit, in excess of a half-million dollars a year.

It is well worth while, therefore, to make a study of the cull-heap, classifying and determining the relative importance of the various blemishes which cause oranges to be thrown into a lower grade or into the cull-heap. We will also consider how far it is practicable and by what means the proportion of culls to packed fruit may be reduced.

The blemishes of citrus fruits may be classified according to their causes. For convenience we may group them under four heads, namely: insect, fungus, mechanical, and physiological blemishes.

As a result of counts of Navel culls made in twelve packing-houses during January and February, 1910 and 1911, it appears that on the average, the most prolific causes of culls are as follows, according to their importance: splits, bruises, thorn stabs, thrips scars, sunburns, and worm holes. These six kinds of blemishes are responsible for upwards of seventy-five per cent of the culls. These counts, however, did not take into consideration the brown spot which usually does not develop until the fruit has left the packing-house.

INSECT BLEMISHES

Insect pests and their control will be discussed rather fully in Chapter XXII and it is only necessary here to name those blemishes of the fruit which are due to insects. They are: thrips scars; tortrix worm holes; scale insects such as red, yellow, purple, and the sooty mold which follows and grows upon the excretions of the black, gray, and brown scales; mealy bugs; red spiders; silver mites; grasshoppers; katydids; and some others.

The presence of a few scale insects on fruit intended for some markets in the East need not condemn it, but there are other markets, such as certain ones in British Columbia, where inspectors condemn all scaly fruit even though citrus fruits be not grown in the region.

FUNGUS BLEMISHES

The fungi which produce injury to the fruit are: brown rot, *Pythiacystis citrophthora;* blue mold, *Penicillium* *italicum;* green mold, *Penicillium digitatum;* gray mold, *Botrytis cinerea;* sooty mold, *Meliola camelliæ;* cottony mold, *Sclerotinia libertiana;* gray scurf, fungus not as yet identified; wither-tip, *Colletotrichum glœosporioides;* black rot of the Navel, *Alternaria citri;* and stem-end spot, *Cladosporium sp.* (secondary).

Most of the fungus diseases which cause blemishes on the fruit result in complete loss. The nature of these diseases, together with control measures, will be discussed in detail in Chapter XXI.

The fungus causing gray scurf or scab on lemons has not as yet been identified. The fungus apparently acts as a secondary agent; the primary cause is probably the slight bruising of the young tender fruit by the wind. The best remedy for this trouble is the growing of windshields and close planting of the lemon trees. By proper pruning also the branches may be made stiffer and more resistant to the swaying and whipping effect of the wind.

The stem-end spot of oranges is a very different thing from stem-end rot, and occurs mostly on Navels and on fruit which has hung late on the trees. It consists of a breaking down, browning, and shrinking of the skin in certain small spots near the stem. Ordinarily this causes little injury, but occasionally during rainy weather a species of *Cladosporium* grows on the dead tissue of these spots, giving them a black color which detracts very much from the appearance of the fruit. The only remedy at present available for this trouble is to pick the fruit early in those orchards where the trouble becomes serious.

MECHANICAL BLEMISHES

Much otherwise good fruit is ruined by carelessly injuring the fruit mechanically. Growers and packing-house men rarely realize how serious are the losses resulting from such causes.

Bruises. — Fruit which is bruised by careless handling is almost sure to decay. Careful handling should be the cardinal principle of every picker and packer. When a stack of boxes of fruit is accidentally overturned in the packing-house, the fruit should be set aside for ten days and then sorted over, the decaying fruit being eliminated.

Thorn stabs. — Much fruit is ruined by thorns. In wet weather such thorn-pricked fruit decays, but in dry weather the broken skin may cauterize and result in a spot. Sometimes a fruit continually swinging against a thorn will develop a thick horny rind at that point, which ruins its appearance. Thornless varieties, careful pruning, and windbreaks are the remedies.

Cultivator scars. — Cultivators and other tillage implements should be covered by a smooth tin shield which will allow low-hanging fruit to slide over them without injury. Metal projections on harness are also objectionable. When it is necessary to cultivate close up under the trees a great deal of fruit will be ruined unless protected by some sort of shield attached to the implements.

Clipper cuts. — When the use of pointed clippers was in vogue the loss from clipper cuts was very great. Now, however, round pointed clippers are used, and there is no excuse for clipper-cutting the fruit.

Stem punctures. — When the stems are not properly cut off square and close, they puncture a great deal of fruit in the box, and as they pass through the packing-house machinery. A close watch kept on the pickers should prevent this.

Machine injuries. — Some years ago a certain packing-house foreman complained of excessive decay which could not be explained. Finally one of the employees discovered a loose screw in one of the guide bars of the brushing machine hopper. The sharp head projected an eighth of an inch and made a little nick in every orange which rolled by. Passing over the brushes each nick was thoroughly inoculated with decay germs. The guilty screw head was driven home, after which the decay in transit dropped from 35 per cent to 4 per cent. The remedy for this is to keep a close watch for screw heads or splinters on all machinery and for projecting nails in field boxes.

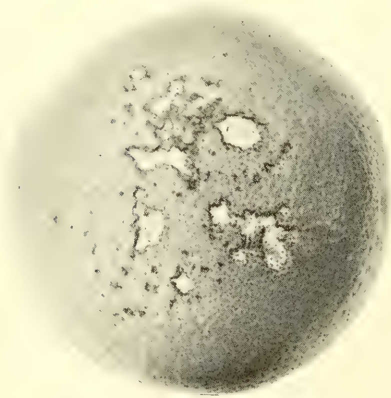

Fig. 123. — Fumigation scars.

Fumigation scars. — Oftentimes fruit is pitted and burned by carelessly overdosing trees with gas during fumigation. Fumigators should be held responsible for such injury. Occasionally, however, it happens that a sudden change in the weather or condition of the atmosphere will result in wholesale pitting of fruit even with the same dosage which was harmless a few hours earlier. No remedy has been found for this difficulty, and fumigators are not to blame. Fortunately such occurrences are rare.

Shoulder spots. — Where two oranges grow touching each other the point of contact is often shown by a light colored area with a reddish spot in the center. Such spots are not very serious and cannot be remedied unless the fruit be thinned. Thinning citrus fruits has never been practiced in California.

Hail scars. — Hail storms are of rare occurrence in the citrus districts. When they do occur they pit the fruit. If the hail is followed by dry weather, most of the pits will dry and little injury will result. In wet weather, however, some fruit will decay on the tree with blue or green mold, while in some cases a species of *Cladosporium* will grow on the pits and turn them black in color.

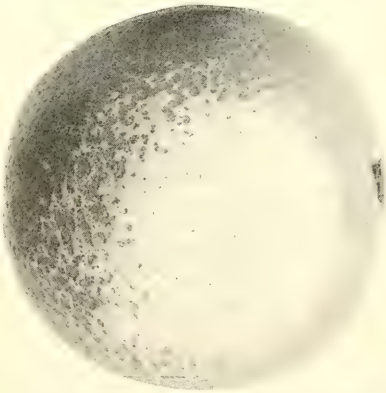

Fig. 124. — Scar caused by rubbing on the ground.

Soil scars. — Where heavy crops of fruit bend the branches down much fruit often rests on the ground. When the wind moves the branches the rubbing of the fruit on the ground causes a gray callous spot which ruins its appearance.

Windfalls. — Occasionally strong winds will whip a large part of the orange crop from the trees, as was the case in September, 1911. It is rarely safe to send a windfall to the packing-house, as it is very apt to develop decay.

Cement dust. — In certain localities the fruit is coated on the upper side with a crust of cement dust which comes from near-by cement mills. This dust collects in the pores of orange skin and sets, being very difficult to remove. It injures the appearance and reduces the grade.

PHYSIOLOGICAL BLEMISHES

This class of blemishes is not only large and the losses serious but the causes are as a rule not well understood. The total number of troubles of this kind is very large and new ones are continually appearing. Only the most important will be mentioned here.

Sunburn. — Both oranges and lemons which hang fully exposed to the sun are often injured. The exposed side becomes dwarfed in growth, resulting in malformation, and the skin of oranges becomes thick and pale colored and adheres tightly to the flesh. In interior valleys where the sun is very hot the skin may die and a hard black spot result. In such situations the trees should be pruned in such a way as to encourage the production of inside fruit, which is always much finer in appearance. Lemons are often noticed in the markets which are lop-sided, the distance from stem to apex being greater on one side than the other. This is caused by slight sunburn and is a sure sign that the lemon grew in an exposed position on the tree. There is a curing house trouble of lemons known as red rot, or, more properly, red blotch, which develops as a rusty brown color, gradually drying down into a sunken condition with a dark red or black color. This has been attributed to sunburn, as it is most common in lemons from exposed parts of the trees.

Frost. — The losses from frost are of course very large, but many fruits are only slightly frosted, and while they should be packed under a frost label they are good for consumption. Oranges usually exhibit no outward signs of frost unless severely frozen. Occasionally, however, certain oranges, especially those having more or less thick skins and growing low down on the north side of the tree will show a number of characteristic brownish spots on the exposed side even though but slightly frosted.

Off-bloom. — Occasionally orange and pomelo trees will blossom out of their regular season. The cause of this is not always apparent, although it is often due to irregularities in irrigation. Fruits developing from off-blooms are usually malformed and inferior. Navel off-blooms produce fruits with sunken instead of protruding navels. Pomelo off-blooms produce fruits which are distinctly pear-shaped as compared with the regular crop. Regularity and thoroughness of irrigation and cultivation will reduce the amount of off-bloom fruit to a negligible quantity.

Mottled-leaf. — This disease is not at present well understood. It results in the production of very small oranges and lemons of a whitish color, often quite unfit for packing. (See Chapter XXI.)

Exanthema. — This trouble appears on the fruit as dark reddish blotches or crusts. In severe cases the fruit is dwarfed in growth and cracks open on the trees. (See Chapter XXI.)

Malformation.— Many kinds of malformations are common. They may be divided into two classes: those due to sporting such as corrugations and color stripes of the rind, bottled-necked fruits, and others, which may be remedied by pruning out all of the sporting branches; and those due to an excess of food and teratological factors. Many Navel oranges, especially those borne on the topmost branches, exhibit a double or proliferated navel. Often this takes the form of a small secondary orange superimposed upon the navel. These are very common and are always thrown into the cull-heap because the small orange would have to be broken off before packing and this would result in decay. Often twin oranges partly attached are met with which are discarded for the same reason. The fruit borne near the large upright central branches often has coarse, grooved skin about the stem. This is caused apparently by the superabundance of food and may be largely prevented by proper pruning.

Brown spct. — The brown spot of the Navel orange may be described as occurring irregularly over the surface of the orange. From one to fifty or more spots may develop on a single fruit. The spots vary in size from a mere point to one inch in diameter, averaging about one-fourth inch.

This brown spot occurs only on the Navel oranges, and is uniformly worse on fancy, smooth, thin-skinned fruit. The total money loss from this particular spot is very large. For further particulars see Chapter XXI.

Cracks and splits. — Cracks differ from splits in being transverse rather than longitudinal openings in the rind of the orange. They are of rare occurrence and their cause is unknown. Splits, on the other hand, are very common and cause heavy losses, especially with Navel oranges in interior valleys. Splits are of two kinds:

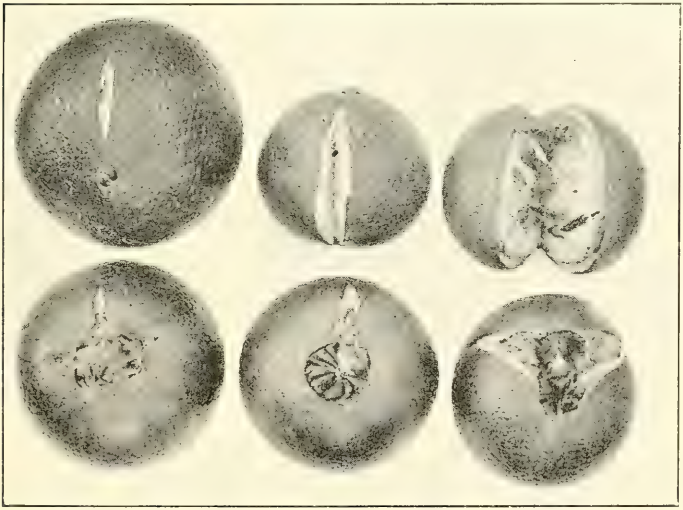

Fig. 125. — Orange splits. Side splits above and navel-end splits below.

side splits and navel splits. Side splits are caused by teratological cavities or seams in the skin. Thus weakened the skin is unable to withstand the growth pressure, and a split results.

A Navel orange which is split even a fourth of an inch at the navel must not be packed for long distance shipment, for such an opening is almost sure to be inoculated with decay.

All such oranges must be graded out but may often be sold to local peddlers for enough to pay for picking and hauling. The most common theory in regard to the cause of splits is that an irregular water supply, causing wide variations in the moisture content of the soil, produces a greater fluctuation in the growth of the interior than in the skin of the orange. Such a theory is quite reasonable, but such a cause should be regarded as contributory only, inasmuch as only a part of the fruit on any given tree will split. If a number of navel-split oranges are cut in longitudinal sections, it will be found, almost without exception, that the thickness of the rind varies, being quite thick and often creased at the stem end, and as thin as paper near the navel. Specimens with uniform thickness of skin very rarely split. Hot, dry spells of weather alternating with damp cloudy weather, together with careless irrigation, cause a high percentage of splits among this class of oranges. While much may be done toward overcoming this loss by careful irrigation and cultivation, the most important remedy is probably the propagation of trees from carefully selected bud-wood. By this means we may largely eliminate from our future orchards the un-

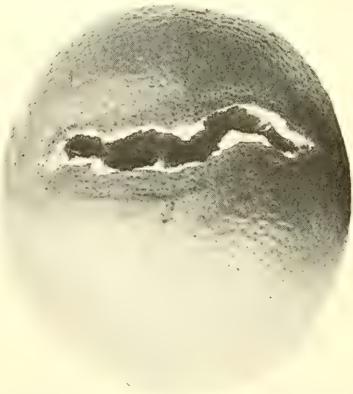

Fig. 126. — Horizontal cracks are very different from splits.

desirable types which are so prone to split during unfavorable weather.

Puffing. — When oranges are left too long on the trees, they will often become puffy. The rind becomes weak, with many cross creases and much unevenness. Finally the whole orange becomes soft and structureless. The walls of the juice vesicles become much thickened and the juice partly disappears, leaving the fruit dry, crumbly, and insipid. The remedy for this trouble is to pick the fruit earlier in those localities where puffing is serious.

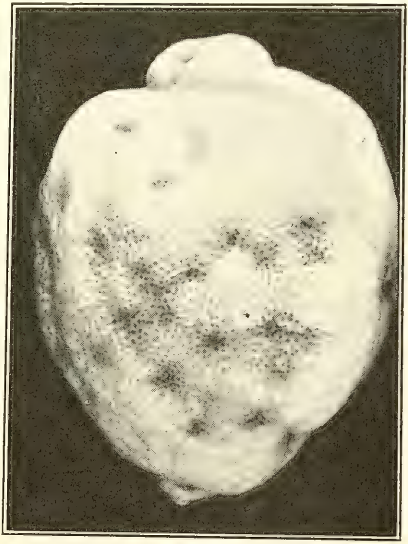

Fig. 127. — Peteca of lemon.

Peteca.—This trouble appears in the form of deep sunken pits in the rind of lemons after they have been in the curing house for some time. The tissue at these spots is found to be dried and shrunken prematurely, somewhat after the fashion of the brown spot of the Navel orange. The cause of peteca is not known.

Dry center of lemon. — A peculiar trouble which has become quite general in recent years. The vesicles collapse in groups, turn brown, and dry up. Injury is always greatest near the blossom end and is often accompanied by germination of the seeds while still within the fruit. In advanced cases the interior of the lemon may become filled with a mass of roots from the seeds. While this trouble results in a loss of juice, the housewife who cuts the lemons through the center is not apt to discover their inferiority as there is little surface indication of dry center. In many ways this trouble resembles bitterpit of the apple. At present neither the cause nor a remedy is known.

CHAPTER XVIII

BY-PRODUCTS

Until very recently it has been the custom in California to haul the cull fruits from the packing-houses and dump them in waste places. A very few growers returned the culls to the orchards and plowed them into the soil for the sake of their humus value and the small amount of plant-food they contain. But the bulk of the culls have been thrown away, and when we consider the enormous waste resulting from this practice the question arises as to whether a part at least of this large tonnage of fruit may not be profitably converted into valuable by-products.

That citrus by-products are in strong demand in the United States is proved by our annual importation of these items from abroad. The imports of the year 1909 are fairly typical of other years and are given on page 332. The values given are the appraised wholesale values at the port of export and would be considerably higher if appraised in this country.

At the present time nearly all citrus by-products are produced in Europe, while small amounts come from Paraguay, China, and California.

The chief reason why citrus by-products have not been more largely produced in the United States is that the cost of labor is from three to five times greater than in the citrus producing regions of Europe. At present, however, there is a widespread interest in this subject in California. Several small factories are already in operation, and several more are in process of construction.

Importation of Citrus By-products into the United States for the Year ending June 30, 1909

	Quantity	Value
Citric acid — lb.	243,010	$74,209
Citrate of lime — lb.	3,917,274	489,031
Lemon, lime, and sour orange juice		81,386
Orange and lemon peel not candied, preserved, or dried		4,833
Citron or citron peel, candied or dried — lb.	991,341	79,519
Citron preserved in brine — lb.	4,075,835	100,224
Orange and lemon peel, preserved, candied, or dried — lb.	436,129	20,692
Oil of bergamot — lb.	89,957	281,211
Lemon oil — lb.	405,695	358,197
Lime oil — lb.	21,991	9,973
Oil of neroli or orange flower — lb.	23,184	170,342
Orange oil — lb.	87,591	151,860
Total		$1,821,477

In Europe the citrus by-product industry is largely centered on the Island of Sicily and in Calabria. In these districts the two chief products are citric acid and lemon oil. About one-third of the total lemon crop of this region is consumed in the manufacture of citrate of lime, and from the peel of these same lemons comes the enormous quantity of essential oil, or essence of lemon, which furnishes practically the world's supply.

COMMERCIAL BY-PRODUCTS

For convenience those by-products at present manufactured on a commercial scale will be grouped separately from a number of domestic recipes which are included. Several of the products described under domestic recipes may of course be produced on a commercial scale, should the demand warrant.

Citric acid. — Citric acid is manufactured from the juice of the lemon chiefly, although lime juice is used to some extent. The peel is first removed and used for the production of lemon and lime oil which will be described later. The lemons are halved and the pulp scooped out with a sharp spoon. The pulp is then passed through toothed cylinders which shred it, and the juice is extracted from the mass by a high power press. The crude juice contains water in abundance, citric acid, malic acid, several kinds of sugar, albuminoids, and mucilage. The crude juice is filtered, placed in boilers, and heated nearly to the boiling point. Finely powdered chalk, mixed to a cream in water, is slowly added, while the hot liquid is being constantly stirred. The chalk or carbonate of lime unites with the citric acid, forming calcium citrate, which is insoluble and precipitates from the juice as a white powder, which is collected, washed, and dried into cakes. Great care is used to add just enough chalk to take up the citric acid as shown by litmus tests. As citric acid must pay a duty of seven cents a pound on entering the

United States and citrate of lime is free, most of the Italian product is shipped to this country as citrate of lime, and the final step in the process is completed in this country. This final step consists in treating the citrate with dilute sulphuric acid, which forms sulphate of lime and leaves citric acid in solution. This solution is evaporated in leaden boilers until the pure citric acid crystallizes out, and is washed and dried. Citrate of lime contains about 65 per cent of citric acid.

Lemon oil, orange oil, bergamot oil, and lime oil. — The peel of all citrus fruits is thickly dotted with small glands yielding an essential or highly volatile oil. The oils from the different kinds of citrus differ considerably in their characteristics. These oils are in great demand for flavoring extracts and perfumery, and the demand for the different kinds is in the order given. Of these, lemon oil is used in much the largest quantities. Any person may easily demonstrate the presence of this volatile oil by squeezing a piece of fresh peel in such a way as to cause the oil to spurt out into the flame of a lighted match. It will burn with a flash, showing its high volatility.

The major part of the oils now on the market come from Sicily and Calabria. The contrivances for extracting the oil are very crude, much hand labor being necessary. As before stated, the fact that labor in Italy costs only one-third as much as in California is the chief reason why California has not produced a larger amount of citrus oils.

After the pulp has been removed from the halved lemons and pressed for citrate, the peels are soaked in cold water for a few hours to increase the turgidity of the cells. They are then taken by men who press out the oil entirely by hand. The pressers sit on low stools with a small lipped bowl between their feet. Across the top of the bowl rests a strong notched stick which supports a large sponge. Each half lemon is placed against the sponge and given three or four sharp squeezes, using almost the entire weight of the body. The oil spurting out of the peel is caught by the sponge and drips through it into the bowl below. From time to time the bowl is raised and the oil is blown off by the breath into a graduated glass receptacle, the lip retaining the small amount of water and residue. After the oil is filtered through a paper filter it is ready for market. In Calabria a crude machine is used in which is a bowl lined with sharp metal points. The fruit is placed whole in this bowl and revolved, the points puncturing the peel, from which the oil drips through an opening in the bottom of the bowl. This device is called an ecuelle, and is used chiefly in the making of bergamot oil, for the reason that bergamot oranges are round in shape and revolve to better advantage in the machine.

Some few operators lacerate the rinds of lemons or oranges and distill the oil, but the use of this method results in water white oil of very inferior grade.

A large amount of oil of limes is made in the West Indies. The oil is extracted from whole fruit by hand in ecuelle pans, the pulp being later pressed and the juice concentrated by evaporation and sold as lime juice to be used as a drink.

Unfermented orange juice. — "A very palatable and attractive beverage can be made from oranges. The chief difficulty is the mechanical one of rapidly and economically separating the juice from the solid parts of the fruit. The juice can easily be made perfectly and permanently clear by settling and filtration. Sulfurous acid in very small amounts (4 ounces potassium metabisulfite to 100 gallons of juice, an amount well below the limit allowed by law) is necessary to prevent fermentation and the production of a bitter taste during settling. The cleared juice keeps perfectly after bottling if pasteurized at 180° F., which does not injure the flavor perceptibly. Good oranges will yield over 130 gallons per ton; frozen oranges a much less amount."[1]

Orange oil, for which there is a good demand, may be extracted from the skins of the oranges used in the manufacture of juice.

Orange vinegar. — A good quality of vinegar may be manufactured from the juice of cull oranges which are well matured and have a total sugar content of 10 per cent or more. Cruess[2] has shown that orange juice containing 11 per cent will, on fermentation, give about 5.5 per cent of alcohol, and that this on conversion into acetic acid will yield about 5.5 per cent of acid, which is considerably over the legal limit of 4 per cent of acetic acid.

Inasmuch as many samples of orange juice may be expected to contain 9 per cent or less of total sugars, it is apparent that the resulting vinegar will closely approach or even fall below the legal limit unless considerable care be used in the selection of the raw material as well as in the fermentation process.

[1] W. V. Cruess, "Utilization of Waste Oranges," Calif. Exp. Sta., Bull. No. 244, 1914.

[2] *Ibid.*, p. 164.

Orange wine. — Most of the so-called orange wines found on the markets are made from orange juice flavored with orange oil, fortified by the addition of alcohol or brandy, and sweetened by the addition of sugar or sirup. Such liquids, of course, have no right to be called orange wine.

An agreeable pure orange wine can be made by the use of proper methods. Such methods consist in "defecating the fresh juice after the addition of moderate amounts of potassium metabisulfite to prevent fermentation for a short time, fermenting the clear juice with pure yeast, and filtering the finished wine to clear it. This cleared wine may be turned into sparkling orange wine by the addition of a small amount of sugar and by subsequent fermentation in bottles." [1]

Candied citron. — Most of the citron consumed in the United States comes from the Mediterranean region and especially from the Island of Corsica. The chief reason why citron is not more largely produced in California is the difference in the cost of labor. Citron is admitted to the United States from Corsica duty free when it is shipped pickled in brine or ordinary sea water. Practically all imported citron is candied in this country. There is one firm now engaged in the growing and processing of citron near Riverside, California.

The fruit as it first begins to assume a bright yellow color is picked and placed in brine for a month or longer, the brine being renewed occasionally. Sometimes tender young leaves of the citron tree are soaked with the fruit to deepen the green color. The fruit is then boiled in fresh water to remove the salt and soften it. It is then

[1] *Ibid.*, p. 170.

halved, the pulp and seed scooped out, and immersed in cold fresh water to intensify the greenish color. After this it is covered with hot sugar sirup and allowed to stand three or four weeks, during which time the strength of the sirup is gradually increased. The fruit is then put into boilers with crystallized sugar sirup and cooked; then allowed to cool, more sugar is added, and it is cooked again until it will take up no more sugar. It is then dried and packed in wooden boxes, each piece being coated with white sugar crystals and wrapped in tissue paper.

Oil of neroli. — This product is made chiefly in the vicinity of Grasse in the French Riviera. Neroli is made by distilling the flowers of the bitter or bigarade orange, known in California as sour-stock. Both oil and water pass through the still; and as they condense the oil collects on the surface, is skimmed off, and sells for a very high price (from $20 to $50 a pound). Three hundred pounds of flowers are required to make one pound of neroli. The water which distills over absorbs some perfume from the oil and is sold as *eau de fleur d'oranges,* bringing about twenty-five cents a gallon.

Petit grain oil. — This oil is used in perfumery and is prepared by distilling the young and tender leaves and shoots of both bitter and sweet oranges. It sells for from two to five dollars a pound. A large part of the petit grain oil now comes from Paraguay, where orange trees have run wild and occur in forests over a large area.

Tincture of orange flowers. — This is a perfume which is prepared by steeping the fresh flowers in alcohol until all the perfume has been absorbed by the alcohol.

Essence of orange flowers. — This perfume is produced in large quantities in Europe and imported into this country. Apparently there is no reason, except the high cost of labor, to account for the lack of production in the United States. As orange trees produce many times the number of flowers that are needed for setting a crop, and most of them fall off normally, the preparation of essence need not hinder fruit bearing. The making of the perfume is a simple matter, and the preparation of a small supply for home use might furnish a pleasing pastime for young people living among orange groves. In the early morning orange blossoms are collected as soon as the petals begin to fall, by shaking the tree over a sheet spread on the ground. A tree yields from two to ten pounds of flowers. The perfume is generally extracted by enfleurage. Shallow trays containing layers of fresh blossoms are slipped into the grooved sides of a large air tight box. The box is filled with trays, but between each two trays is inserted a sheet of wire gauze or linen holding a thin layer of wax or mixed grease. The odor of the flowers is absorbed by the grease, the flowers being replaced by fresh ones every morning for a month, when the grease, or " pomade " as it is called, is collected and treated with alcohol for a month. The odor leaves the grease and passes to the alcohol, which is then known as essence of orange flowers.

Dried and candied peel. — Both orange and lemon peel are in good demand, both candied and dried. When dried, the peel is simply removed from the pulp, cut into thin shreds, and dried in the sun. When candied, the process is very similar to that used for citron, and the orange and lemon peels are not shredded, but left in halves.

Lime juice. — Large quantities of limes are grown on the islands of the West Indies. The green limes are harvested and shipped to market in barrels, turning yellow on the way. The ripe fruit which falls to the ground is gathered up and converted into several different by-products, such as citric acid, lime oil, and lime juice. In making raw lime juice which is to be used as a beverage, only clean, sound fruit is used. The juice is expressed by passing the fruit between heavy granite rollers. The juice is allowed to stand until the mucilage or albuminous matter is thrown down, after which it is filtered and bottled. If the fruit used is clean and sound, the raw juice should keep without any preservative being added. Lime juice cordial is made by mixing the raw juice with various brandies and other ingredients.

Orange paste. — A large amount of orange paste is used by confectioners. It is made by grinding and macerating fresh orange peels, and after the addition of an equal weight of sugar evaporating down into hard cakes which are broken up and packed in wooden buckets. This orange paste is one of the few citrus by-products which is already being manufactured in California.

Crystallized baby oranges. — The small green oranges which drop from the trees during June and known as the "June drop" may be gathered and made into a pleasing confection known as crystallized baby oranges. Fruits between one-half and one inch in diameter are best and should be gathered frequently and not allowed to wilt on the ground. The fruits are placed in brine, gradually increasing the strength until fermentation is prevented. They may remain in brine indefinitely, provided the brine is changed occasionally. When ready for processing, the fruits are boiled in several changes of fresh water until free from salt, and tender, after which a hot weak sugar sirup is poured over them. This solution is replaced by one more dense each day until the fruits will take up no more sugar. They are then dried and dipped in a very thick sugar solution and allowed to cool slowly when the sugar will crystallize out over the surface. The fruit is now ready for packing.

Glacéd kumquats. — Chinese and Japanese prepare a quantity of glacéd kumquats, a certain amount of which is shipped into this country. The fruits are picked when ripe and several slits made in the sides. Sometimes the seeds are squeezed out through the slits, sometimes not. The fruit is boiled until tender and then carried gradually through a series of sugar solutions of increasing density until they will take up no more. They are then dried and dipped in a very heavy hot sirup and quickly dried. Instead of crystallizing the sugar will glacé over the surface.

DOMESTIC RECIPES

In addition to the foregoing there are a large number of pleasing preserves, marmalades, and other preparations which may be made to advantage in the home kitchen. Some of these, such as Dundee marmalade, are manufactured in quantity and shipped to distant markets. While it is deemed inadvisable to give a very large number of home receipts, still a few of the more important ones may prove of interest and value.

Orange or lemon jelly. — Slice fruit thinly, rind and all, place in double boiler with cover, and boil slowly for 20 minutes without stirring. Press out juice and filter through several thicknesses of muslin. Add a little more than an equal volume of sugar. Boil on slow fire three minutes and pour into jelly glasses while hot. In some cases a small amount of gelatine is added before boiling, but if properly made as above directed this should not be necessary.

Orange marmalade. — Large amounts of orange marmalade are made in Dundee, Scotland, from whence it is shipped to all parts of the world. The oranges used in the manufacture of this marmalade are the bitter oranges grown in the district of Valencia in Spain and shipped to Scotland after being shredded and canned. Most of the marmalade made in California is made from sweet oranges and pomelos. A little of the characteristic flavor of the bitter orange may easily be secured by replacing a few of the sweet oranges with bitter ones.

Slice one dozen oranges thin, throwing away ends, and one-half dozen lemons, removing all seeds. Measure the fruit, and add half as much water. Let stand over night. Next morning boil the fruit in the same water until tender. Remove from fire and weigh and to each pound of fruit and liquid add one pound of sugar. Boil until it jellies, which should require about twenty minutes. Do not have the fruit too ripe; it should be fresh and firm.

Pomelo marmalade. — Slice one pomelo, one orange, and one lemon, rejecting seeds and core. Measure the fruit and add to it twice the quantity of water. Let stand in an earthen dish over night and next day boil slowly until peel is tender. Let stand another night and the second morning measure and add an equal volume of sugar.

Place in covered double boiler and boil slowly for a half hour or until it jellies. The fruit should not be stirred during boiling.

Citrus-rhubarb marmalade. — Take six pounds of fresh rhubarb, four large oranges, four lemons, and one large cup finely chopped walnuts. Cut the oranges and lemons into thin slices, rejecting ends and seeds. Add to the rhubarb, which has been cut into small pieces. Put four large cups of sugar over this and let stand over night. Next morning add four more cups of sugar and boil down. Just before placing in jars and while still hot stir in the chopped walnuts.

CHAPTER XIX

MARKETING

The different methods of selling California citrus fruits may be grouped for convenience under four general heads, which, with the proportion of fruit now (1913–14) sold by each method, are approximately as follows:

13 % Miscellaneous sales.

5 % Sales by independent growers who ship to market.

20 % Independent association sales.

62 % Sales through the California Fruit Growers' Exchange.

Under the head of miscellaneous local sales, fruit is disposed of in various ways. It may be sold either for a lump sum on the trees to itinerant packers and speculators, or it may be contracted for by hotel syndicates to be delivered as needed. The management of the dining cars and eating houses of a large railroad company, for example, often selects certain crops of oranges which are bought for a stated price per pound, to be picked and delivered as needed. Commission men will sometimes secure a contract for a certain amount of fruit of a certain grade to be delivered in the East or in Australia or Hongkong, and then send an agent around the country buying the fruit wherever it can be secured. Such buyers will usually contract with some independent local packing-house for the packing of the fruit.

Under the head of independent grower-shippers are included certain large growers who have sufficient acreage to warrant a packing-house of their own. In most cases such shippers have old and especially favorable connections in certain markets where their reputation is high and their old customers secure. Independent shippers usually have some special or unique advantage which relieves them, to an extent, from the common vicissitudes of the market. The chief stockholder in a large hotel in Chicago or Boston, for instance, who owns a winter home in an orange grove in California, will naturally ship his fruit to his own hotel for consumption.

Independent associations are groups of small growers who have united together in building a coöperative packing-house, yet who for some reason have not affiliated with the Exchange, but sell their fruit through commission men in the various markets. Many of these associations who think they are doing a little better outside the Exchange would quickly join and support the Exchange should it ever appear in danger of failure through lack of support. They prefer for the present, perhaps, to sail in the calm water close under the lee of the Exchange.

THE CALIFORNIA FRUIT GROWERS' EXCHANGE

This great coöperative organization of growers is the child of necessity. The season of 1892–93 was particularly disastrous as far as turning fruit into money was concerned, and the market conditions and arrogance of the railroads were intolerable. Accordingly the Southern California Fruit Exchange was organized in Los Angeles on October 2, 1895, in order to provide certain marketing of the fruit by more uniform methods. Ten years later the name of the organization was changed to the present title.

The California Fruit Growers' Exchange has its home office in the Consolidated Realty Building in Los Angeles. Its organization is tersely described by G. H. Powell, the General Manager,[1] as follows:

"The California Fruit Growers' Exchange is an organization which acts as a clearing house in providing the facilities through which 6500 growers distribute and market their fruit. There are three foundation stones in the exchange system — the local associations of growers, the district exchanges, and the central exchange. The local associations, the district exchanges, and the central or California Fruit Growers' Exchange are organized and managed by the growers on a non-profit coöperative basis, each of them operating at cost, and each distributing the entire net proceeds to the growers after operating expenses are deducted."

The local exchange. — "The California Fruit Growers' Exchange comprises 115 local associations, each of which has from 40 to 200 members. The growers usually organize as a corporation without profit, under the laws of California, issuing stock to each member in proportion to his bearing acreage, to the number of boxes he ships, or in equal amounts to each grower. The association assembles the fruit in a packing-house, and there grades, pools, packs, and prepares it for shipment. The associations are man-

[1] *California Cultivator*, March 13, 1913.

aged by a board of directors through a manager and are conducted exclusively for the benefit of the growers. They declare no dividends and accumulate no profits. The fruit is pooled each month, or for a shorter period, each grower receiving his proportion of the proceeds received for each grade shipped during the pool. Many of the associations pick the fruit, and some of them prune and fumigate the trees for the members. Each association has brands for each grade, and when a carload is ready for shipment it is marketed through the district exchange, of which the association is a member, through the agents and facilities provided by the California Fruit Growers' Exchange."

The district exchange. — "There are seventeen district exchanges. These exchanges are corporations without profit. There may be one or more district exchanges in a community, depending upon the number of local associations and other local conditions. The district exchange acts as a clearing house in marketing the fruit for the associations through the California Fruit Growers' Exchange and acts as a medium through which most of the business relations between the exchange and the local associations are handled. The district exchange orders cars and sees that they are placed by the railroad at the various association packing-houses; keeps record of the cars shipped by each association, with their destinations; informs itself, through the California Fruit Growers' Exchange, of all phases of the citrus marketing business; places the information before the associations; receives the returns for the fruit through the central exchange, and returns the proceeds to the associations."

The central exchange. — "The California Fruit Growers' Exchange is a non-profit corporation under the laws of California. It is formed by 17 district exchanges, with a paid-in capital stock of $1700. It is managed by a Board of 17 directors through a general manager, one director representing each district exchange. The function of the California Fruit Growers' Exchange is to furnish marketing facilities for the district exchanges at a pro-rata share of the cost. The exchange places bonded agents in the principal markets of the United States and Canada, defines the duties of the agents, and exercises supervision over them. It gathers information through them of conditions in each market, receives telegraphic advices of the sale of each car, and furnishes the information every day in bulletin form to the local associations. The exchange business is on a cash basis; it makes prompt accounting of returns to the growers through the district exchanges; takes care of litigation that arises in connection with the marketing of the fruit; handles all claims; conducts an extensive advertising campaign to increase the demand for citrus fruit; develops new markets and performs such other functions as are set forth in the contract between the central exchange and the district exchanges. The central exchange levies an assessment against each district exchange for a pro-rata share of the expense on the basis of the number of boxes shipped. It declares no dividends. It does not buy or sell fruit or any other commodity, and exercises no control either directly or indirectly over sale or purchase. Its function is to provide facilities for the distribution and marketing of the fruit for those shippers who desire such facilities. Under the exchange system every shipper reserves the right to regulate and control his own shipments; to develop his own brands of fruit; to use his own judgment as to when and in what amount it shall be shipped, and the price he is willing to receive, reserving the right of free competition with all other shippers, including the members of the same organization, uncontrolled by any one. The agent in the market acts directly under the order of the shipper, who determines the prices at which each car shall be sold outside of the auction markets, and all other matters connected with its distribution, the California Fruit Growers' Exchange acting as the medium through which orders pass from the agent to the shipper, but never selling a car or determining the price at which the fruit shall be sold.

"The exchange is a democratic organization; the growers exercise control over all matters. Membership in the exchange is voluntary; a grower may withdraw from an association at the end of a year; an association may withdraw from a district exchange, and a district exchange may withdraw from the central exchange, — these relations being set forth in the various contracts that hold the members together. There is no attempt on the part of the central exchange to regulate shipments, to eliminate competition, divide the territory or business, or to influence prices. In this connection its functions are to keep the associations informed daily regarding the shipments from the state; the general movement of exchange cars, the general conditions of the different marketing points; the prices at which the exchange fruit is sold; and in furnishing such other information as will allow the growers and shippers through their association and district exchanges to decide the questions of distribution and marketing for themselves.

"One third of the entire shipments are sold at public auction, the remainder through unrestricted private competition. There is no uniformity in price in the different brands, because the fruit in each section, on account of the soil and other local conditions, has an individuality of its own, and every brand sells on its own merits.

"The exchange is organized into several divisions; sales, legal, traffic, advertising, insurance, and mutual protection, and a supply department which furnishes the materials used in the packing-houses and on the ranches, at cost to the members. The exchange does not consign fruit. It is shipped on order; sold f. o. b.; or sold 'delivered, subject to usual terms.' The exchange maintains district managers in all of the important cities of the United States and Canada. These employees are exclusively salaried agents, engaged only in the sale of fruit, in the development of markets, and in handling the local business problems of the exchange."

The money received by the selling agents for fruit is deposited by them in national banks to the credit of the central exchange, which forwards it to the district exchange and is by them distributed to the growers. The exchange has collected more than one hundred and thirty-nine millions of dollars in addition to freight charges for citrus fruits in the last ten years, and the losses from bad debts to date have been less than seven thousand dollars. The exchange returns (f. o. b. California) for fruit shipped in the season 1913–14 were about eighteen million dollars.

The exchange carries on two forms of advertising.

Space in daily newspapers in all important cities is bought to the extent of $200,000 or more a year. In order to secure the chief benefits of this advertising for the members of the exchange, who pay for it, there has been devised a special quality brand known as "Sunkist" (see Fig. 112), the copyright for which is owned by the exchange. This brand is used by all exchange associations as an additional sticker placed on their best brands only. The tissue paper wrappers used on fruit under this brand bear the "sunkist" emblem and such wrappers are redeemable in part payment for table silverware. This ware is triple plated and of good quality and bears a special orange design. In 1912, 1,750,000 pieces of silverware were distributed in return for orange and lemon wrappers, and the exchange has become the largest single buyer of this class of silverware in the world. In the Chicago office, forty mailing clerks are required to take care of this business.

The expense of maintaining the exchange, including advertising and every other expense, has never been as high as 3 per cent of gross sales, while ordinary commission and brokerage charges of other agencies vary from 5 to 10 per cent for selling alone. In 1914 the total cost of selling, including advertising and the maintenance of the sub-exchanges, amounted to $6\frac{59}{100}$ cents a box.

It is not a difficult matter to organize an association. The money required for incidental and organization expenses will be supplied by the membership fees of five or ten dollars. The money required for building the packing-house and beginning work is usually borrowed from the banks on association notes personally indorsed by the directors. When the sale of fruit begins a small amount to the box is held back with which to gradually pay off the notes. When real property, such as a packing-house and site, is acquired it may be mortgaged for as much as possible in order to relieve the directors of personal liability on the first notes issued. The membership fee should be kept low in order that new members may join at any time as old members drop out for one reason or another. Most associations desire as large a membership as possible, as it is more economical to pack fruit in large quantities and in a large, well-equipped house.

Every association should act squarely and honestly with its customers. Special markets should be developed and fruit of uniformly good grade shipped regularly to those markets regardless of fluctuation in prices. It is usually poor policy to chase high prices by changing quickly from one market to another. It should be the ambition of each association to develop a high reputation for its brands of fruit on certain markets and then stay by those markets through the season, always striving to give good values and please the old customers.

"The distribution of the oranges and lemons of each grower must be uniform throughout the year on a merchandizing basis; neither the grower nor shipper can afford to speculate on the market. The fruit should go forward naturally from each grove during the period when it possesses the best quality for that district. Regular distribution increases consumption; stabilizes the business of the shipper, the jobber, and the retailer. It furnishes the consumer a supply at the lowest average return because the product is handled by every one at a reasonable distributing profit. The distributing cost of citrus fruit after it reaches the jobber, like many other food products, represents approximately 45 per cent of the consumer's cost. Erratic, speculative distribution increases the distributing costs; it results in a lower price to the producer and a higher cost to the consumer."[1]

Some years ago the citrus growers of Florida sent a committee to California to study the methods of the California Exchange. As a result of this the Florida Citrus Exchange was organized in the fall of 1909, and is now a successful organization. About 22 per cent of the Florida Crop of 1913–14 was handled through the Exchange.

Citrus Protective League of California

This is a voluntary organization formed in March, 1906, by representatives of growers, shippers, and shipping organizations in nearly all of the citrus growing localities of the state to handle the public policy questions that affect the industry as a whole. Its purpose is to represent the grower and shipper in handling such questions as: railroad rates and transportation problems; customs tariffs and other governmental relations; state and federal legislation that applies directly to the business, and all other questions of a general nature that affect the upbuilding of the industry, except the marketing of fruit.

The League is directed by an Executive Committee of nine and by a secretary and manager, the Executive Committee having been appointed by an Administrative Committee of thirty of the principal growers and shippers

[1] *Report of G. H. Powell, General Manager, California Fruit Growers' Exchange*, 1914.

who act as a governing committee, and who were selected from the representative delegates who organized the League in 1906. The League represents about 90 per cent of the growers and shippers of the state, and is supported by funds raised by general assessment based on the number of cars of fruit shipped by each member during the preceding year.

In conclusion it may be well to point out that during the last decade the citrus fruit acreage in California has more than doubled. From 1900 to 1914 the size of the crop increased 254 per cent. In order that consumption may keep pace with this rapid increase in production, it is extremely important that the growers loyally support the organizations which are developing a comprehensive, economical, and efficient system for distributing, selling, and advertising citrus fruits.

It is also highly important that a profitable by-product industry be established. A means of disposing of low-grade fruit at home will do more than anything else toward keeping such fruit from glutting the markets and depressing the prices of fancy fruit. This is bound to result in an improvement in the grades of fruit shipped to market, with consequent marked increase in consumption.

CHAPTER XX

PROFIT AND LOSS

If the question is asked, "Does citrus culture really pay?" we are compelled to answer "Yes and no." It pays handsomely where proper conditions are combined with knowledge, industry, common business sense, and capital. It does not pay in many cases where these things are not combined. Some persons make very large, almost fabulous, profits growing citrus fruits, and these examples are widely quoted by real estate agents and land boomers. Other persons lose money consistently year after year. When we consider the total production of any crop in the United States, such as corn, wheat, or cotton, we find the average yield an acre is surprisingly low. Citrus fruits are no exception to the rule. The Citrus Protective League has collected a great deal of data on the cost of production of citrus fruits, and Victor Newland, a student at the University of California, has worked out the average prices received. Such large collections of figures should not be taken too seriously, yet they possess considerable indicative value. It appears that the average box of oranges for the five years preceding 1913 returned a net profit of 15 cents to the grower, while the average box of lemons produced during the same period returned a loss of about

20 cents. And yet skillful growers have commonly made much higher profits on lemons than on oranges, and a good bearing lemon grove will sell for more money to-day than an orange grove of similar age. This means that there have been a larger proportion of failures with lemons than with oranges.

There are, of course, many reasons why some citrus trees fail to pay. Some trees are planted with the object of producing fruit; while others, we regret to have to say, have been planted for the purpose of making it easier to sell the land. There is a great deal of land that will grow a beautiful young tree for a few years, but upon which bearing trees will soon fail. A considerable acreage of either very questionable or impossible citrus land has been planted out in large blocks and then divided up and sold to unwary investors, who in most cases are inexperienced persons newly arrived from other parts of the country. Much citrus acreage is sold by mail to absent buyers, a very bad practice. It is strange how many unsophisticated persons there are in Northern cities who will trustingly send their money by mail to some agent with the request that he "Be sure to select a nice orange grove for them." Where there is such an absolute lack of business sense as this, it is not surprising that there are so many failures.

Absentee ownership is one of the banes of the citrus business. If a person cannot visit his property at least once a month and look after the various operations in person, he should sell out to some one who can.

Another trouble is over-capitalization, which is encouraged by speculation. Many beautiful towns and cities have been built literally in the orange groves and the increase in value of the land for residence and other purposes has increased the capital and taxes to a point where it becomes difficult to make any but the most expertly managed citrus orchards pay.

Many orchards are composed largely of degenerate types of trees; many have been ruined by the mottled-leaf disease; and many are too frequently visited by frost.

Let us not dwell too much on the dark side, however, but hasten to give assurance that any one with sufficient capital, a reasonable knowledge of horticultural operations, and ordinarily good business judgment may easily make a good profit raising citrus fruits, provided he or she is careful to see that the following requirements are satisfied:

1. A location in a proved citrus district, reasonably free from frosts and winds and within hauling distance of a packing-house.

2. An easily worked, fertile, well-drained, deep soil, purchased at a reasonable price.

3. An ample supply of good water.

4. Strong, thrifty, clean trees grown from carefully selected buds of standard varieties.

5. Proper preparation of ground and planting of trees.

6. Personal care of the trees with conscientious cultivation, irrigation, fertilization, and pruning.

7. The exclusion of scale insects and proper treatment for fungus and other diseases.

8. Membership in a local coöperative marketing association.

These may be called the eight fundamental requirements for success. Failure in any one of these requirements may bring about the failure of the grove, although failure does not necessarily follow in every case. On the other hand, if each of these requirements is fairly met, success is as sure as almost any horticultural venture can be. In addition to these things it is advisable for the beginner to coöperate with the neighbors toward the general good of the district by joining loyally in fumigating and frost fighting campaigns. The College of Agriculture should be freely consulted, and the beginner will usually find it to his advantage to enroll for the free correspondence course in citrus fruits conducted by the College.

CAPITAL REQUIRED

The next question to be considered is, "How much money will be needed to meet the eight requirements for success outlined above?" This question permits of no definite answer on account of the very wide variations in costs in different localities and under different conditions. In some localities good citrus land may still be had at $150 an acre, while in other districts it may be considered cheap at $500 an acre.

Water also varies very widely in cost. In some localities where there is comparatively little frost, combined with good soil and other natural advantages, the cost of water has soared surprisingly high. After the local supply has all been appropriated, additional water is often brought from great distances. This is usually accomplished by forming a water company which purchases sufficient water bearing lands and installs the necessary pumping plants, tunnels, and aqueducts. The necessary amount of water stock in such a company (which is the water right) sometimes costs as much as $200 an acre and the annual assessments for pumping expense and repairs may be as much as $40 an acre a year.

The following estimate gives some general idea of the cost of bringing a young grove into bearing in the San Gabriel Valley:

Cost of Bringing a Ten Acre Orange Orchard to Bearing

10 acres orange land	$1500	
Clearing and grading	2000	
Water right	1500	
Trees, 1000 @ $1	1000	
Planting trees at $7\frac{1}{2}$¢ each	75	
Irrigating system	200	
Irrigating and cultivating, 5 years	2000	
Taxes and incidentals, 5 years	250	
Fertilizer, 3 years	250	
Pruning	200	
Total expense		$8975
Returns from fruit less packing charge, 3 years		1200
Total investment at beginning of 6th year		$7775

A well managed orange orchard in full bearing ought to yield 250 packed boxes an acre. Many orchards average much more than this amount. The cultural, packing, and selling costs ought not to exceed $2.00 a box. The average selling price for oranges for the last five years has been about $2.80.

At the time the reduction of the tariff on citrus fruits was under discussion in Congress, the Citrus Protective League made an extensive investigation of the cost of producing oranges and lemons. The publications of the League contain some very extensive tables showing all items of cost in great detail, from which the following figures are taken:

Data on 26,000 Acres of Oranges

Average cost of materials an acre	$83.24
Average cost of labor	52.82
Average cost of crop an acre	$136.06

Data on 4,186,983 Boxes of Oranges

Cost per Box

Picking	$.0771	
Hauling	.0287	
Packing	.3246	
Picking, hauling, and packing		$.4304
Cultural cost		.8633
Freight		.828
Refrigeration		.0789
Selling and collecting		.07
Total cost laid down in market		$2.2706

Data on 1,391,711 Boxes of Lemons

Cost per Box

Cost of growing	$1.000
Cost of picking	.253
Cost of hauling	.039
Cost of packing	.596
Cost of freight	.840
Cost of refrigeration	.026
Cost of selling	.070
Total cost laid down in market	$2.824

In estimating the amount of capital required to conduct a bearing citrus orchard for a year, the following figures, also taken from the League reports, may be found of value. The cost of superintendence, administration, and depreciation are omitted :

Cost of Operating Bearing Grove an Acre a Year of	Oranges	Lemons
Cultivating	$18.00	$20.00
Pruning	8.00	22.50
Irrigating	7.50	12.00
Fumigating (materials and labor) when necessary	18.00	20.00
Spraying (when necessary)	7.50	7.50
Spreading fertilizer	2.50	2.50
Other tree care (propping, caring for sick trees, etc.)	3.00	5.00
Chemical fertilizer	30.00	35.00
Barnyard manure (when used)	30.00	30.00
Water	18.00	20.00
Forage and grain (feed for work stock)	20.00	20.00
Taxes	12.00	10.00
Maintenance and repairs	7.00	7.00
Incidentals	2.50	2.50
Frost protection (when used)	30.00	40.00

The above columns of figures are not added for the reason that no orchard requires all of these expenditures in any one year. The same orchard would not be fumigated and sprayed, and manure would not be applied every year as sufficient supplies are not available. These figures are also open to the objection that they represent averages between different districts and hence are not strictly typical of any one district. Inasmuch as they are susceptible to such wide variations, they should be accepted as rough approximations only. See also statement No. 1 on pages 162 and 163.

The Citrus Protective League has published the following figures on average yields including all varieties of oranges and lemons.

Year	Oranges ave. 26,000 Acres Boxes per Acre	Lemons ave. 6137 Acres Boxes per Acre
1906–7	150.1	149.1
1907–8	129.5	187.1
1908–9	167.2	220.9
1909–10	136.7	196.1
1910–11	191.0	211.2
Average for 5 years	157.6	196.2

The average f.o.b. price received for oranges for the last ten years is about $1.50 per box and for lemons $2.00 per box.

JUDGING ORCHARDS AND LANDS

It is poor policy to examine a piece of prospective land or a bearing orchard without a program. This is especially true when different propositions are to be contrasted with a view to deciding on a purchase. Many inexperienced people buy land without digging into it, but this practice cannot be too strongly condemned. In arid countries surface indications are not reliable guides as to what may be expected below the surface. Holes should be dug at least six or seven feet deep in various places and the soil examined for changes in character, hardpan, stone, and so on.

It is suggested that the following list of points be used in going over every piece of land. Each point may be weighted after the fashion of a score-card and thus accurate comparisons between different propositions made easier.

Score-card for Citrus Land

1. Freedom from frost.
2. Water; legal right, amount, quality, cost.
3. Kind and quality of soil. Topography.
4. Continuity of tract and freedom from waste land.
5. Freedom from stones and brush. Cost of clearing and grading.
6. Freedom from hardpan.
7. Freedom from alkali.
8. Drainage outlet.
9. Susceptibility to wind.
10. Distance from scale infested orchard.
11. Nearness to town.
12. Nearness to packing-house and railroad siding.
13. Quality of roads.
14. Price per acre.

Additional Points for Bearing Groves

15. Uniformity and yield record of trees.
16. Freedom from scale insects.
17. Freedom from mottled-leaf and other diseases.
18. Condition of trees as to pruning and general care.
19. Adaptability of variety to district.

CHAPTER XXI

DISEASES AND THEIR CONTROL

CITRUS trees are susceptible to a large number of diseases, some of which are due to the attacks of parasites and some to physiological derangements of nutrition. Practically all of the fungus diseases have been investigated by scientists and are fairly well understood, while comparatively little progress has been made in the study of physiological diseases. In Florida and some other humid citrus growing regions the fungus troubles are most common, while in California and other places where the climate is more or less arid the fungus troubles are less abundant and derangements of nutrition due to unfavorable soil conditions, alkali, excessive heat, and perhaps to excessive illumination and transpiration are very frequently met with.

GUM DISEASES

Citrus trees are apt to excrete gum from a number of different causes, some of which fall in each of the classes mentioned above.

Brown Rot Gum-Disease

Among citrus growers this trouble is usually known simply as "gum-disease." Until recently it was thought to be due solely to physiological causes. H. S. Fawcett has now shown that the true cause is none other than that old enemy of the citrus grower, the brown rot fungus *Pythiacystis citrophthora*.

Fig. 128. — The Fawcett method of treating gum-disease. Note types of scrapers.

Brown rot gumming is most common on lemon trees and is characterized by a copious exudation of gum from the trunk just above the bud union. A certain area of bark surrounding the gum dies, becomes hard and dry with no outer evidence of fungus growth, and is often pushed slightly away from the cambium by the pressure of the rapidly forming gum. This kind of gum-disease may be largely prevented by avoiding the soil conditions most favorable for the growth of this soil-inhabiting fungus. No water should be allowed to stand in contact with the trunk. Heavy or adobe soils should be kept well worked under the trees and prevented from being mounded against the trunks. It will do no harm to draw the surface soil away from the trunks, even exposing the crown roots, provided the irrigation water is prevented from running into the basin thus formed.

The fungus gains access to the tree either through abrasions of the bark or directly through the lenticels or breathing pores. The bark of the sour orange is very resistant to infection and trees budded six or more inches high on sour stock are quite resistant.

When a case of brown rot gumming is discovered, the tree trunk should be treated by cutting away every particle of diseased bark and painting the trunk with bordeaux mixture paste, made as follows: one pound of bluestone and two pounds of unslaked lime with water to make a thick whitewash. It is advisable on all heavy, fungus infested soils to apply this paste as a preventive to all healthy trees so situated as to be liable to gum-disease. This treatment should be repeated every second year at least.

Botrytis Gumming

Another form of gum-disease is caused by the fungus *Botrytis vulgaris* and is fairly common on old lemon trees growing on low, heavy soils. It occurs on the trunks and is characterized by a much less copious flow of gum but a much more general infection. The outer bark becomes soft and dies gradually from the outside inward, differing radically in this respect from the brown rot gumming. In moist weather the disease is accompanied by cushions of small dark gray fruiting bodies scattered over the surface of the dead bark.

The proper treatment is to scrape off the outer dead bark, leaving the inner bark wherever it is alive, and applying the bordeaux paste. Special tools have been developed for scraping and they should be kept in the bucket of paste when not in use. The application of bordeaux paste to healthy tree trunks is suggested as a good preventive for this disease.

Scaly-bark

The sweet orange alone is subject to this form of gumming which occurs in patches quite generally over the trunk and large limbs to a considerable height. In this case the outer bark breaks and comes away in small, dry scales, leaving the living bark underneath with a rough and noduled appearance and with a large number of small gum pockets which exude only a small amount of gum. In severe cases, the infected tree or branch drops its leaves, and after languishing for a year or two, finally dies. In some cases, large vigorous trees may support a few scaly-bark patches for many years without any serious reduction in crop. While this disease has been investigated for a number of years, the cause has not yet been discovered, and no satisfactory treatment is known. Where the disease occurs only on the branches, they should be cut off below the diseased area and burned. Where the disease occurs on the trunk, it is advisable to scrape the bark thoroughly and apply bordeaux paste, inasmuch as in certain instances this has appeared to be of some value.

Twig Gumming

Young trees and nursery stock are sometimes affected with gumming of the twigs which is apparently caused by copious irrigation when the soil has become too dry. The gum breaks out along the small twigs all over the tree with splitting of the bark, dropping of leaves, and dying back of twigs. Vigorous trees always recover and the trouble may be prevented by giving due attention to regular irrigation. Sometimes this form of gumming is caused by a period of desiccating north wind. Such winds do not affect the mature wood, but often cause the bark to split and drops of gum form on vigorous young shoots.

Leaf Gumming

This is very common, especially on orange trees, in hot localities. Dark reddish colored, slightly raised spots or areas appear on the leaves in places where they have been turned up and the under side exposed to the sun or frost. These spots are formed by the secretion of a gum-like substance in the tissue just under the epidermis and are simply the result of sunburn or frost injury at a time when the leaves are young and tender. The trouble is not serious and need not be feared.

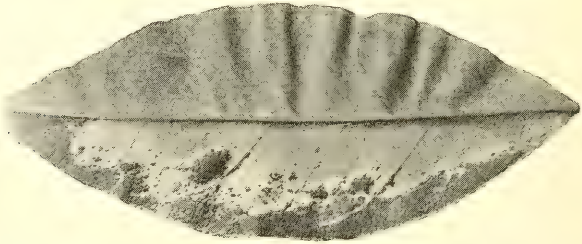

FIG. 129. — Reddish gum areas on under side of leaf caused by sunburn.

Gumming of Seed Bed Stock (Pythiacystis citrophthora)

It often happens that the brown rot fungus, becoming established in the soil used for seed beds, will infect large numbers of sweet orange seedlings, especially where the soil is allowed to become too wet. Many of the seedlings are girdled at the surface of the ground and entirely ruined and have to be discarded when the plants are dug for sale. Sour orange plants are somewhat more resistant, but even they will sometimes show a considerable amount of gumming, as immunity to the brown rot fungus is not fully acquired until after the plants have been transferred to the nursery row.

In order to prevent this trouble, the surface soil should be kept as dry as the health of the plants will permit. When the first indication of disease is noticed, the beds should be thoroughly sprayed with bordeaux mixture, applying the liquid in quantities sufficient to drip down and moisten the entire surface of the soil.

Exanthema or Die-back

This disease was first described as occurring in Florida in 1875 and has since assumed great economic importance, having appeared in every citrus growing district in that state. The annual losses directly attributable to exanthema are very heavy.

In California and Arizona, however, the losses sustained from the effects of this disease have been comparatively light. It has been reported from several localities in southern California, but in very few cases has the outbreak been widespread or sufficiently severe to attract very much attention.

There is a widespread misunderstanding in regard to the term "die-back." There is of course a dying back of the branches due to any one of a very large number of causes, such for example as mottled-leaf, cottony-mold fungus, frost, and the like. Seeing dead twigs in their trees, many persons are apt to jump to the conclusion that the trouble is die-back, which presents itself to their minds as a vague though no less terrible malady, the symptoms of which they do not clearly understand. The term "exanthema" is a Greek word meaning an eruption or pustule which was given to this particular disease by Swingle and Webber in 1896 and is much to be preferred to "die-back." There is only one exanthema but there may be many kinds of die-back.

Exanthema has more symptoms than almost any other plant disease, and there is little excuse in failing on a diagnosis. The first indication of exanthema appears as an abnormally dark green color of the leaves near the center of the tree. This is followed by a dying back of the young growth with the formation of small swellings or gum pockets at the nodes. These often crack open and tears of gum are exuded from the very young twigs, while the cracks on larger twigs appear filled with a red or brown gummy substance. Often affected twigs will attempt a new growth but succeed only in forming clusters of sickly, pale colored buds in the axils of the leaves. Water sprouts often arise from healthy wood below the diseased tissue, which in turn may or may not become affected. The fruit on badly affected branches either falls or remains small and pale yellow in color. Usually the fruit which reaches some size exhibits a very characteristic dark brownish red stain which appears as irregular patches of gummy material laid over the surface. These red areas are usually slightly elevated, and badly affected fruit often splits open longitudinally while hanging on the tree. Affected fruit is usually abnormally thick skinned, contains numerous

FIG. 130.—Exanthema pustules on Valencia orange twigs.

gum pockets at the center, and in the case of oranges has an insipid sweet taste. In many cases exanthema is accompanied by mottled-leaf, although this is probably merely a coincidence, as there is no known connection between the two diseases. Exanthema is most common on the orange although it has been found by the writer on both lemon and pomelo.

From all its appearances exanthema would naturally be supposed to be a fungus disease, but this appears not to be the case. A great deal of scientific investigation has been expended, but as yet no fungus or other parasite has been found connected with the trouble. Experiments have shown moreover that the disease can be produced in healthy plants without the aid of any parasite whatever. For these reasons it is considered to be a physiological derangement of the vital functions caused by irregular or improper food and moisture supply; in other words, a form of plant indigestion. Citrus plants appear to be especially susceptible to various forms of malnutrition.

In Florida the cause of this condition has been fairly well established. It has been found to be due to an excess of ammonia in the soil resulting from applications of stable manure or other form of organic nitrogen. Florida growers are almost certain to have exanthema if they apply large amounts of dried blood or cottonseed meal, or plant the trees on land previously occupied by cattle pens or chicken yards. By being scrupulously careful to avoid these things Florida growers have been able to reduce the amount of exanthema to a minimum.

In California, however, the conditions are very different. Here growers apply organic manures in very large amounts with apparent impunity, as far as exanthema is concerned. Why this marked difference should exist is certainly a mystery, but it exists nevertheless. The chief causes of exanthema in California are improper soil drainage and faulty soil structure; or as Lipman has recently suggested, the direct cause may be an abnormally slow nitrification in the soil accompanied by abnormally rapid ammonification, thus forcing the plants to take up ammonia compounds.

Exanthema may be cured entirely by the removal of the conditions causing the trouble. Where ground water is the cause, the land may be drained, but where an open porous subsoil allows the water to pass down, but on account of its open nature does not permit the return of the water by capillarity, the remedy is very difficult or impossible. Such lands should not be planted to citrus fruits.

Mal-di-gomma or Foot-rot

In European citrus districts as well as in Florida foot-rot has caused heavy losses. In California, however, it is comparatively rare. It is thought to be caused by a fungus of some kind which produces rotting of the roots quite distinct from that described above. The decay starts in the bark of the main roots, which becomes soft and slimy, and gradually spreads from the surface of the ground downward. This is accompanied by a yellowing and dropping of the leaves in that part of the top directly over the diseased roots. When disturbed, the rotten roots have a peculiar and offensive odor.

Lemon roots are quite susceptible, sweet orange somewhat less so, while sour orange is quite resistant. Apparently the only conditions under which the disease can exist are extremely poor drainage and very wet, heavy soil about the roots. Badly diseased trees are difficult to revive but may be replaced provided the soil conditions are improved.

The use of sour orange stocks together with good drainage and aëration of the soil are the best methods of prevention.

Toadstool Root Rot

Most mushrooms grow only on dead material but there are some which are actually parasitic on living plants. The mushroom known as *Armillaria mellea* has caused heavy losses of fruit trees both in Europe and America. The fungus is native to the roots of oak and some other trees and occurs most commonly on lands previously occupied by oak trees. After the oak trees are cut down, the fungus lives for some years on the dead roots in the soil and should citrus trees be planted on the land at once, their roots are very likely to become infected. The fungus usually kills the tree in from two to four years, although in some instances diseased trees may remain alive, though unprofitable, for an indefinite period. In affected trees, usually only a part of the top dies at first, the dead branches gradually increasing in number. If the roots are examined, certain ones will be found decayed and soft. Just under the bark may be seen fan-shaped pieces of felty white fungus with the not unpleasant odor of fresh mushrooms. Soon after a root is attacked there may be seen along the side, and closely appressed to the bark, the rhizomorphs or long black strands of the fungus which resemble hay wire, although very crooked. During prolonged periods of rainy weather, the fungus sends up from the diseased roots large clusters of a dozen or more toadstools which are brownish tan in color, six to ten inches high, and each one, where not crowded, three or four inches broad on top. Armillaria lives only on the roots of the trees and cannot remain for any length of time in soil which contains no tree roots. There is no danger (as some think) of increasing the spread of the fungus from tree to tree by application of barnyard manure.

From the nature of this trouble it is apparent that no such remedy as spraying the foliage can have the least effect on the disease. There is at present no satisfactory remedy. It is not known whether sweet, sour, or pomelo root stocks are equally susceptible. It is urgently recommended that four or five years at least be allowed to elapse between the digging out of all oak roots and the planting of citrus trees, in order that the fungus may die out. During this time, the land may be planted to vegetables or alfalfa if water is available.

Mottled-leaf

For the past ten years a very peculiar and baffling disease of citrus trees has been gradually extending through southern California. It is known as mottled-leaf, and up to the present time has been considered to be a derangement of nutrition due to physiological causes. This disease is probably the most serious problem now before the California citrus growers. The injury to some of the finest orchards in the state has amounted to millions of dollars in the aggregate.

Mottled-leaf is a kind of chlorosis of which there are several common on citrus trees. Mottled-leaf, however, is the only form which is widespread or very serious. The trouble first appears as light colored areas situated between the veins of the leaves. The contrast between the color of the veins and interspaces is very striking. Mottled leaves are found only towards the ends of the shoots and represent leaves in which the green color has never completely developed, rather than those in which the chlorophyll has once existed and then disappeared. Leaves which are once green never become typically mottled, although they may become lighter

Fig. 131. — Mottled-leaf disease on Eureka lemon.

in color or even bright yellow, as in other forms of chlorosis. As the mottling increases there is a decided shortage in yield of fruit and in bad cases the fruit present is very small, and turns pale yellow or white when about an inch in diameter. There is considerable dying back of the branches and many sickly shoots put out along the trunk and large limbs. In a good many symptoms this disease is similar to peach yellows.

Mottled-leaf affects all kinds of citrus trees, regardless of the kind of stock they are budded upon. It affects other trees also, including elm, maple, camphor, eucalyptus, and particularly Japanese privet. The disease occurs in many parts of the world, but apparently it has been seriously destructive only in California. It is quite general in the Riverside-Redlands district, at Corona, Rialto, Bloomington, Pomona, and Covina. In San Diego, Ventura, and Santa Barbara counties it is much less severe. It occurs in parts of Tulare County. In the Sacramento Valley it is as yet exceedingly rare in spite of the fact that many carloads of slightly mottled nursery trees from southern California have been set out.

A great deal of scientific investigation and study has been put upon this disease and a great many theories have been advanced as to the cause. Up to the present time the true cause has not been definitely proven nor has a satisfactory remedy been clearly demonstrated.

Some years ago the writer, working on the hypothesis that mottled-leaf, like peach yellows, might be transmitted by buds used in propagation, performed the following experiment: buds from badly mottled twigs of both oranges and lemons were inserted in healthy sour orange stocks. On account of the weakness of the buds only a few grew, but these finally grew up into as healthy trees as any in the nursery.

This showed that mottled-leaf is not transmitted by budding.

In 1910 R. R. Snowden[1] advanced the theory that mottled-leaf was due to an excess of magnesia or an improper ratio between magnesia and lime in the soil. Snowden showed that the soils of some healthy groves averaged about 2.5 parts of lime to 1 of magnesia, while the soils from sickly groves averaged 1.18 of lime to 1 of magnesia. This theory was much discussed at the time, but subsequent study brought to light so many exceptions to the supposed rule that the theory was greatly weakened. Heavy applications of lime moreover have by no means proved a cure for the disease.

Fig. 132. — Advanced stage of mottled-leaf disease showing formation of multiple buds.

[1] *California Cultivator*, Aug. 11, 1910.

Some prominent citrus growers have held that starvation or a lack of humus in the soil is the cause of the trouble. In answer to this it may be said that some of the worst affected groves in the state are situated on apparently ideal soil and are among those best fertilized and otherwise well cared for.

Mottled-leaf is much more prevalent on sandy and gravelly soils than on heavy adobe soils. In orchards where a certain area or streak of mottled-leaf runs through the orchard this usually corresponds to an area where the subsoil differs much from the top soil, usually being more coarse and open. This has led Smith[1] to conclude that "the most prevalent and typical form of mottled-leaf is due to an irregular supply of moisture and plant food."

In 1912 J. R. Hodges, an horticultural inspector at Covina, California, noticed nematode worms in the soil near the roots of trees suffering from mottled-leaf. He advanced the theory[2] that the disease was caused by these nematodes. The matter was further investigated at the University of California Pathological Laboratory at Whittier where it was discovered that the nematodes were actually parasitic on the roots. E. E. Thomas of the laboratory staff published a preliminary report[3] on the distribution of nematodes in the state and the possible relation between the worms and the disease. The nematode theory was by far the most plausible of any offered up to that time and at once attracted the attention of many scientists to the problem, which was now attacked from an entirely new angle. The name with a description of this nematode worm is given in Chapter XXIV.

Several years will be required for the definite working out

[1] R. E. Smith, *Cal. Sta. Bull.* No. 218, p. 1139.
[2] *Cal. State Com. Hort. Mo. Bull.*, Vol. II, No. 6, p. 555.
[3] *University of Cal. Agr. Exp. Sta. Cir.*, No. 85, February, 1913.

of the relation between nematodes and mottled-leaf. Meanwhile a great deal of survey work is being done. The theory is still held in abeyance on account of the fact that the worms are not always found on the roots of mottled trees and they are occasionally found in small numbers on the roots of apparently healthy trees. Experiments are now being carried on with potted trees in sterilized soil which has been inoculated with the nematodes.

In May, 1914, Kellerman and Wright [1] published the theory that mottled-leaf was commonly caused by nitrogen starvation following the plowing under of mature straw rather than a green cover-crop. It was explained that the mature straw contained large amounts of cellulose and that the molds and bacteria which decomposed the cellulose in the soil used up the available nitrate nitrogen present in the soil. They suggested further that in maintaining the humus of citrus soils, green, succulent materials be used rather than mature or dry straws. While this theory appears to be borne out by greenhouse experiments it is considered inadequate to account for any large proportion of the mottled-leaf disease in California.

Perhaps the most plausible theory yet offered is that recently published by Chas. B. Lipman.[2] It is explained that a poor nitrifying power on the part of the soil, with the ammonifying power remaining normal, may result in the change of practically all the nitrates in the soil to ammonia compounds. It is further shown that while some plants, such as rice for example, prefer their nitrogen in the form of ammonia compounds, that such compounds are actually

[1] *Jour. Agr. Research*, Vol. II, No. 2, pp. 101–113.

[2] "The Poor Nitrifying Power of Soils a Possible Cause of Die-Back in Lemons." *Science*, n. s., Vol. XXXIX, No. 1011, May 15, 1914.

poisonous to citrus trees, which show a decided preference for nitrates. With the condition in the soil favoring slow nitrification and rapid ammonification the trees are forced to take ammonia compounds or go without nitrogen entirely, as in many California soils the ammonia resulting from the decomposition of organic matter is actually set free in the air and lost entirely. Experiments are now being performed in the hope of finding a practicable method of treating orchard soils which may accelerate nitrification and at the same time retard ammonification.

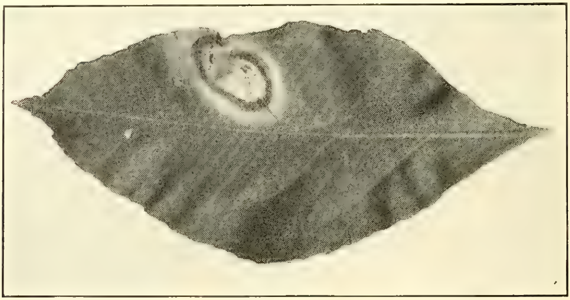

FIG. 133. — Spot on old lemon leaf due to wither-tip.

Wither-tip (*Colletotrichum glœosporioides*)

This disease is said to be quite common in Florida and especially on limes in Cuba, causing a spotting of the old fruit and leaves, killing back the twigs, and causing the young newly set fruit to drop off.[1] In California, however, it ap-

[1] A recent investigation at the University of California has shown that in Cuba and Florida, two distinct diseases have been confused. The killing and deforming of young foliage and fruits of the lime are due to a fungus which somewhat resembles *Colletotrichum glœosporioides* but is entirely distinct from it. This

pears to be of little practical importance, for although the fungus has long been present in abundance throughout the citrus growing areas, it very rarely attacks healthy trees as an active parasite. On senile leaves or young leaves weakened by fires, frost, fumigation, or otherwise, it causes dead spots, on the surface of which may be seen the minute black fruiting bodies of the fungus. The fungus occurs also on twigs weakened from any of the above mentioned causes. Trees suffering from gum-disease, foot-rot, gopher injury, alkali, or from other troubles, often show an abundant growth of wither-tip. Spraying with bordeaux mixture will reduce the amount of the fungus, but perhaps a more logical procedure would be to remove the causes of weakness and promote a healthy and disease-resistant growth. In certain rare cases, especially in very wet, cold weather and near the coast, it is possible of course that this fungus may occasionally act as a true parasite, in which case spraying with bordeaux mixture is a simple remedy. Certain very small red or salmon colored spots which sometimes occur on lemons in Ventura County have been found to be due to this fungus.

It may be added that chiefly on account of its common name, "wither-tip," orchardists are very apt to refer to a large number of their tree troubles as wither-tip which are in no way attributable to *Colletotrichum glœosporioides*.

new fungus has been called *Glœosporium limetticolum*. It causes a very injurious disease of limes and may attack lemons under artificial conditions but has not been known to do so under natural field conditions. Oranges and pomelos are not attacked. Extremely warm and humid atmospheric conditions are necessary for the development of the fungus, and it is not known to occur in California. See Clausen, R. E., "A New Fungus Concerned in Wither-Tip of Varieties of Citrus Medica," *Phytopathology* II, 6, 217, December, 1912.

When lemons which have been grown in the warmer sections are stored for a long time they finally break down with a soft rot at the center known in the packing-houses as "old age decay" or "core rot." The general exterior appearance of the lemons may be normal, but when pressed between the fingers they collapse. This decay is not yet clearly understood but is probably due primarily to the wither-tip fungus, which usually kills the buttons after they have been weakened by age. Later, as the fruit ages and becomes less resistant to encroaching organisms, a species of *Alternaria* penetrates the fruit by way of the dead button, following and turning brown the central core of pith and also the fibrovascular bundles as they radiate through the spongy tissue of the rind. The juice vesicles seem to be the last to be affected. After the vascular system is broken down the lemons lose their elasticity and appear dead to the touch. Fruit in such a condition should not be shipped, as it has very poor carrying qualities and decays very quickly when exposed for sale in warm weather. The chief remedy for this trouble is to avoid allowing the fruit to ripen on the trees, and to store in houses where the temperature may be accurately controlled. When the buttons succumb to wither-tip the fruit should be closely watched and hurried to market at the first indication that the fungus is entering the fruit.

Twig blight (*Sclerotinia libertiniana*)

All kinds of citrus trees sometimes exhibit a sudden withering and dying of small twigs and occasional branches up to one inch in diameter. The green leaves suddenly wither and remain attached to the twig, which dies from the point of infection outward, and with its dead leaves shows very prominently in the green foliage of the tree as though it had been broken and remained hanging. At the point of infection a few drops of gum usually form. During rainy weather the sclerotia (small black bodies a little larger than a grain of wheat) will often be formed on the outside of the bark near the point of infection. Sclerotia rarely form in hot, dry weather. Apparently, infection can only occur by spores finding lodgment in abrasions of the bark. While the spores of this fungus are very plentiful in southern California, often causing serious losses in the packing-houses, yet for reasons not at present understood, blighting of the twigs is so rare as to cause but little damage. While the casual observer may notice a blighted twig here and there in almost any orchard either of oranges or lemons, it has never been reported as doing sufficient damage to the trees to warrant remedial measures. This trouble is very often mistaken for wither-tip. As a matter of course all blighted branches should be removed when the trees are pruned.

This fungus has also been found on the bark and roots of old trees. The bark is decayed and, when dried out, comes away in fibrous shreds very characteristic of this fungus. Remedial measures for this form of the disease have not been worked out. Meanwhile the treatment advised is to cut away all diseased tissue and paint the wound thoroughly with bordeaux paste.

Cottony mold (Sclerotinia libertiniana)

The same fungus described above develops not only on citrus twigs but upon the vetch used as a cover-crop and on orchard soils. The sclerotia which form on the twigs and on the vetch finally dry and fall to the ground. The following rainy season, after being thoroughly moistened they give rise to small funnel-shaped toadstool-like bodies which produce the spores of the fungus in great quantities. These spores apparently require an abrasion in order to germinate and grow in the fruit. Once the fungus has begun growth in a lemon its progress is rapid. A large amount of white

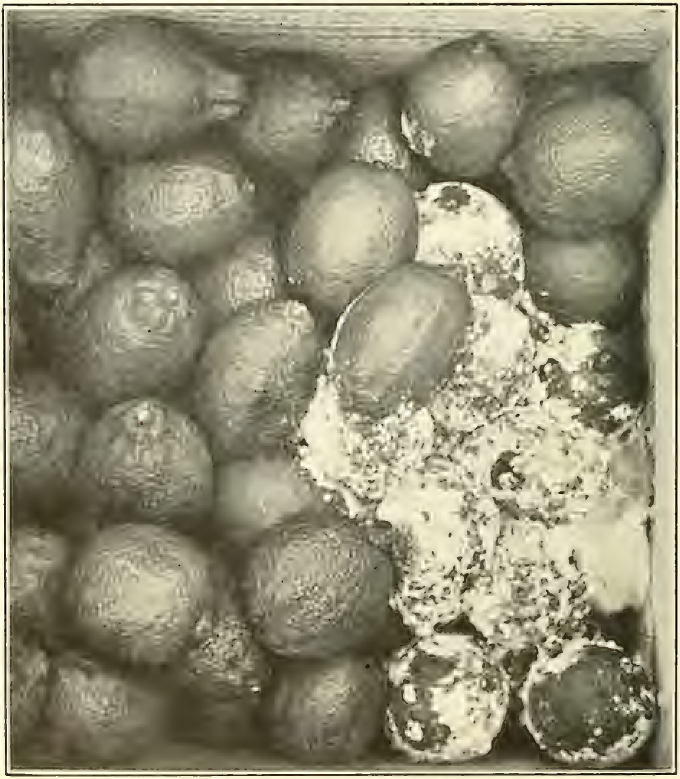

Fig. 134. — A "nest" of cottony fungus.

cotton-like mycelium is produced in which the characteristic black sclerotia are formed. An important point to bear in mind is the fact that while the spores of the fungus require an abrasion for inoculation, the white mycelium is abundantly able to grow into and infect a perfectly sound lemon at any point. The decay is often very serious in stored lemons, the fungus spreading rapidly in all directions from the lemon originally infected. Unless discovered and removed in time cottony mold often destroys an entire half-box or even a whole stack of stored lemons. For this reason packing-house men are always on the watch for "nests" of the cottony fungus, carefully removing the source of infection as soon as discovered, and disinfecting the contaminated boxes with very strong bluestone solution.

The disinfecting solution used in the wash-water against brown rot does not kill the thicker walled spores of this fungus; in fact, bluestone solution of sufficient strength to kill the spores would produce serious spotting of the lemons. Preventive measures must therefore be taken in the orchard when the lemons are picked. It is suggested that the lug-boxes be placed on bare ground or at least not left standing for days in the vetch where the spores of the fungus are produced. Empty boxes so placed may easily become dusted with spores, and inasmuch as it is the custom in many houses to submerge the full lug-boxes in the wash-water as the lemons are gently emptied, the spores are readily transferred to the water. The cut surface of the stem of the lemon where it was severed from the tree affords ample opportunity for spore infection in the washing-tank.

Cottony mold is most severe on lemons and occurs sporadically, being worse in certain sections and in certain years. It may be wise to temporarily discontinue the use of vetch as a cover-crop in orchards where cottony mold has become well established.

Brown rot fruit decay (*Pythiacystis citrophthora*)

It has been shown that this fungus causes gum-disease of the tree. It also causes a serious decay of the fruit. The fungus lives normally in the soil even at considerable depths. It comes to the surface during wet weather in winter and produces spores on the surface of the ground, especially in damp, shady places, such as under citrus trees. The spores are motile and can swim around in a thin film of water. The drip from the tree splashes these spores upon fruit hanging within two or three feet of the ground. The spores enter the stomata or breathing pores, germinate, and grow within the fruit, producing a soft, watery decay which has a peculiar brown color and a characteristic odor. All citrus fruits are affected, but lemons are especially susceptible. During wet winters, the losses from this cause are often very great. The decay spreads rapidly in the packing-house as the mycelium is able to infect perfectly sound fruit by contact. If not discovered and removed, the decay starting from one lemon may run through an entire box or a stack of boxes in storage, and, in a short time, reduce the whole to a watery mass.

Fortunately a simple and very effective remedy is now in use in all packing-houses. The spores of the fungus being very thin walled are extremely susceptible to copper sulfate, and in order to free any packing-house of this pest it is only necessary to add bluestone to the wash-water. The common practice is to add $1\frac{1}{2}$ pounds of bluestone to each 1000 gallons of water in the morning and then fortify this with an additional pound at noon after considerable fresh water has entered the tank. As bluestone attacks metal, wooden or cement tanks should be used. Some prefer metal tanks coated with asphaltum. Should the wash-water contain alkali the bluestone may be neutralized, and in such cases a chemist should be employed to study the water and advise as to the proper procedure to keep the solution of bluestone as near as possible at a strength of $\frac{1}{50}$ of one per cent.

In order to reduce to a minimum the loss of lemons on the trees it is advisable to keep the branches pruned up somewhat from the ground, and summer cultivation should extend well under the trees. It has been found well worth while also to spray the ground under the trees each fall before the rains begin with bordeaux mixture, as this largely prevents the fungus from fruiting at the surface of the ground.

Blue mold (Penicillium italicum) and green mold (P. digitatum)

Most of the decay of citrus fruit is due to blue and green molds. Being only very slightly parasitic on uninjured fruit, the decay is practically confined, under ordinary conditions, to fruit which has been injured in handling. The spores of these fungi are very common in the air everywhere and are almost sure to get into any slight abrasion of the skin of fruit. They produce a soft rot while the fungi fruit abundantly over the surface, the spores appearing as a blue or a greenish powder according to which species is present. Frequently the two kinds occur together, although the green is the most universal. For all practical purposes these two species of penicillium may be treated as one. About the only difference is the color of the spores and the fact that in pure culture the blue mold shows a wider band of white exposed mycelium between the fruiting area and the sound skin. The universal preventive for these decays is careful handling of the fruit in field and packing-house, which, if conscientiously enforced, will reduce the losses to a minimum.

Gray mold (*Botrytis vulgaris*)

Occasionally lemons while in storage will develop what is known as gray mold. It appears as a dark brown discoloration and softening which is followed by the mycelium which appears at the surface and produces gray or mouse-colored spores. The fungus is apparently dependent on abrasions for access to the fruit and would no doubt be much more abundant were it not for the fact that the blue and green molds usually monopolize such opportunities for development.

Black rot of Navel orange (*Alternaria citri*)

Navel oranges only are subject to black rot which may be recognized by the premature ripening, abnormally large size, and very deep red color. The affected fruits are very conspicuous on the trees before the main crop has colored up. The spores of the fungus gain entrance at the navel end through slight imperfections of the peel or perhaps through the stigma of the blossom, and produce a black, decayed area under the skin. This decay does not immediately spread through the entire

Fig. 135. — Black rot of Navel.

fruit, but remains for weeks as a small black mass of fungus. Decayed tissue may occasionally extend to the surface, but more often this is not the case and the fruit finds its way into the hands of the consumer.

There is no known remedy for this trouble which occasionally affects as much as one per cent of the crop in certain localities. It is suggested, however, that all affected fruits should be gathered up and burned in order to reduce the number of spores in the orchards.

Brown spot of Navel orange

The brown spot of the Navel orange may be described as occurring irregularly over the surface of the orange. From one to fifty or more spots may develop on a single fruit. The spots vary in size from a mere point to one inch in diameter, averaging about one-fourth inch. In outline they seem to follow no rule and may be quite irregular, although the circular spot is most common. The color of the spot varies in different localities from a pale brown, which attracts little notice, to almost black, in which case the good appearance of the fruit is ruined. The eating qualities of spotted oranges are not injured in the least. The color of the spot seems to be lighter near the coast and darker in the interior valleys. Losses from brown spot have been heaviest from the upper San Gabriel and Santa Ana valleys, because in these regions the spotting is more common and the color changes to a darker brown. On the other hand, the fruit from many of the packing-houses near the coast shows brown spots of such a pale tint as to attract no notice on the market. The spots are darker on early picked fruit, and it seems to be true that if the fruit is left on the trees until very late it will not spot at all. The spots are slightly sunken on account of the fact that the surface cells have collapsed. The dead and collapsed tissue extends from the surface to about one-fourth the thickness of the rind. No spots are visible while the fruit is on the trees and as a rule the spots are not noticeable till from 15 to 25 days after picking. On this account it is not possible to grade against this spot in the packing-houses, unless storage houses of sufficient capacity are built to hold the pickings of three or four weeks.

Fig. 136. — Brown spot of Navel orange.

The brown spot has been observed so far chiefly on the Washington Navel orange, and dealers have complained of it only on this variety. In 1914 the writer received specimens of Valencia oranges from Highland which had been picked about the first of June which showed almost typical brown spot. The color was lighter and less damaging than usually occurs on the Navel. Spotting is uniformly worse on fancy, smooth, thin-skinned fruit. The fruit which grades highest as it comes from the orchard always spots much more than the rough fruit, which often remains exempt. Examination of the spots with a hand lens fails to show any abrasion or opening in the epidermis.

Orange packers have been complaining of the brown spot for only four or five years, but it is probable that it has existed, though varying in severity, as long as the Navel orange has been cultivated in California.

Up to the present time neither the primary cause nor a remedy has been discovered. After an extended investigation the writer was led to conclude [1] "That the direct cause of brown spot is the oxidation of the protoplasm by enzymes which occur in the protoplasm itself but which are prevented from acting as long as the orange is joined to the tree and receiving water and certain nutritive substances from the tree. Thus the resistance of the protoplasm to enzyme encroachments gradually grows less from the time the orange is picked." This conclusion merely takes the real question one step farther back, for the practical citrus men will, of course, wish to know the primary causes which bring about such premature death. This question cannot be answered at the present time.

Damping-off (Rhizoctonia sp. and Fusarium sp.)

Citrus seed-beds are often seriously injured by damp-off fungi. The very young plants begin to die in spots which, rapidly extending, involve large areas if not checked. Two forms of the disease are recognizable, one caused by the Rhizoctonia which kills the stem just above the ground, while the other shows itself in dead spots on the stem at any point.

These troubles should be prevented by strict attention to proper methods of planting and watering. No manure or freshly decaying organic matter should be applied to the seed-bed, commercial fertilizers being used exclusively. The seed should be covered with a layer of clean, fresh sand which will prevent the surface from becoming too wet. For the inexperienced grower, particularly, it is better to make wide furrows, two inches deep, about a foot apart, planting the seed broadcast on the ridges between. The water may then

[1] "The Brown Spot of the Navel Orange," *Proc. Soc. for Hort. Sci.*, 1900.

be run in these furrows and allowed to soak into the ground laterally, thus keeping the surface of the sand dry. Where the seed is sown broadcast over the whole surface of the bed and the water applied by sprinkling, watering should always be done on sunny mornings and no oftener than is absolutely necessary. In most cases a good watering once a week is sufficient to keep the soil under the sand sufficiently moist. Should the seedlings begin to damp off in spite of all precautions, it is advisable to allow the bed to go as dry as is reasonably safe, and then spray the surface of the bed with a rather weak bordeaux mixture, being careful to wet the entire surface of the soil.

Citrus Canker

Very recently a new disease has appeared in the Gulf States which is described as the most serious which affects the pomelo. Sweet oranges are apparently immune. It exists in Florida and Alabama, the first specimens being collected in 1912. So far it has not been reported from California. H. E. Stevens describes the trouble as follows:[1] "The disease appears as small, circular spots, from less than one-sixteenth to one-quarter of an inch across. They may occur singly, or several together may form an irregular area. They are raised above the surrounding tissue, are light brown, and composed of a spongy mass of dead cells covered by a thin (white to grayish) membrane that finally ruptures and turns outward, forming a ragged margin around the spot. The general appearance of the spots is much the same whether they are found on the leaves, fruit, or twigs. The older spots often become overgrown with saprophytic fungi, and may be pink or black on account of secondary infection by species of Fusarium or Cladosporium.

[1] "Citrus Canker." H. E. Stevens, *Florida Exp. Sta. Bull.* No. 122, 1914.

"The infections on the leaves appear first as small watery bulging dots, which are usually of a darker green than the surrounding tissue. They may appear on either surface of the leaf, but do not penetrate through the leaf tissue at this stage. The spots gradually increase in size, change to a light brown color, and become visible on both sides of the leaf. The spot may project from the surface on one or both sides of the leaf. Each spot is surrounded by a narrow yellowish band or zone. Later the surface of the spot becomes white to grayish, and finally ruptures, exposing a light-brown spongy central mass.

"The spots on the fruit are similar to those on the leaves. They project from the surface and retain a circular outline. They do not penetrate far into the rind, and may be scattered singly over the surface, or several may occur together, forming irregular masses.

"The spots on the older twigs are more prominent and usually larger and more irregular in shape. They show the same spongy tissue and the same color as those on the leaves. On growth more than a year old, the spots assume a cankerous appearance and the membrane covering the surface disappears. The spots do not penetrate to the wood, but are confined to the outer tissues of the bark.

"The organism causing the disease has not been determined, but it is probably a fungus. Several different fungi have been found associated with the spots, among which a species of *Phyllosticta*[1] occurs most frequently. This fungus is suspected of being the cause of the trouble, and experiments are now in progress to determine this.

"The disease is infectious, as is shown by the results of some experiments in which it was transferred from diseased material to healthy leaves and shoots of grapefruit."

[1] Later found to be a species of *Phoma*. See Wolf and Massey, Circular 27, Alabama Experiment Station.

Control measures have not yet been fully worked out. On account of the presence of this fungus, the state of Florida is now quarantined against the introduction of nursery stock or bud-wood from Alabama.

Melanose and Stem End Rot (*Phomopsis citri*)

These diseases, which are both caused by the same fungus, have been prevalent in Florida for many years. The fungus occurs in Australia, Jamaica, Porto Rico, and Algeria, but so far has not been found to exist in California.

The disease lives normally and produces spores on dead twigs in citrus trees. The spores are washed by the rains over the surface of the fruit, causing, particularly on pomelos, peculiar brownish streaks known as tear-staining or melanose. These marks are nearly the same on leaves, stems, and fruit, and consist of raised areas of brown gum-filled cells forming dots, lines, rings, or irregular spots which greatly injure the general appearance of the fruit while not injuring the eating quality.

Stem-end rot causes the fruit to drop, beginning with immature fruit in August and continuing till after the fruit has been sent to market. It even causes decay after the fruit has reached market. The softening begins at the stem end and is especially common on fruits which have scale insects about the stem end. It is more severe during a warm fall and winter, and infection seems to be more common in damp shady situations. Sound picked fruit can be infected by contact with diseased fruit. The fungus inhabits the soil under infected trees and the spores develop in spring and summer on dead twigs, bark, and on mummified fruits.

The application of fungicides to the trees or disinfectants to the wash-water does not control the disease. The most successful method of control is to keep the trees carefully pruned and free from all dead twigs, stubs, and mummified fruits. The prunings should not be plowed into the soil, but should be removed from the orchard and burned before the fungus has time to grow and produce spores upon this material. All diseased fruit which falls to the ground should be collected and destroyed. Careful culling at the packing-house and refrigeration in transit are aids to control. Also it is advisable to keep the trees as free as possible from scale insects.

Nail-head Rust (*Cladosporium herbarum var. citricolum*)

In Florida the nail-head rust is quite common, while it has not as yet been found in California. It is often called scaly-bark in Florida, but it is very distinct from the California scaly-bark, the cause of which has not yet been discovered. The disease appears on the twigs and small branches as slightly raised rusty spots, as implied by the name. The fungus also produces spots on the fruits which are hard, circular, sunken, and more or less corky. Affected fruits color and drop prematurely. The spots due to this fungus are found only on sweet oranges. Various control measures have been suggested, such as top-working the trees to pomelos; heading back and spraying with bordeaux, followed by an insecticide; and carefully pruning out all dead wood.

Scab or Verrucosis (*Cladosporium citri*)

Citrus scab is another disease which occurs in Florida and other parts of the world but has not so far been found in California. The following description of scab is from the Florida Experiment Station Bulletin No. 108, page 41.

"This disease, which is especially common on sour oranges and lemons, makes its appearance on the fruit as irregular light brown or corky projections from the surface. It is caused by a fungus which attacks the fruit or leaves when quite young. Its attack on sour oranges and lemons (and sometimes on Satsumas and grapefruit) often results in making them misshapen and unsightly. In severe attacks, projections of a dark gray to corky or even tan color will be seen extending out from the surface. The surface of the fruit between the warts is usually of a normal color. Often these irregular corky projections coalesce to form a large raised corky scab. In less severe attacks, especially when scab occurs on grapefruit and on tangerines (or rarely on sweet oranges), the warty irregular projections are wanting, and there will be seen more or less raised platform-like patches variable in shape and extent. The surface of the raised portion is finely scabbed or lightly scurfed, as is seen in the case of thrips marks or silver scurf. In this milder form it can usually be distinguished from thrips marks or other forms of scurf by its being raised, but can be distinguished with certainty only by the use of the compound microscope.

"The scab can be completely controlled by the use of weak bordeaux mixture (3-3-50). Since (in Florida) the use of bordeaux on orange trees, however, kills the friendly fungi [1] and allows a rapid increase of scale insects or white-fly, this

[1] It should be explained for the benefit of those not familiar with conditions in Florida that there are a number of kinds of fungi which prey as parasites upon the scale insects and white-fly larvæ and are thus of very great benefit to the citrus growers. Some of these friendly fungi occur in India and other places, but so far none have been successfully established in California, where the air is too dry perhaps for their success. In spraying with bordeaux for fungus diseases in Florida, the killing off of these friendly fungi has to be considered, for an application of bordeaux usually must be followed by an insecticide on account of the great sudden increase of scale insects.

spray is not recommended except when it is absolutely necessary. When it must be resorted to, a good insecticide should be used as soon as the scale insects begin to increase rapidly. Some of the harm from increase of scale insects may be prevented by spraying the bordeaux as much as possible only on the fruit, and keeping the spray off of the larger limbs and the inside of the tree where the friendly fungi may be left alive."

Diplodia Rot of Oranges (Diplodia natalensis)

A form of fruit decay which occurs in Florida and South Africa but has not so far been reported from California. H. S. Fawcett gives the following description of it in Florida Exp. Sta. Bull. 108, p. 46:

"In the early stage this rot shows as a patch about the stem end similar to stem-end rot. The discoloration becomes darker as the decay proceeds, and appears as dark wide bands corresponding to the divisions between the segments. The fruit becomes black as the decay advances and very light in weight. The rot often advances quickly through to the 'blossom' end, and a patch of discoloration shows there before all the peel is involved. The Diplodia rot often starts also in thorn punctures or similar injuries. It is usually accompanied by the exudation of a small amount of thin gum, or a considerable amount of amber-colored sticky juice. This amber-colored juice less frequently accompanies the stem-end rot. Many of the characteristics of the two rots are so similar that for practical purposes they may be classed together. The citrus fruits are much more resistant to Diplodia rot than to stem-end rot. Diplodia rot appears to be less common on immature fruits on the tree, and the fungus causing it is less parasitic. The same methods of treatment given for stem-end rot hold good for the Diplodia rot."

Red Blotch of Lemon

It is in stored fruit alone that red blotch develops. It is often called "red rot" by packing-house men but as it is apparently not due to any parasitic organism the latter name is misleading. It is characterized by the rind shrinking and turning to a dark color in large spots or blotches. The discoloration is usually limited to one side of the fruit and gradually changes from rusty bronze to dark red and finally to black. On cross section, affected fruit shows the discoloration about the seeds, the central core, and along the partitions, while the vesicles appear normal. The disease does not spread among the lemons by contact. It is unusual for red blotch to develop in large amount in any one house, although the losses in the aggregate are large. It has been suggested that red blotch may be caused by sunburn or overheating of the lemons on the tree, but so far neither the true cause nor a remedy has been demonstrated.

Yellow Spotting of Oranges

In all the interior valleys of southern and central California and in Arizona it is the usual thing for oranges of all varieties to develop small bright yellow spots before the oranges are mature. Often these spots are very conspicuous on account of the contrast with the green rind. Usually all the oranges on the exterior of the trees and especially those near the ground show the spots. When the fruit colors naturally there is no longer any contrast and the spots are no longer visible to any but an experienced eye. As these spots do not damage the fruit for eating or for sale but little interest has been shown in determining the cause. They are probably due to the bites of some small insect such as a leaf-hopper, many species of which are common in the orchards. At one time it was thought that these spots later developed into the brown spot of the Navel orange, but this has been shown not to be the case.

Stem End Spot

The California stem end spot of oranges is a very different thing from the stem end rot common in Florida and previously described. It appears as small dried out and sunken spots immediately adjacent to the stem of the fruit and is most serious on the Navel orange. It occurs only on fruit which is beginning to age. The cause has not been clearly demonstrated. Sometimes during wet weather, saprophytic fungi may grow on these dead spots, in which case the appearance of the fruit is injured and it is not safe to ship it to market. The remedy is to pick and ship the fruit earlier.

FIG. 137. — Stem end spot of orange.

Trunk Rot (*Schizopyllum commune*)

The decay of the trunks of citrus trees due to this fungus is especially common in the moist coast region and in northern California. Where stubs have been left in careless pruning of the large limbs the spores gain entrance, and in time the white bracket-like fruiting bodies appear. The fungus is thought not to be strongly parasitic on sound healthy tissue, but once started it may cause dying back of the wood. The disease may easily be prevented by paying proper attention to the

Fig. 138. — Pruning stub on orange tree affected with *Schizopyllum.*

disinfection of pruning wounds and by covering all large cuts with a suitable dressing. Inasmuch as the presence of this fungus indicates neglect, it reflects discredit upon the orchardist.

There are several other kinds of fungi which have not been identified which, after getting started in sunburn cracks or frost injuries, may cause a progressive decay of the wood of citrus trees. All these may be prevented by care and attention to injuries. When once well started it may require rather extensive tree-surgery to entirely rid the tree of the infection.

Galls and Knots

Occasionally large galls are found on the branches of citrus trees in California. They are not common or very injurious, and the only remedy suggested is to prune them out. These galls may be due to the crown gall organism which produces similar galls on the roots of peach, almond, and other fruit trees. Crown gall has been produced on citrus trees experimentally by C. O. Smith of the University of California.

Recently Florence Hedges[1] investigated a rather serious and contagious form of gall on citrus trees from the Island of Jamaica. The cause was discovered to be a fungus, *Sphæropsis tumefaciens*. All the galls so far found in California have been different and the contagious *Sphæropsis* gall is not known to occur either in California or Florida, although common in Cuba.

Black Pit of Lemon (Bacterium citriputeale)

A serious blemish which occurs occasionally on tree-ripe lemons late in the spring. This trouble is apparently confined to southern California. It appears as large dark red or black spots, the surface of which is firm and markedly depressed below the general surface of the rind. The spots do not increase in size rapidly or progress into a general decay, but the appearance of the fruit is ruined. The cause

[1] "A Knot of Citrus Trees Caused by *Sphæropsis tumefaciens*" by Florence Hedges and L. S. Tenny, *U. S. D. A. Bureau Plant Industry, Bull. No.* 247, 1912.

is a bacterium which gains access to the rind through thorn punctures. Apparently an abrasion is necessary before the bacteria can enter. The trouble may be prevented in three ways: pick the fruit before it becomes tree-ripe, grow thornless varieties, or protect the orchard by windbreaks.

CHAPTER XXII

CITRUS INSECTS AND THEIR CONTROL

The number of insects which seriously attack citrus fruit trees in California is not large; their lack in numbers, however, is more than offset by their aggressiveness and their ability to withstand control measures. While it is true that fumigation for scale and spraying for red spider or mites, if properly done, is supposed to kill all the individuals on the trees at the time of treatment, yet in actual practice a few usually survive and later reinfest the trees, so that in the course of time remedial measures must be repeated.

The financial loss due to the various citrus pests is large, the cost of control amounting to more than half a million dollars a year in southern California, according to a recent estimate. This does not take into account the secondary losses due to weakened trees, dirty fruit, and fruit scarred by thrips or mites. The state as well as the nation is spending large sums annually in studying citrus pests and in devising better methods of control, while in addition to this most counties employ a horticultural commissioner and a corps of inspectors whose chief duty is to assist in controlling pests already established in the county and to prevent the introduction of foreign species.

The distribution of the various citrus insects in California is greatly influenced by the different climatic conditions obtaining in the different parts of the state. The purple scale has so far not become established nor is the black scale serious on citrus trees in the hot dry air of the interior valleys. The red and yellow scales are both found in the San Joaquin citrus districts, although not in injurious numbers, while the yellow scale alone is found in the Sacramento districts. Before the introduction of various insect pests into California from Florida, the general opinion prevailed that such insects would not thrive when taken from a humid into a comparatively arid climate. The fact that any particular insect has not so far become established in a given region must not be taken as sufficient evidence that it will not thrive when an opportunity to infest trees presents itself.

At the present time, it is very encouraging to note the fact that in the better kept citrus orchards of the state it is often difficult to find specimens of certain insects for study. In some localities where red and yellow scale, mealy bug, or silver mite were once very abundant, it may now require a diligent search to locate a single individual, so effective has been the work of the inspectors and the application of remedial measures.

A point which should be emphasized is the importance of keeping orchards and fence rows free from weeds which harbor scale. One of the worst offenders among weeds is the common nightshade (*Solanum nigrum*) which is so abundant throughout most of the state. Even after thorough fumigation of the trees has been accomplished, a few scales living on the nightshade will start a new infestation, the blame for which is often unjustly charged to carelessness of the fumigators.

For sake of convenience, insects are usually divided into two general groups, the biting insects and the sucking insects. The biting insects are those which bite or tear off pieces of the plant tissue and actually consume parts of leaves or the tissues upon which they are feeding. The sucking insect on the other hand pierces the tender plant with a slender proboscis or tube-like mouth-part and proceeds to extract the sap from the cells. All the scale insects, the mealy bugs, the plant lice, and the red spider have sucking mouth-parts, the thrips have mouth-parts fitted for both rasping and sucking, while the rose beetle, the orange tortrix, and the diabrotica are biting insects.

A proper understanding of the manner in which an insect obtains its food is necessary before remedial measures can be intelligently applied. For biting insects, a stomach poison such as paris green or arsenate of lead should be used, while for sucking insects, a solution or gas which kills by contact, such as lime-sulphur or kerosene emulsion or hydrocyanic acid gas, is necessary. A contact insecticide either fills up the breathing pores which are located along the sides of the body of the insect, thus suffocating them, or produces fatal irritation. The sucking insects are by far the most destructive and troublesome in citrus orchards as well as the most difficult to control.

Black Scale (Saissetia oleæ)

The black scale is widely distributed over the earth, since like other scale insects, it is very easily carried from one country to another on young nursery trees and ornamental plants. This scale is perhaps the most damaging insect

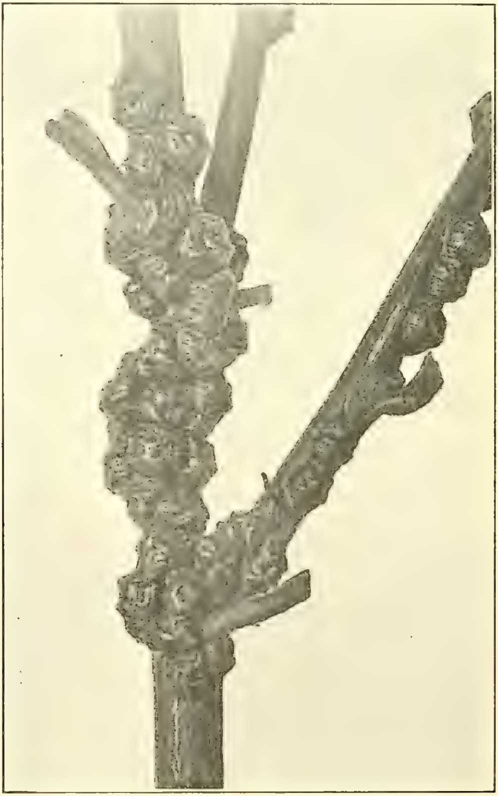

Fig. 139. — Black scales on orange twig.

pest of the citrus districts in the Mediterranean region. The exact date of its introduction into California is not known.

According to a report published in 1880, it was well established at that time. It is found in nearly all the counties of the state, although as a citrus pest it is troublesome chiefly in southern California, especially near the coast. In Los Angeles, Santa Barbara, and Orange counties it takes first rank among citrus insects, while in Ventura and San Diego counties it is given second rank. In Western Riverside and San Bernardino counties, it is also a serious pest, as is shown by the fact that 75 per cent of the insect control work in Riverside county in 1910 was directed against the black scale, although such a high percentage is unusual.

The black scale injures the tree by sucking the sap. The greatest injury, however, is done indirectly by the sooty mold which accompanies the scale. The insect excretes copious amounts of a substance, known as honey-dew, which falls upon the leaves and fruit below. This furnishes a suitable medium for the growth of the sooty mold fungus (*Meliola camelliæ*) which not only clogs up the breathing pores of the leaves and renders them incapable of performing their normal functions, but also forms a black coating over the fruit which necessitates thorough washing before the fruit can be packed for market. This washing is often of necessity so severe as to cause abrasions in the skin and a considerable increase in the amount of decay during transit to market.

The size of the adult scale will average about one-seventh of an inch in length and not quite as broad. It may be distinguished from closely related species by a plainly outlined letter H on the back of the full grown females. The color of the mature female is usually very dark, often jet black. The male scale is minute and is very seldom seen. When mature the male emerges from its pupal case as a winged insect.

The life history of the black scale varies in different sections, but in general it is about as follows:

Eggs are produced most abundantly in May, June, and part of July, the average number found under each scale being about eighteen hundred. In about twenty days the eggs hatch. At the end of a day or two the young insects make their way out from under the protecting mother scale, and crawl around for two or three days before settling down, the leaves and tender twigs offering the most suitable feeding ground. Unlike the armored scales, the black scale is, up to a certain age, able to withdraw its sucking mouth-parts from the tissues and move to more favorable pasturage. This accounts for the fact that only a few mature individuals are seen on the leaves, while such large numbers are found on the branches.

The yellowish half grown females are most common from about the middle of September to the middle of December, while during the spring and early summer months the dark adult scales are most abundant. Although there seems to be but one generation of the black scale during the year, it is not uncommon along the coast to find all stages at one time. It is this irregularity in the appearance of the young scales that makes the problem of control so difficult. The insect is naturally most susceptible to any destructive influence during the two or three days when it is crawling around searching for a suitable place to feed. The hot dry air of the interior valleys kills them off in large numbers and they are not able to establish themselves so readily as in the coast sections.

The young insects may readily be seen crawling about over the leaves and stems, but a little observation will show that their powers of locomotion are very limited; they are not able to crawl from one tree to another over the rough ground and must depend upon some other agency to carry them any considerable distance. Probably the most common agents for their dispersal are the ladybird beetles. These and other insects are often found with one or more young scales on their backs, and when the beetles fly to other trees, the scales are carried along to start new infestations. Birds are probably responsible for transporting young scale insects long distances, as the latter have ample opportunity to crawl upon the bodies of birds which are roosting in the trees or resting between flights. Man, however, has been mostly responsible for the wide distribution of the black and similar scales, especially by the shipment of promiscuous lots of nursery stock from one country, or one section to another. In the orchard the young scale is very liable to be distributed during the ordinary operations of cultivation, pruning, picking, and hauling to market. In some packing-houses the precaution is taken of fumigating all lug-boxes as they are emptied. They are loaded directly into the wagons from the fumigating room, to be taken back to the orchard. In this way the danger of introducing scale into a clean orchard by means of lug-boxes is reduced to a minimum.

There are several natural enemies of the black scale in California. Among these, the most important is the parasite, *Scutellista cyanea*, which was introduced from South Africa in 1900 and is now found in most of the districts where black scale abounds. The Scutellista is an egg parasite and the larvæ feed only on the eggs which are deposited by the mature black scale. In some cases all the eggs under one scale may be consumed, but in other cases the parasites come to maturity with a greater or less number of eggs untouched. Even if the eggs are completely destroyed in the parasitized scales, there are usually a sufficient number of female scales which are not parasitized to carry on the infestation. While the Scutellista aids materially in reducing the numbers of the scales, it cannot be depended on alone for the effective control of the pest.

Another egg parasite, *Tomocera californica*, is found in some sections but is not nearly so effective as the preceding. There are at least four ladybird beetles as well as an internal parasite of the male insect which also prey upon the black scale.

Where only a few trees around the house are infested or only young trees require treatment, spraying with distillate emulsion or kerosene emulsion is recommended. The emulsion is made as follows:

Kerosene	1 gallon
Soap (laundry)	½ pound
Water	15 gallons

The soap should first be dissolved in about a gallon of hot water, and while still hot, add the kerosene, away from the fire. The mixture may then be emulsified by churning it back and forth for several minutes until it becomes of the consistency of cream, when it is diluted to make the sixteen gallons. The oil should be thoroughly emulsified before being used, as free oil in the mixture is apt to cause serious injury to the bark of young trees. Where the soil is sandy the concentration of the spray material which runs down the trunks and reaches the soil may cause injury at the collar. In such cases the oil-saturated soil should be removed from about the collar and replaced by a few handfuls of fresh soil. This should be done three or four hours after the spray has been applied.

Fumigation is usually more effective, however, in controlling black scale, as the gas penetrates to all parts of the tree and the fumigation properly done kills both the mature and half grown scales.

The Red or Orange Scale (Chrysomphalus aurantii)

The red scale is found along with the black scale in the southern coast counties, where it is a serious enemy of citrus

Fig. 140. — The red scale on orange.

trees. It takes first rank as a pest in San Bernardino and Riverside counties, while in Orange and Los Angeles counties it takes second place. It was found in California in 1878, and the origin of that infestation was traced to Australia, although China is usually regarded as its native home. It occurs in nearly all tropical and semi-tropical countries on a large number of plants, but is especially a pest on citrus trees. Unlike the black scale, it does not produce honey-dew. The injury to the tree is due either to the loss of sap or to the poisonous effects upon the cells of the tissues attacked. While the black scale is never known to kill a tree upon which it is feeding, the red scale quite commonly affects its host plant very seriously if not fatally. It also settles upon the fruit, marring its appearance and market qualities. The life history differs from that of the black scale in the fact that the mature female does not produce eggs but gives birth to living young. These young scales are minute, but may be observed from June to September or later as yellowish mites crawling on the leaves, stems, or fruit. They do not migrate far from the parent scale unless the food supply is scarce or the feeding surface dry and hard, in which case they may travel several feet. The scaly covering which the young insect begins to form over itself as soon as it is settled is simply for protection, and is not a part of the body, as in the case of the half grown black scale. It consists of a mass of light cottony threads secreted by the young scale; later this is enlarged by the two cast-off skins of the growing larvæ. Under this protection, they continue to feed until mature, which requires from two and a half to three and a half months. The mature female scale is reddish in outward appearance and about the size of the head of an ordinary pin. The mature male scale is smaller and more elongated than the female. The male sheds its skin four times and emerges as a winged insect in from one and a half to two months.

Although each female produces but from forty to eighty young, the fact that in southern California there are four

Fig. 141. — Work of red scale on orange tree.

generations during the season accounts for their rapid increase. The same agents responsible for the spread of the black scale also disseminate the red scale.

The internal parasites of the red scale do not seem to be at all effective in reducing their numbers, as only a small percentage of the scales are parasitized. Several species of the ladybird beetles are commonly found attacking the red scale, but are not of much assistance in their control. Fumigation according to the schedule given in Chapter XXIII is the most effective remedy.

Yellow Scale (*Chrysomphalus aurantii var. citrinus*)

The yellow scale is but a variety of the red scale, and is identically the same in structure. It is somewhat yellow in color, although the color becomes much darker after the insect dies, when it is more difficult to distinguish from the red scale. The distribution is about the same as that of the red except in the Sacramento Valley, where the yellow scale seems to occur exclusively.

The feeding habit of this scale differs from that of the red as its attacks are almost wholly restricted to the leaves and fruit. The seriousness of the injury is therefore much less and the health of the trees is not so seriously injured.

The life history agrees with that of the red scale. There is an internal parasite which sometimes kills 25 per cent of the scale, but fumigation must be relied upon for its complete control.

The Purple Scale (*Lepidosaphes beckii*)

The date of introduction of the purple scale into California seems to have been either 1888 or 1889, when two carloads of orange trees were received from Florida and planted in

Los Angeles and San Diego counties without disinfection. It now occurs in San Diego, Los Angeles, Orange, Ventura, and Santa Barbara counties, and a strict inspection is being maintained in the more inland counties to prevent its introduction. The purple scale attacks all parts of the tree as well as the fruit, upon which they attach themselves so firmly that the ordinary washing is of little avail in removing them. They also cause the fruit to appear spotted in ripening, a green color persisting around the scales. Whole trees are seldom if ever killed by this scale, although the lower branches and often one whole side of the tree may be fatally affected.

Eggs of the purple scale are most commonly found during the spring and early summer, although all stages may occur in the orchard at other seasons. The female produces from thirty to forty eggs, which hatch in about eighteen days during the summer months. The young remain under the protection of the mother for a short time, after which they make their way out and migrate in search of a place to feed. After they have once settled down and formed the protecting scale over their bodies the females are stationary during their entire existence. The mature female scales are elongated, and shaped somewhat like an oyster shell, the color varying from a dark brown to purplish. The male scale is much smaller and narrower. The average length of time from the egg to maturity is about two and one-half months for the male and three months for the female. After the production of eggs, the female soon dies.

During the ordinary season, there are from three to four generations. The young seem to be more able to adapt themselves to unfavorable feeding conditions than either the red or the black scales, and the percentage which become established is much greater.

Several species of ladybird beetles prey upon the purple

Fig. 142. — The purple scale. (Enlarged.)

scale, but only one internal parasite has so far been reared. This parasite is not very widely distributed and is only partially effective wherever it is found. In orchards where the red, black, and purple scales occur together, fumigation is mainly directed against the purple; if it is killed, the dosage is usually fatal to the other two.

Cottony Cushion Scale (*Icerya purchasi*)

The account of the introduction, spread, and final control of the cottony cushion scale forms one of the most interesting

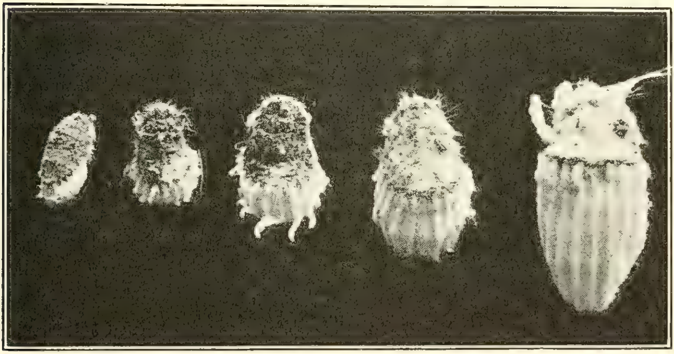

Fig. 143. — The cottony cushion scale. (Enlarged.)

chapters in the history of California horticulture. Having been introduced from Australia in 1868 (see Chapter I) it spread so rapidly during the next twenty years that its ravages proved a very serious menace to the citrus industry of the southern part of the state. The Australian ladybird beetle which was introduced into California from Australia in 1889 for the purpose of controlling this scale was so successful, to all appearances, that except for occasional outbreaks it ceased to be considered as a serious citrus pest, and fumigation or other measures of repression are no longer necessary.

The mature scale is very easily distinguished from other scales. When mature, they are about one-fourth of an inch long and consist of the red or yellowish body and a large fluted cottony white mass which serves as the egg-sac. From five to eight hundred eggs are produced by each female, May and June being the season of greatest production. These hatch in about ten days in summer, but a longer period is required in winter. The young scales are very active, and feed at first largely upon leaves but later seem to prefer the twigs and branches. The females are able to move about during most of their life, but become stationary as soon as the egg-sac is formed. The time required for development from egg to adult varies considerably even during the same season; the average, however, is about three and a half months. There are at least three generations in southern California, and during the summer months they increase very rapidly if not held in check by their natural enemies. The cottony cushion scale produces a large quantity of honey-dew, on which the sooty mold fungus grows readily.

Soft Brown Scale (Coccus hesperidum)

The soft brown scale is widely distributed over the earth and has a large number of food plants other than citrus. Its injury to citrus trees is due largely to the exudation of honey-dew, and the accompanying growth of the sooty mold fungus. It is only occasionally injurious, and seldom infests an entire orchard, being usually held in check by several internal parasites. This scale is usually accompanied by a great number of ants which feed upon the honey-dew.

The young scales are produced alive during the summer months and settle down soon after leaving the protection of the mother. They either remain fixed from that time or occasionally move about until they are half grown. There may be several generations in a season, as they require from sixty-five to ninety days to mature in summer. The scales often crowd so thickly on the leaves or along the stems as to overlap each other. The body of the mature female is oval, flat, and soft, varying in color from a dark straw yellow to brown, often with deeper markings. The male scales are much smaller and lighter in color, the mature form emerging as a winged insect.

As stated above, this insect is seldom serious, but occasionally it happens that the parasites do not effectively control it, and it becomes necessary to fumigate or spray.

Citricola or Soft Gray Scale (Coccus citricola)

During the past five years a scale supposed to be a variety of the soft brown has caused much damage to citrus trees both in the coast country and interior valleys. Recently the insect has been described as a distinct species.[1]

The citricola scale excretes large amounts of honey-dew which becomes covered with sooty mold, necessitating the washing of the oranges. The presence of the scale is usually first noticed in July and August, when the sooty mold is forming. In the spring the adult females can be observed on the smaller twigs and branches, often being so numerous as to overlap each other and cause the twig to appear twice as large in diameter as ordinarily. This scale is not fatal to the tree, but saps its vitality and results in small crops of undersized sooty fruit.

The adult female is grayish in color, usually about one-fourth inch long and about three-sixteenths wide, and elongates oval in shape. Eggs are laid during May and June and hatch immediately. In fact, in some cases the eggs hatch before they are laid, and the young are born alive. The

[1] Roy E. Campbell, *Entomological News*, June, 1914.

parasites of the citricola scale do not control it effectively, and it has increased in the citrus orchards at an alarming rate. The chief method of control is by fumigation, which is done in July and August at the time when the greatest percentage of young scales are susceptible to the gas.

Hemispherical Scale (Saissetia hemisphærica)

Although this scale is not a serious pest in citrus orchards, it sometimes becomes abundant on trees growing near the coast. It attacks the twigs and leaves, upon which it quite commonly settles along the very edge. It may be distinguished from the black scale by the absence of the letter H on the back, its regular oval shape, and polished brown surface without markings. The same control measures used for the black scale are also efficacious for this species.

Greedy Scale (Aspidiotus rapax)

This species is of only minor importance as a citrus pest but sometimes attacks the twigs and may be found upon fruit remaining upon the trees from the previous season. As its name implies, it seems to have no choice of host plants, but thrives on both wild and cultivated shrubs or trees. The mature scale is gray or almost white and somewhat translucent, showing the yellow body of the insect beneath. It is ordinarily associated with other species on citrus trees and remedial measures directed against this scale alone are seldom if ever necessary.

Oleander Scale (Aspidiotus hederæ)

The oleander scale is another species which only occasionally attacks citrus trees. It sometimes appears on lemons, usually on tree-ripe fruit, and the common name of "lemon peel scale" has been applied to it. Although its normal color varies from light to dark gray, it may assume a reddish tinge when found on lemons and may then be mistaken for the red scale.

Citrus Mealy Bug (*Pseudococcus citri*)

The mealy bug does not have to be reckoned with as a continuous pest in California citrus orchards. When climatic and other conditions are favorable, it becomes a very serious citrus insect and is quite difficult to control. It is found in all the citrus regions of the state, but has been particularly troublesome in Ventura and San Diego counties. It not only attacks the leaves and branches, but seems to be especially fond of the fruit, often collecting in masses on both oranges and lemons. When concealed in the navel of the orange or around the stems of lemons, the insects may escape detection and continue to breed while the fruit is in storage or on the way to market.

The honey-dew excreted by the mealy bug is very sticky and makes the task of cleaning the fruit exceedingly difficult.

From three hundred and fifty to four hundred eggs are deposited, mostly during the fall and early winter, in a mass of loose, cottony fibers, excreted at the time by the female. The eggs hatch in eight to ten days during the summer months, and in about sixteen days during the winter. The young insects move about actively, the distance depending upon the amount and condition of the food supply. The females continue to move about during their lifetime, but the males form a cocoon and go through a stage of transformation and emerge in six weeks as two-winged insects, at which time the females are about half grown. The females require about two and a half months to develop, often commencing to produce eggs before they reach full size. The full grown mealy bugs are about one-fourth of an inch in length and conspicuously clothed with a white, mealy excretion. They have a border of short appendages around their bodies, the posterior appendages being but little longer than the lateral. They have the habit of settling down in protected places such as the bases of the leaves and fruit stalks, often causing the leaves and young fruit to drop prematurely.

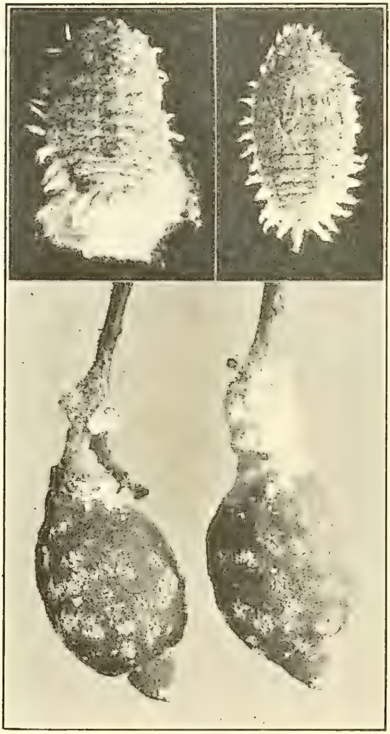

Fig. 144. — Citrus mealy bug.

The mealy bug passes the winter in the egg stage, but on account of the uneven hatching during the warm weather of southern California, usually all stages may be found during the winter season.

On account of the habit which the mealy bugs have of secreting themselves in protected places, control measures by means of spraying are difficult. They seem to be quite resistant to fumigation, and unless scale insects are also present in sufficient numbers to require fumigation, such treatment is not recommended. The greatest success has been obtained by the use of distillate emulsion spray, ten to fifteen gallons being applied to an ordinary tree. The emulsion consists of four gallons of distillate oil, one gallon of liquid soap to two hundred gallons of water. If the insects are abundant, it may be necessary to spray two or three times. The best time for application is during the winter when there are large numbers of egg masses, or in the spring when the young have been hatched.

There are several predaceous insects as well as parasites which assist in controlling the mealy bug; these include different species of ladybird beetles, lace-wing flies, and internal parasites.

Citrus Red Spider (Tetranychus mytilaspidis) and Six Spotted Mite (T. sexmaculatus)

There are two species of red spiders which attack citrus trees in California. They occur throughout the citrus districts and rank second to scale insects as citrus pests. They injure the plant by sucking the juices from the tissues, giving a characteristic mottled and sickly appearance to the leaves. The green fruit also is attacked, and an objectionable pale silvery color produced. Red spiders also sometimes injure lemons in packing-houses while the lemons are in storage.

Since the citrus red spider is the one usually responsible for injury to citrus trees, that species is the one which will be discussed here. The common red spider or six spotted mite does not limit itself to citrus as a food plant, although in San Diego County it is sometimes a more important lemon pest than the other species.

The citrus red spider was introduced from Florida on nursery stock about 1890 and has been a serious pest since

1895. It is very minute, red in color, and often becomes so abundant on a leaf as to give it a reddish hue also. The red eggs are placed separately on the leaves, and are elevated upon short stalks held in place by radiating guy threads fastened to the surface of the leaf. The number deposited by each female will average about thirty. During the month of May and the summer months, about ten days are required for hatching, although it may take three weeks in the cooler seasons. The young begin to feed immediately and grow rapidly, only twelve days being required to reach maturity and begin egg-laying.

Sulfur is the universal remedy for red spider. It was first applied in the dry powdered form, dusted over the trees either with a small bellows or a power blower, preferably when the foliage was damp. Lime-sulfur sprays have recently met with great favor and are being extensively used. Natural enemies, such as predaceous beetles and the lace-wing flies, assist materially in reducing the damage due to red spider. The commercial lime-sulfur preparations are commonly used, one gallon to thirty-five gallons of water being recommended. About six or seven gallons of the solution are required for the ordinary tree, making the cost about fifteen cents, considerably less than the cost of fumigation.

Silver Mite (Eriophyes oleivorus)

The silver mite is not a true insect but belongs to the same class as the red spider. It was introduced from Florida into San Diego County in 1889 and its ravages have been restricted to a section of that county. The mite attacks the bark, foliage, and fruit, producing the greatest injury to the fruit. Green lemons if attacked take on a silvery appearance, due to the extraction of the oil and green coloring matter from the cells of the rind. On oranges it produces a russet color of the fruit, hence it is sometimes known as the rust mite.

The eggs of the silver mite are deposited singly or in small clusters on the leaves or fruit and hatch in from five to fourteen days, depending upon the season. The young mites grow rapidly, only eight to ten days being required to reach maturity, and in the course of the season they may become very abundant. The adults are scarcely visible to the naked eye, but their presence is indicated by the characteristic silvery color produced on the lemons as well as on the leaves. Such fruit is either thrown out as culls or utilized in making by-products. The control measures are the same as for the red spider.

Orange Thrips (Euthrips citri)

Thrips are very common insects in nearly all kinds of flowers, including citrus. Blossoms shaken over the hand will generally dislodge a number of both young and adults; the latter, being very active, either jump or fly away. Thrips which occur in flowers, however, do not usually belong to the above species, as there are numerous kinds which do comparatively little damage. The true orange thrips are most abundant in Arizona and in the San Joaquin citrus district, but are also occasionally injurious in the Redlands district.

The presence of the thrips is usually evidenced by their work upon the young leaves, which are commonly distorted in growth and leathery. On the fruit they produce scars which may form regular rings around the stem end, or appear in irregular spots over the surface. The mouth-parts of the thrips are intermediate between the sucking and biting insects and consist of a chafing or rasping rather than a biting organ, which accounts for the scars produced upon the leaves and fruit. Although not injuring the edible qualities of the oranges, such scars affect the market value by placing the fruit in poorer grades.

The adult thrips hibernate over winter in protected places and appear about the middle of April, feeding upon the ten-

Fig. 145. — Scars due to citrus thrips.

der leaves. The eggs are produced throughout the summer months and hatch in six to ten days after being deposited. The young are very active and resemble the mature forms, except that they are much lighter in color and without wings. It has been estimated that there are from eight to ten generations a year in the San Joaquin Valley, about twenty days being required for development from egg to adult, and about twenty-three days the average length of life after reaching maturity.

The most effective remedy for thrips seems to be spraying. The formula recommended by the U. S. D. A. Bureau of Entomology is as follows:

Commercial lime sulfur (33°)	$2\frac{1}{3}$ gal.
Black leaf extract . . .	2 gals. of $2\frac{3}{4}\%$ or 14 fluid oz. of 40%
Water	200 gal.

It is necessary to use a very strong pressure, 175 to 200 pounds, in applying the spray so that all parts of the tree shall be reached. The first application should be made as soon as the petals have fallen; a second and third spraying is advisable at intervals of about ten days.

While spraying for thrips has been practiced on a large scale, it is a fact that at present but little spraying is done. Inasmuch as the thrips is severe only in occasional years, most growers prefer to take the risk rather than to go to the expense of spraying.

Melon Aphis or Plant Louse (Aphis gossypii)

This species of plant louse is very common throughout California on melons, gourds, and weeds, and at times becomes abundant on citrus trees, especially in early spring. They attack the tender young growth and under sides of the leaves, causing the latter to curl. Such infestations are rarely very extensive, the injury being usually confined to a few scattered branches. Unfavorable weather, ladybird beetles, and other natural enemies ordinarily keep the numbers of plant lice reduced. In case they are doing much damage to young nursery stock, however, a spray of nicotine extract or weak soap solution will be found effective.

Orange Tortrix (Tortrix citrana)

The orange tortrix attacks a great variety of plants, both wild and cultivated, feeding mostly upon the leaves, which it fastens together by silken threads. It was first described in 1889, and has been reported occasionally as injuring various plants, including the fruit of orange trees. In 1910, its injury to oranges in southern California, especially in Los Angeles County, caused the growers no little alarm, as high as ten per cent of the fruit being found wormy in some of the packing-houses. The damage is done by the larva or small worm which burrows its way into the fruit, seldom going deeper than the rind, however. These holes in the rind not only cause the fruit to be graded as culls but also provide an entrance for the germs of decay.

The eggs are deposited on leaves or fruit in small masses of from ten to thirty-five eggs, overlapping each other like fish scales. They hatch in about twelve days and the larvæ feed at first upon the surface of the fruit or on the leaves but later burrow into the rind, where they remain until full grown. At this time they are about half an inch in length. They form a chrysalis either in the burrow or in a protected place outside, and at the end of ten days emerge as yellowish gray moths, less than half an inch long. According to observations which have been made in the orchards, there are probably three generations of the tortrix in southern California.

So far no effective method of control by insecticides has been worked out. Fortunately the serious outbreaks are spasmodic, occurring only in occasional years. Often they are confined to small localities or even particular groves. Perhaps the most practicable remedy is to destroy the fallen fruit before the larvæ have emerged, and also to destroy the wormy culls from the packing-houses.

Fuller's Rose Beetle (*Aramigus fulleri*)

The injury done by Fuller's rose beetle is most serious on young trees and young, tender foliage of larger trees. The adult beetles live on the foliage, feeding mostly at night, while the larvæ or grubs feed on the roots, so that both stages do considerable damage where they are abundant. The beetle is wingless, grayish brown in color, and about three-eighths of an inch in length; the head tapers into a short snout.

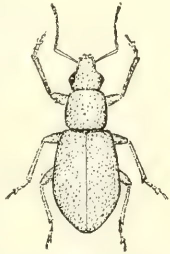

FIG. 146. — Fuller's rose beetle. (Enlarged.)

Since the adults are unable to fly, they may easily be prevented from reaching the foliage of trees by bands of cotton or tanglefoot placed around the trunks. The band of cotton about four inches wide is wrapped around the trunk and tied tightly along the lower edge; the upper half is then pulled down over the lower so that it flares out a little from the trunk. This remedy is especially effective

FIG. 147. — The work of Fuller's rose beetle.

where old trees have their tops removed for top-working. In such cases a few beetles may quickly destroy all the buds inserted in the stump.

Western Twelve-spotted Cucumber Beetle (*Diabrotica soror*)

This species of Diabrotica is liable to attack the leaves and flowers of almost any kind of plant which it happens to find. The young and tender foliage of citrus trees is often seriously injured by the beetles although orange leaves seem to be much preferred to those of the lemon. The beetles appear in such numbers at certain seasons that control measures must be used to protect young plants from their attacks. During the early morning, while they are inactive, the beetles are quite easily jarred from the trees into a vessel containing kerosene or on to a tarred screen. Spraying will also be found effective, arsenate of lead, eight pounds to two hundred gallons of water, being recommended.

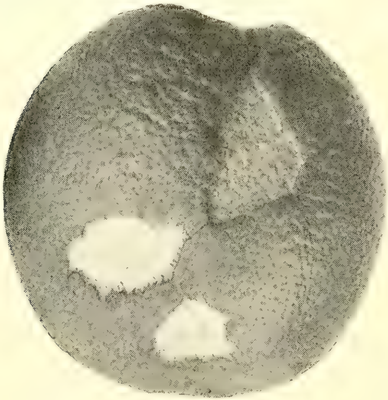

Fig. 148. — Scars on rind of orange caused by katydid.

Katydids often produce scars on oranges such as are shown at Fig. 148. The insects eat away the exterior of the rind while the fruit is quite small. As the fruit increases in size the scars enlarge.

CHAPTER XXIII

INSECT CONTROL BY FUMIGATION

THE control of insects by fumigation was first seriously considered in California in 1886 when the cottony cushion scale was ravaging the orchards of Los Angeles County. At the request of certain citrus growers, E. W. Hilgard of the California Experiment Station detailed F. W. Morse of the University of California to carry on an investigation looking toward the control of the scale by fumigation. Mr. Morse began work in April, 1887, and soon found that hydrocyanic acid was the most effective of any of the gases experimented with. The results achieved by Morse attracted the attention of the Los Angeles County Board of Horticultural Commissioners, who offered to pay the expenses of a more comprehensive investigation. This was made later in the same summer, and the results published as bulletins 71 and 73 of the California Experiment Station dated June 12 and August 27, respectively.

It then became known that D. W. Coquillett had discovered the value of hydrocyanic acid for fumigation in the fall of the previous year, but had kept the fact secret while endeavoring to perfect the method for the purpose of securing a patent. Later Coquillett accepted an appointment as Special Agent for the Division of Entomology of the U. S. Department of Agriculture and continuing his experiments with fumigation published a series of reports on the subject which proved of great value to the industry.

About the year 1901, a much cheaper method of con-

Fig. 149. — A fumigation demonstration.

trolling scale by spraying with distillate oil was introduced. It was soon found, however, that spraying was much less effective than fumigation. The black scale increased to an alarming extent, and the thorough washing made necessary by the sooty mold caused a great increase in the decay in transit. As soon as it was proven that a large proportion of the decay in transit was due primarily to the presence of black scale in the orchards, the growers took a renewed interest in fumigation. R. S. Woglum of the U. S. Department of Agriculture was detailed to make a comprehensive investigation of the whole subject, which he did with marked success. Woglum's work in California has been continued for seven years and has resulted in a number of very valuable publications and much good to the industry.

The methods of fumigation have thus been developed until now it may almost be considered a science by itself. The practice has spread to other parts of the world, and bids fair soon to become the almost universal method of controlling scale insects on citrus trees. Woglum states that in the five southern counties of California the amount of money spent on fumigating citrus trees during an average season 1909–1910 approximated $1,000,000. This statement not only gives some idea of the extent to which fumigation is practiced, but it shows what a fearful tax and unnecessary handicap the presence of scale insects place on the citrus industry.

The great success of hydrocyanic acid gas in controlling scale insects is due to the ease of its generation, and its exceedingly poisonous nature. The chief difficulty has been to find the exact dosage which will give maximum results in the numbers of insects killed, and at the same time produce a minimum of injury to the tree. The different scales vary in their susceptibility to the gas, and separate dosage tables have now been worked out for all the important scales. For a long time a serious obstacle was the frequent burning of the leaves and fruit. This was largely overcome by confining all fumigation to the night, when lower temperatures prevailed. This was so successful that now all fumigation is done at night.

Tent fumigation of citrus trees in California at the present time is practically limited to districts in the southern part of the state, although it is being used to some extent in Tulare County in controlling the citricola scale. The cost of fumigating the average sized tree is about 30 cents, which means an expense to the growers of \$30 to \$40 an acre. Fumigation may sometimes be necessary every season; if thoroughly done, however, it may be necessary only once in two or three years.

Various systems are in operation among the growers for carrying on the work of fumigation. A large part is performed by contractors who make a business of furnishing the materials and doing the work for a stipulated sum. Local associations in which the growers coöperate for mutual protection and benefit, often own fumigating outfits and treat the infested orchards belonging to their members. Such work is usually done under the supervision of a county inspector who sees that the fumigation is properly done. In San Bernardino County, until quite recently, the Horticultural Commission owned several hundred tents and performed annually an immense amount of fumigation wherever needed. This finally became such a great burden to the Commission that the service has been discontinued and the work is now done in various other ways. In many cases, private individuals or companies having a large acreage in citrus trees keep their own fumigating equipment. At Highlands, California, an agreement has been made by a number of growers in the district for the sole purpose of protecting their orchards from scale and other insect pests, each grower agreeing to share part of the expense of fumigation, whether his own orchard is infested or not; the point being that the grower should rather combat scale in some orchard other than his own.

FUMIGATION BY HYDROCYANIC ACID GAS

Fumigation by hydrocyanic acid gas is accomplished by covering the trees at night with air-tight tents, and placing under them earthenware gas generators containing a mixture of sulfuric acid, water, and either potassium or sodium cyanide.

Tents

Fumigation tents are ordinarily made of the best eight ounce army duck obtainable, and vary in size, twenty-foot tents being large enough for small trees and thirty-six-foot tents for the ordinary sized tree. For very large trees, much larger tents may be necessary, although smaller sized ones can be lapped over when such trees are to be fumigated. In order to save material the tents are made in the shape of an octagon. New tents are usually dipped in a solution of oak bark extract of tannin, one pound to five gallons of water heated nearly to the boiling point. The tents are immersed in this hot solution for twenty to thirty minutes, after which they are spread out on the ground to dry. This treatment is practiced to make the tents proof against mildew, but is not absolutely necessary in the climate of southern California, if proper care of the tents is taken in the field as well as in storage. The average length of life of a fumigation tent is three or four years, although the period of usefulness can of course be greatly extended by careful handling.

In the old system of fumigation the method of calcu-

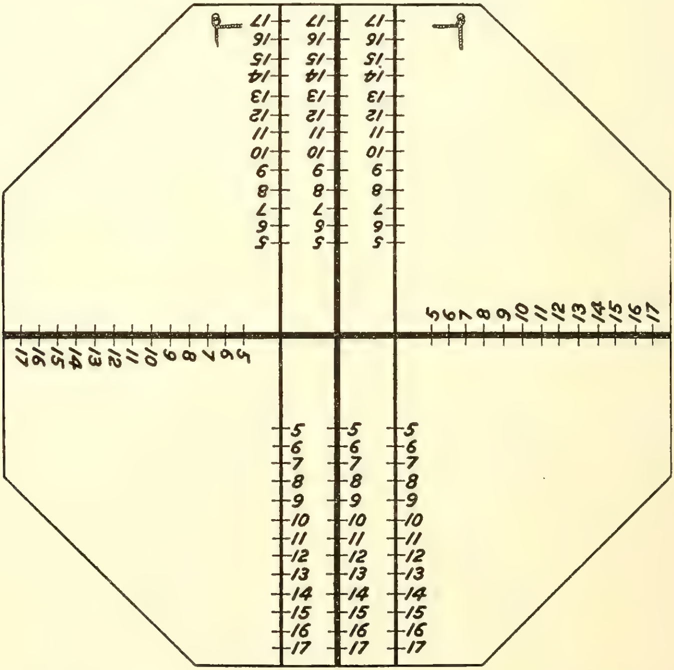

Fig. 150. — Method of marking fumigating tent. (After Woglum.)

lating the dosage for a tree was mostly guesswork, the operator gauging the size of the tree by eyesight and basing the dosage upon previous experience. Such methods sometimes produced fairly good results but in general the work was very irregular and poor. The tents now in use are plainly marked, as shown in the accompanying diagram, the measurements being marked in feet from the center of the tent. When the tent is enfolding a tree, the distance over it can readily be determined by adding the number that touches the ground on one side of the tree to the number that touches the ground on the opposite side. The two auxiliary lines are necessary, as in actual practice the middle line may not fall over the middle of the tree but to one side, and in such a case the line nearest the center is used for measurement. The two side lines may be either three or four feet from the middle line.

Equipment of Tents

For elevating the tents over the trees, either poles or derricks are used, the latter being necessary only for very tall trees. Fourteen- and sixteen-foot poles are most commonly used. One end is sharpened to prevent its slipping on the ground. To the other end is fastened a rope about three feet longer than the pole. Sometimes rings are attached to the edge of the tent, and these are slipped over the ends of the poles; it is usually more satisfactory, however, to double-lap the edge of the tent over the ends and secure it firmly by a half-hitch of the pulling ropes.

Generators

Another part of the outfit is the set of earthen jars or containers called generators. These are made especially for the purpose, usually without covers, and of two gallon capacity. The two gallon size is preferred, as it is large enough to accommodate 20 ounces of cyanide in medium sized lumps without boiling over. When trees requiring more than this amount are to be fumigated, two or more generators may be used under one tent. Generators with lids are desirable as the lids not only aid in throwing the gas outward but prevent spattering of the acid on to the tent. Acid holes in tents cause serious leakage, reduce efficiency, and necessitate frequent and expensive patching. So far, however, no lids manufactured have proved entirely satisfactory. The most improved type of generator has the outside of the bottom flat as usual but the inside of the bottom is cup-shaped, with the depression in the center. This is a great advantage when working with very small trees as it assures a more thorough decomposition of the small quantity of cyanide used for each charge.

Still another part of the fumigating outfit is the supply cart in which are carried the cyanide, sulfuric acid, water, scales for weighing the cyanide, graduated glass for measuring the acid and water, rubber gloves, dosage schedules, and lantern. There is on the market an excellent supply cart designed especially for this purpose which is highly desirable where funds will permit, although simpler and less expensive carts answer very well.

Cyanide

Potassium cyanide was used in all fumigation work until recently. Now, however, sodium cyanide is used exclusively for the reason that it is not only cheaper but will supply a larger amount of hydrocyanic acid gas. The cyanide should be kept dry in storage and exposed to the air as little as possible, since moisture decomposes it.

Acid

Sulfuric acid for fumigating should be about 66° Baumé, which is approximately ninety-three per cent pure. It is sold either in iron drums containing about 2000 pounds or in glass carboys of about ten gallons capacity. On account of its corrosive action glass or earthenware containers are used for distributing the acid in the field. A replaceable copper or glass pipe fitted into the bottom of the container on the supply cart is connected with a rubber tube bearing a large pinch-cock for regulating the flow. Care must be used in handling the acid as it will quickly burn wherever it comes in contact with the skin; for this reason, rubber gloves are advisable.

It has been found that the 1–$1\frac{1}{2}$–2 formula recommended by the Bureau of Entomology is most economical and produces a complete reaction. This formula calls for 1 fluid ounce of commercial sulfuric acid, $1\frac{1}{2}$ ounces (avoirdupois) 129 per cent sodium cyanide, and 2 fluid ounces of water. The water is measured and placed in the generator first, then the acid is measured and poured into the water. Lastly, when everything is in readiness, the cyanide is weighed and placed in the solution, the operator quickly retreating and closing the tent.

The addition of water to the acid is very important. It dilutes the acid and raises the temperature of the mixture, thus accelerating the evolution of gas. The by-product resulting from the reaction is sodium sulfate, a solid. The water dissolves this solid as fast as it is formed and prevents it from forming a coating over the lumps of cyanide and retarding the reaction. If sufficient water is not used, the sulfate will solidify, thus "freezing" the residue, as it is called. This necessitates extra labor in emptying the generators. When concentrated acid is diluted with an equal amount or more of water, nearly pure hydrocyanic acid is given off. If the concentrated acid is used without water another gas known as carbon monoxide is formed.

The cyanide should always be used in lumps about the size of a hen's egg. If finely powdered cyanide is used, the reaction is too violent and endangers the operators. If the cyanide should be dissolved in water before the acid is added, the reaction will be so violent as to be classed as an explosion, greatly endangering the operators and injuring tents and trees. Paper bags are no longer used for depositing the cyanide in the generators. Cakes of compressed cyanide weighing one ounce each are now on the market, and have proven very satisfactory and convenient. Under proper conditions the evolution of gas will have been completed in about five minutes.

Operation

An orchard requiring fumigation should be thoroughly examined regarding the slope of the land, length of tree rows, convenience to water supply, smoothness of the ground over which the supply cart is to be drawn, and similar factors which influence the ease of operation. A tent and a generator are unloaded at each tree and the tents unfolded on the side away from the direction in which they are to be moved. Commencing at one end of the row, the tent pullers fasten the two poles to the edge of the tent in the manner previously described, place the sharpened ends of the poles on the ground at the sides of the tree opposite the trunk, and holding the bottom of the pole to the ground with one foot, pull on the rope. When the poles are so elevated that they no longer slip, each puller moves away from the bottom of the pole and out from the tree so that the continued pulling will bring the edge of the tent over the tree and down on the other side. When thus covered, the edge of the tent should be kicked in so that it hangs evenly all around and does not inclose unnecessary space. After the tree has been fumigated the required length of time, the tent can be pulled over on to the next tree by this same process without lowering it entirely to the ground.

The next step in the process is the calculation of the approximate space inclosed by the tent and the proper dosage to use. Schedules given on pages 450 to 453 indicate the proper dosages for the principal citrus insects which require treatment. Knowing the distance over the tree (found as previously directed) and the circumference of the tent near the base, one will have no difficulty in using the tables. The number found at the intersection of the vertical and horizontal rows on the table indicates the number of ounces of cyanide to be used.

With the ordinary outfit of five men, the work may be distributed as follows: two men handle the tents, a third takes the measurements and calls them out to the men at the supply cart, who immediately consult the dosage

FIG. 151. — Flashlight picture of marked fumigation tents

table, weigh out the cyanide, and measure the sulfuric acid and water into the generator.

While the cyanide man lifts the edge of the tent, the other places the generator underneath. The former then puts in the cyanide and drops the tent. While the chemical men are thus applying the proper dosage to one tree, measurements are being made on the next and the process is repeated until the entire row is fumigated.

Fumigation gangs are usually equipped to handle about thirty tents at a "throw," as they call it. When kept busy these 30 tents are "thrown" or moved once in every forty-five minutes or once every hour as the variety of scale will determine. Thus, except with very large trees, the number of trees fumigated per night does not vary according to the size of the trees, the difference simply being a difference in the time the men have to rest between throws, as all must be left over the trees a stated period of time. As a rule fumigators, when the nights are favorable, begin work about 5 P.M., and if the night is not too cool or a fog arises, will work till 6 A.M., giving a twelve-hour night if an hour is taken off at midnight for lunch and rest. Thus with twelve-hour nights and throws every hour, a gang operating 30 tents will fumigate about $3\frac{1}{2}$ acres provided the trees are planted regularly twenty feet apart each way. Fumigating in short rows, on contours, or in rough ground is slower, of course.

Season of Fumigation

The time of year at which fumigation is done depends upon two factors, the life-stages of the scale insect and

THIS SCHEDULE HAS BEEN RECOMMENDED FOR USE WHEN TREATING TREES INFESTED WITH COCCUS CITRICOLA

DISTANCE AROUND, IN FEET.

DISTANCE OVER, IN FEET.

	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
10	2	2	2	2	2																																	10
12	2	2	3	3	3	3																																12
14	3	3	3	3	3	3	4	4	4	4	4	5																										14
16	3	3	3	3	4	4	4	4	4	5	5	6	6	6																								16
18	3	3	3	4	4	4	5	5	5	5	6	6	6	7																								18
			20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
20			3	4	4	5	5	6	6	6	6	7	7	7	8	8	9	9																				20
22					5	5	6	6	6	6	7	7	8	8	9	9	9	9																				22
24						5	6	6	6	7	7	8	8	8	9	9	10	10																				24
26							6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	12																26
28								7	7	8	8	9	9	10	10	11	11	12	12	12	13	13																28
								30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
30								7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17											30
32											10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18											32
34												11	11	12	12	12	13	14	15	15	16	16	17	17	18	19	19											34
36												11	12	12	13	14	14	15	15	16	17	17	18	18	19	20	20											36
38													13	13	14	14	15	16	16	17	18	18	19	19	20	21	21											38

Distance Over, in Feet.	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
40	13	14	15	15	16	17	17	18	19	19	20	20	21	22	22											40
41		14	15	16	16	17	18	18	19	20	20	21	22	22	23											41
42			15	16	17	17	18	19	19	20	21	22	22	23	24											42
43				16	17	18	18	19	20	21	21	22	23	23	24											43
44						18	19	20	20	21	22	23	23	24	25											44
						50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
45						19	19	20	21	22	22	23	24	25	25											45
46						19	20	21	21	22	23	24	24	25	26											46
47						19	20	21	22	23	23	24	25	26	26											47
48						20	21	21	22	23	24	25	25	26	27											48
49						20	21	22	23	23	24	25	26	27	28											49
											60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
50											25	26	26	27	28	29	30	31	31	32	33	34	35	35	36	50
51												26	27	28	29	29	30	31	32	33	34	35	35	36	37	51
52													27	28	29	30	31	32	33	34	34	35	36	37	38	52
53														29	30	31	32	32	33	34	35	36	37	38	39	53
54															30	31	32	33	34	35	36	37	37	38	39	54
																70	72	74	76	78	80	82	84	86	88	
55																32	33	34	35	35	36	37	38	39	40	55
56																	33	34	35	36	37	38	39	40	41	56
57																		35	36	37	38	39	40	40	41	57
58																			36	37	38	39	40	41	42	58
59																				38	39	40	41	42	43	59

DOSAGE SCHEDULE 110% A, FOR HIGH GRADE SODIUM CYANIDE (IN OUNCES).

THE ABOVE SCHEDULE IS FOR 129% SODIUM CYANIDE, AND IS CALCULATED ON THE BASIS OF ONE OUNCE OF 98–99% POTASSIUM CYANIDE TO THE 100 CUBIC FEET.

DISTANCE AROUND, IN FEET.

DISTANCE OVER, IN FEET.

	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
10	2	2	2	2	2																																	**10**
12	2	2	3	3	3	3																																**12**
14	3	3	3	3	3	3	4	4	4	4	4	5																										**14**
16	3	3	3	3	4	4	4	4	4	5	5	5	5	5																								**16**
18	3	3	3	4	4	4	5	5	5	5	5	5	5	6																								**18**

	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
20	3	4	4	5	5	5	5	5	5	6	6	6	7	7	8	8																				**20**
22			5	5	5	5	5	5	6	6	7	7	8	8	8	8																				**22**
24				5	5	5	6	6	6	7	8	8	8	8	9	9																				**24**
26					5	6	6	7	7	8	8	8	8	9	10	10	10	11	11	11																**26**
28						6	7	8	8	8	8	9	9	10	11	11	11	11	12	12																**28**

	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
30	7	8	8	8	9	9	10	10	11	11	11	11	12	13	14	14	14	15	16	16											**30**
32				9	10	10	11	11	12	12	12	13	13	14	14	14	15	16	16	17											**32**
34					10	11	11	12	13	13	14	14	14	14	15	16	16	17	17	17											**34**
36					11	11	12	13	13	14	14	15	15	16	17	17	17	17	18	19											**36**
38						12	12	13	14	14	15	16	16	17	17	17	18	18	19	20											**38**

	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
40	12	13	14	14	15	15	16	17	17	18	18	19	20	20	20											**40**
41		14	14	15	15	16	17	17	18	18	19	20	20	20	21											**41**
42			15	15	16	17	17	18	19	19	20	20	20	21	21											**42**
43				16	17	17	18	19	19	20	20	20	20	21	22											**43**
44						17	18	19	19	20	20	20	21	22	22											**44**

Distance Over, in Feet.	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	
45	17	18	19	20	20	20	21	22	23	23											**45**
46	18	19	20	20	20	21	22	22	23	23											**46**
47	18	19	20	20	21	22	22	23	23	24											**47**
48	19	20	20	21	22	22	23	23	24	24											**48**
49	19	20	21	21	22	23	23	23	24	25											**49**
						60	**62**	**64**	**66**	**68**	**70**	**72**	**74**	**76**	**78**	**80**	**82**	**84**	**86**	**88**	
50						23	23	24	25	26	26	27	28	29	29	30	31	32	32	33	**50**
51							24	25	25	26	27	28	28	29	30	31	32	33	33	34	**51**
52								25	26	27	28	28	29	30	31	32	32	33	34	35	**52**
53									26	27	28	29	30	31	32	33	33	34	35	36	**53**
54										28	29	30	31	32	33	33	34	35	36	36	**54**
											70	**72**	**74**	**76**	**78**	**80**	**82**	**84**	**86**	**88**	
55											29	30	31	32	33	34	35	36	36	37	**55**
56												30	31	32	33	34	35	36	37	38	**56**
57													31	33	34	35	36	36	37	38	**57**
58														33	34	36	36	36	37	38	**58**
59															34	36	37	37	38	39	**59**

Dosage Schedule A, for High Grade Sodium Cyanide (In Ounces).

The above Schedule is for 129 % Sodium Cyanide, and is calculated on the Basis of One Ounce of 98–99 % Potassium Cyanide to the 100 Cubic Feet.

the condition of the tree and fruit. Most of the fumigation in California is carried on between the latter part of August and the middle of January, as during these months the black scale is most successfully reached and the fruit is large enough to escape the injury which sometimes occurs when it is young and tender. As previously mentioned, fumigation is ordinarily done at night when the air is cool. Occasionally the work may be done on dark cool days, but day work is quite apt to result in burned foliage and fruit. Fumigation is not advisable when the temperature falls below 38° F. or rises above 65° F. as the operator runs some risk of injuring the trees if the work is done much outside these limits of temperature. Another natural factor which operates against successful work is a strong breeze, which may either hasten the escape of the gas from the tent or greatly injure the side of the tree on which the gas becomes densest. Cases of serious injury to trees which were said to have resulted from fumigation when the foliage was wet have been frequently reported. Careful experiments along this line, on the other hand, show that the presence of moisture on the trees can be ignored so far as direct action of the gas is concerned. Due, however, to the fact that the tents become so heavy and retain so much more of the gas on a wet than on a dry night, it is advisable to stop fumigating after the foliage and tents become thoroughly damp.

The insect pests against which fumigation is generally directed are the black, purple, red, yellow, and citricola scales. The susceptibility of these scales to the gas varies more or less, and accordingly several dosage schedules have been worked out. Experiments by Woglum in fumigating for the purple scale demonstrated that the best results were obtained by one and one-half ounces of potassium cyanide to every one hundred cubic feet of air space under the tent, the fumigation continuing for one hour, by the end of which practically all gas had escaped. This is designated as dosage schedule A and upon this the other schedules are based. The three-quarter schedule for 129 per cent sodium cyanide is the one almost universally used at the present time.

Dosages

For the purple scale, dosage schedule No. $\frac{3}{4}$ sodium cyanide should be used with an exposure of one hour.

For red and yellow scales, dosage schedule No. $\frac{3}{4}$ is recommended with an exposure of forty-five minutes to one hour.

For black scale, the dosage varies. When the insects are in the young and tenderer stages, $\frac{3}{4}$ of schedule A is sufficient, and it is during these stages that fumigation is advisable.

Dosage schedules A for sodium cyanide and No. 110 per cent A are reproduced on pages 446, 447 and 444, 445 respectively. They have been tested out experimentally in actual field operations by Woglum. Copies of these schedules printed on cardboard may be secured from the U. S. D. A. Bureau of Entomology, or from dealers in fumigators' supplies. While using the dosage schedule in the orchard, it should be framed with a clear celluloid or glass cover, as otherwise it will soon become so worn and dirty as to be illegible.

New Woodworth Dosage Table

C. W. Woodworth has recently suggested a new way of calculating dosage which appears to have the advantage of greater simplicity and accuracy.

DOSAGE TABLE — SODIUM CYANIDE

RELATIVE SIZE	DOSE PURPLE SCALE	DOSE BLACK SCALE	
64 ft.	40 oz.	20 oz.	
61 ft.	46 oz.	18 oz.	
58 ft.	32 oz.	16 oz.	
55 ft.	28 oz.	14 oz.	
52 ft.	24 oz.	12 oz.	
50 ft.	20 oz.	10 oz.	
47 ft.	18 oz.	9 oz.	Minimum Dose
44 ft.	16 oz.	8 oz.	
41 ft.	14 oz.	7 oz.	Leakage
38 ft.	12 oz.	6 oz.	.40 %
36 ft.	10 oz.	5 oz.	
33 ft.	9 oz.	4½ oz.	
30 ft.	8 oz.	4 oz.	.35 %
28 ft.	7 oz.	3½ oz.	
26 ft.	6 oz.	3 oz.	
24 ft.	5 oz.	2½ oz.	.30 %
21 ft.	4 oz.	2 oz.	
19 ft.	3½ oz.	1¾ oz.	
16 ft.	3 oz.	1½ oz.	.25 %
	2¼ oz.	1¼ oz.	
	2 oz.	1 oz.	.20 %
	1½ oz.	¾ oz.	
	1 oz.	½ oz.	.15 %
	½ oz.	¼ oz.	.10 %

(Relative size equals distance over plus 1 for each 5 ft. of difference between measurements.)

In explanation of this new system Prof. Woodworth has submitted the following:

"The possibility of adding to the distance over an amount dependent on the difference between the two measurements which will indicate the proportionate size of a tent gives us what we may call the 'relative size' of the tent. If the proportions of a tent remained constant, the difference over could then be taken as the relative size. Since the distance around always equals or exceeds the distance over, we may select as standard a tent with these two measurements equal. The amount to be added to this to allow for wider and shorter tents is one-fifth of the difference between the two measurements. Thus a tent 20×30 would have a relative size of 22, and should have a dose equal to that of a tent 22×22.

"The adoption of this plan of relative sizes makes it possible to present a table of dosage in a very simple form, and to make the adjustments for different degrees of leakage also very easy.

"In the foregoing table the first column gives the relative sizes corresponding to the series of doses shown in the second and third columns suitable for tents having the average leakage of 25 per cent.

"The adjustment for leakage is equally simple. Opposite each per cent given in the table is the minimum dose. No matter how small the tree, if a tent leaks 40 per cent, the dose for purple scale should not be less than 12 oz. Indeed, it is unwise to attempt to fumigate with a tent of this degree of leakage except when big enough to hold a sufficient body of gas without its being too concentrated at the time of generation for the safety of the tree."

Costs

Cyanide costs by the ton about 22 cents a pound. Contract fumigators usually furnish the cyanide at 30 cents a pound, including the acid for generation. The sulfuric acid alone costs about $1\frac{1}{2}$ cents a pound. Laborers receive pay by the hour. The rate is usually 35 cents an hour, while the foreman receives 50 cents an hour. Most trees fumigated require between five and eighteen ounces of cyanide. A supply cart completely equipped may be had for about $35. Two gallon generators cost about 45 cents each. Tents cost from $12 to $50 each, according to size. The thirty-six foot tent costs ready-made from $25 to $30 each. The cost of thirty 45-foot tents of special 7-ounce drill, together with the other equipment necessary to complete the outfit, will cost about $1400.

Recently a fumigating machine has been invented which quickly generates the gas in a large metal drum by mixing a water solution of cyanide and acid. The gas is discharged directly into the tent through a four-inch hose. The use of this machine makes generators unnecessary and prevents all acid holes in the tents. It is now being widely experimented with.

CHAPTER XXIV

VARIOUS ORCHARD PESTS AND THEIR CONTROL

There are several pests other than insects with which citrus growers are apt to have to deal. A knowledge of the habits of animals such as gophers and ground squirrels is necessary before intelligent methods of repression can be adopted. Recently the citrus root nematode has attracted much attention, and a rather detailed account of its habits and life history will no doubt prove of quite general interest.

Citrus Nematode (Tylenchulus semipenetrans)

As stated in Chapter XXI this worm has been suggested as the cause or one of the causes of mottled-leaf. On account of the popular interest in the nematode and the great diversity of opinions regarding it, space is given to a more or less detailed account. The data here presented has been largely condensed and adapted from Cobb.[1]

This citrus nematode was first noticed by J. R. Hodges of Covina, California, in 1912, and first mentioned in print by B. R. Jones.[2] A preliminary report was later published by E. E. Thomas of the University of California.

[1] N. A. Cobb, "Citrus-root Nematode," *Journal of Agricultural Research*, Vol. II, No. 3, June, 1914, pp. 217–230.

[2] *Los Angeles County Hort. Com. Bull. No.* 1, 1913, pp. 72–73.

This species of nematode is found only on the roots of citrus trees although it occurs in all parts of the world where citrus trees have been grown for any length of time. The worms are very minute, being barely visible to the unaided eye. The males are smaller than the females and probably do not attack citrus roots. In fact, it is thought that the males do not take food while in the perfect stage. The eggs are large and thin shelled, and are deposited one at a time in batches of twelve to twenty or more, and are sometimes incased in gummy matter. The eggs hatch in a day or two into colorless larvæ which make their way to the nearest citrus root to which the females attach themselves in more or less well defined groups. These groups are very quickly scattered along the fine fibrous feeding roots in enormous numbers. The effect is to sap the vitality of the tree and kill the feeding roots. The movements are slow and weak and the worms cannot migrate through the soil to any great distance.

The females possess an oral spear with which they force the head end into the tissues of the root. That part of the body within the root enlarges somewhat so that it is impossible for them to withdraw. They remain fixed for the rest of their lives, although the exposed part of the body may be moved back and forth. The food consists of sap and protoplasmic cell contents. The entire life cycle occupies from six to eight weeks.

A predaceous nematode of large size (*Mononchus papillatus*) has been found to occur also in the soil about citrus roots. The Mononchus preys regularly upon the males and larvæ of Tylenchulus, swallowing them whole. To what extent the Mononchus may be able to control the citrus nematode is not at present known.

The citrus nematode affects the different stocks about equally. It has so far been found in abundance on the sour, sweet, and trifoliate oranges and on pomelos.

"There can be no doubt that *Tylenchulus semipenetrans* is an injurious parasite. There is conclusive evidence that it kills the feeding roots of citrus trees. The roots die either as a direct result of the attack of this parasite or of the attack of other organisms following in its wake; in other words, the nematode is a primary cause of the death of the feeding roots. Many cases have come under observation in which it was apparent that, had it not been for the nematode, the roots would have remained in a healthy condition. The evidence along these lines is of the same character as that which is relied on in demonstrating injuries due to insects and other macroscopic parasites.

"The extent of the damage which may properly be charged up against this parasite is a different matter, and it will be necessary to collect evidence along this line for several years before a final statement can be made. Up to the present the data obtained indicate unquestionably that the investigations should be continued."

The citrus nematode is very readily distributed from place to place on the roots of nursery stock, and this is especially true when the trees are balled for shipment. The question as to just how much importance to place upon inspection and quarantine in connection with this parasite cannot be answered at the present time. In order to be on the safe side it is well for buyers to specify that the trees be free from nematodes. Control measures such as injecting carbon bisulfide and lime water into the soil are being widely experimented with, but so far without any very promising results. Vaile[1] has shown that nematodes are killed by submersion in hot water at a temperature of 120° F. for ten

[1] *Annual Rpt. Ventura County Hort. Com.*, 1913, p. 10.

minutes. This treatment did not kill the roots entirely, although some of the fine feeding roots were injured. This is not considered important because when trees are transplanted with bare roots they put out new feeding roots anyway. It is possible that some such method of treatment may soon be devised by which infested nursery stock may be freed from the pest.

The Pocket Gopher (*Geomys bursarius*)

Gophers often cause serious damage to citrus trees by girdling young trees at the surface of the ground and by chewing the bark from the crown roots of older trees. They are especially troublesome in orchards near alfalfa fields in sections where open ditches are used for irrigation. Gophers will run for considerable distances over the surface of the ground at night, and entering an orchard without warning begin to dig their runways. The runs extend for long distances underground and are vexatious nuisances when irrigating. Gophers may be controlled both by poisoning and by trapping.

In trapping use a small wire spring trap and set it delicately so it will spring easily. Then open the run under a recently made pile of fresh dirt and insert the trap, pushing it well back into the run. If the run goes both ways, put in two traps to make sure. Then close up the holes with grass or sod so that just a little light can enter. The gopher will soon notice the light, and in attempting to close the opening will be caught. It is well to attach a long string to the trap to prevent their being lost if pulled for some distance back into the hole. Any attempt to drown a gopher by turning irrigation water into the hole will not succeed unless the entire surface of the ground can be flooded as is possible in alfalfa fields.

Strychnine is probably the most effective and safest poison for general use. A sirup poisoned with strychnine is very easily prepared and will be found very effective. It is made according to the following formula recommended by the U. S. Bureau of Biological Survey: "Dissolve an ounce of strychnia sulfate in a pint of boiling water. Add a pint of thick sugar sirup and stir thoroughly. The sirup is usually scented by adding a few drops of oil of anise, but this is not essential. If preserved in a closed vessel, the sirup will keep indefinitely." This quantity will poison about thirty pounds of shelled corn or grain, preferably corn. The grain should be soaked in water overnight and then soaked for several hours in the poisoned sirup. The dry strychnine may also be used by introducing a very small quantity on the point of a knife into carrots, beets, sweet potatoes, entire raisins, or prunes. Such poisoned bait is then placed carefully in the freshly open holes, or in the runways. There are many prepared gopher poisons on the market which may be purchased if one does not care to go to the trouble of mixing the strychnine as directed.

The use of carbon bisulfide for killing gophers is recommended where the soil is moist and the burrows not too extensive. In dry soil, the gas escapes too rapidly to make its use effective. The bisulfide may be poured over a bunch of cotton waste or other material and this pushed quickly into the burrow, which should be closed at once. Since carbon bisulfide is highly inflammable a very common method of application is to ignite the cotton waste after it is placed in the burrows as deeply as possible; the gases produced by ignition are poisonous and seem just as effective a killing agent as the liquid bisulfide. On account of the danger of explosion to the operator and the liability of starting grass fires, the use of bisulfide by ignition is not so advisable as by the former method. Special injectors for forcing the bisulfide into the burrows are on the market and are more effective than the hand method.

Recently a new method of attack has been discovered which is said to work well where only a few gophers have to be dealt with. An automobile is placed over the hole and a short hose attacked to the exhaust, the other end being inserted in the gopher hole and packed with moist soil. After turning an extra amount of lubricating oil into the cylinders for the purpose of making a smoky gas, the engine is started. If smoke is emitted from any hole in the vicinity it is promptly plugged. A few minutes of this treatment naturally produces a condition fatal to the gopher.

Ground Squirrels (Citellus beecheyi)

These animals overrun California, occurring by millions in the interior valleys, where they destroy large quantities of grain, almonds, and dried fruit. They may do great damage to citrus orchards and nurseries but, unlike the gopher, their depredations are largely confined to orchards situated near grain fields or brush land. Railroad embankments, canal banks, and roadsides are favorite places for squirrel burrows. The animals live mostly on grain, nuts, acorns, and weed seeds, but during the rainless summer and fall, when the green herbage dries up, they are apt to visit citrus trees and gnaw the bark. A few squirrels may quickly ruin a large number of trees when the young trees have just been planted out.

Ground squirrels may be poisoned in the same way as gophers, poisoned barley or wheat being most commonly used for this purpose. Whole barley threshed but still retaining its rough outer husk will not be eaten by birds, so it should always be used in this form. The following formula and directions for preparing poisoned barley are suggested:

Whole barley	20 pounds
Vinegar	$1\frac{1}{2}$ pints
Strychnia sulfate	1 ounce
Honey	1 pint
Cyanide of potassium	$1\frac{1}{2}$ ounces
Eggs	1 dozen

Pulverize the strychnine in the vinegar and see that it all dissolves. Dissolve the cyanide in a little water. Beat the eggs thoroughly. Mix all the ingredients together and stir well before adding to the barley. Stir at intervals during the next few hours and dry before using as it will mold if put away wet. Grain coated with poison is more effective than grain soaked in poison for the reason that much of the grain being gathered, carried into the burrows and stored for winter use is not immediately effective. When the grains are coated with poison, enough will be absorbed by the cheek pouches during transit to produce death.

Another very effective poison during the dry season is halved ripe cull oranges, upon the cut surfaces of which strychnine has been smeared.

CHAPTER XXV

BIBLIOGRAPHY

OTHER BIBLIOGRAPHIES

WATERS, CARRIE S. "Citrus Fruits and Their Culture," a Bibliography classified according to subjects. Published 1913 by San Bernardino Free Public Library.

FERRARI, E. Extensive Bibliography of the Lemon. Bol. Abor. Ital. 5 (1909), pp. 145–80.

SAVASTANO, L., and PARROZZANI, A. List of about Fifty Articles on Citrus in European Literature. Annals Royal Italian Experiment Station for Agr. and Fruit Culture, Vol. 1, 1911.

COOK, A. J. "Bibliography of Citrus." In "California Citrus Culture," Calif. State Com. Hort., 1913.

HUME, H. H. "American Citrus Literature." In Chapter XIV, "Citrus Fruits and Their Culture," 1907.

REFERENCES TO LITERATURE DEALING WITH PARTICULAR FRUITS

Orange Growing in United States

CRAW, A. "Working Over Old Orange Trees." Pacific Rural Press, May 9, 1885.

GAREY, T. A. "Orange Culture in California." San Francisco, 1882.

JACKSON, J. R. "Notes on Oranges." Garden. Copied in U. S. D. A. Yearbook, 1887, p. 56.

LUMMIS, C. F. "Oranges 250 Years Ago." The Land of Sunshine, Vol. XVI, Feb., March, and April, 1902.

SPALDING, W. A. "The Orange, Its Culture in California." Riverside, 1880.

SKINNER, L. B. "Orange Culture in Florida." Proc. Am. Pom. Soc. 1911, pp. 70–6.

WHITNEY, J. P. "Educational Orange Growing." Sunset Magazine, Vol. 70, pp. 161–70, Aug. 1906.

WALLACE, T. C. "The Cultivation of Oranges." Pacific Rural Press, Oct. 24, 1908.

SAUNDERS, WM. "Notes on Orange Culture." Rpt. of U. S. Dept. of Agr. 1886, p. 687.

HART, E. H. "The Orange." The American Fruit Culturist, 1908, p. 621.

ONDERDONK, GILBERT. "The Orange in Texas." Texas State Dept. Agr. Bul. 9, p. 7.

MANVILLE, A. H. "Practical Orange Culture." Jacksonville, Ashmead Bros., 1883.

POWELL, E. P. "The Orange, Another of our First Families." Independent, Vol. 60, p. 1089, May, 1906.

MEVERS, W. A. "How to Grow and Cultivate an Orange Grove in Louisiana." La. State Hort. Soc. Proc. 1906, p. 71.

BROWN, E. "Oranges in Northern California." Scientific American, Vol. 88, pp. 138–9, Feb. 1903.

[CARNES, E. K.] "Development of the Orange Industry in California." Natomas News, Vol. 3, No. 1, March, 1913.

HORGAN, H. V. "Growing Oranges under Tents." Country Californian, Vol. 1, pp. 717–19, 750, Dec. 1905.

WICKSON, E. J. "The Orange in Northern and Central California." San Francisco Chronicle, Jan. 1, 1903. Reprinted by State Board of Trade.

WILLIAMSON, ROBERT. "Orange Growing in Central and Northern California." Pacific Rural Press, Vol. 39, p. 2, Jan. 4, 1890.

KINNEY, A. "The Orange, History, Analyses, Varieties." Pacific Rural Press, March 21, 1885, p. 282.

GUINN, J. M. "From Cattle Range to Orange Grove." Pacific Monthly, Oct. 1910.

MOREMEN, M. S. "Present Condition and Treatment of Orange Groves." Florida Agr. Exp. Sta. Bul. 33, 1896.

BENNETT, J. E. "Roofing Over Orange Orchards." Current Literature, Vol. 27, pp. 146–7, Feb. 1900.

Orange Growing in Foreign Countries

FERRARIUS, J. B. "The Hesperides or About the Golden Apples. Their Culture and Use. In Four Books." Rome, 1646.

PYE, THOMAS. "History and Culture of the Orange." Dept. Agr., New South Wales, Bul. 1, 1890.

ALDERTON, G. E. "Treatise and Handbook of Orange Culture in Auckland, New Zealand." Wellington, 1884.

MOODY, J. F. "The Cultivation of the Orange." Dept. of Agr., West Australia, Bul. 34, 1912.

TRABUT, L. V. "L'Oranger en Algerie." Direction de l'agriculture gouv. gen. Algerie, Bul. 44, 1908.

FREEMAN, L. R. "The Orange in the West Indies." Pacific Rural Press, June 21, 28, and July 5, 1913.

BELL, H. H. "Cultivation of Oranges in Dominica." Imp. Dept. of Agr., Barbados, Bul. 37, 1905.

ABELLA, A. "Orange Culture in Montevideo." Min. Indus. (Uruguay) Insp. Nac. Gan. y Agr., Bol. 7 (1913), p. 48.

[Anonymous.] "Orange Growing in Lower California." Pacific Rural Press, Nov. 22, 1884.

AMOORE, H. E. "Japanese Orange Growing." Pacific Rural Press, No. 19, 1887, p. 411.

ORCHARD, P. W. "A Study of the Orange Districts of Spain." The Florida Grower, Oct. 11, 18, 25, 1913.

NEWCOMER, E. J. "Oranges at Seville." Pacific Rural Press, June 7, 1913.

SHAMEL, A. D. "Orange Growing in Brazil." Pacific Rural Press, Jan. 10, 1914, p. 41.

BERTONI, G. T. "The Oranges of Paraguay." An. Rpt. Estacion Agron. de Puerto Bertoni Para 1911 y 1912, p. 195.

SHEPSTONE, H. J. "Jaffa Orange Culture." World's Work (London), Vol. 17, pp. 199–203, Jan. 1911.

EISEN, G. "The Jaffa Orange in Egypt." Calif. Cultivator, Jan. 23, 1913, p. 100.

[Anon.] "The Orange Industry of Palestine." Hacherouth, No. 20, 1913.

AARONSOHN, A., and SOSKIN, S. "The Orange Groves of Jaffa." Tropenpflanzer, Vol. 6.

AARONSOHN, A. "Jaffa Oranges in Palestine." U. S. D. A. Bureau Plant Industry, Bul. 180, 1910, p. 25.

[Anon.] "An Orange Farm." South African Agr. Journ., Feb. 1913, p. 176.

MCILWAINE, R. "The Possibilities of Rhodesia as a Citrus Growing Country." Dept. Agr. Rhodesia, Bul. 2, Feb. 1908.

FARMER, C. E. "Citrus Fruit Trees from Seed to Grove." Dept. Agr. Rhodesia, Bul. 153, Aug. 1913.

"Citrus Fruits in Rhodesia." Dept. Agr. Rhodesia, Bul. 164, Dec. 1913.

"Rhodesian Citrus Fruit." Dept. Agr. Rhodesia, Bul. 166, Dec. 1913.

MCILWAINE, R. "Some Citrus Growing Experiences in Rhodesia." Dept. Agr. Rhodesia, Bul. 182, June, 1914.

Varieties

CHAPMAN, C. C. "Orange Varieties and Their Respective Merits." Rpt. 28th Calif. Fruit Growers Convention, 1903, p. 163.

SAUNDERS, WM. "Washington Navel Orange, Its History and Pollen Production." U. S. D. A. Yearbook, 1887, p. 640.

VAN DEMAN, H. E. "History of the Washington Navel Orange." American Garden, June, 1888, p. 231.

HART, E. H. "History of the Various Navel Oranges under Cultivation." Semi-Tropical Planter (San Diego), May, 1887.

VAN DEMAN, H. E. "The Navel Orange, Another Chapter in Its History." Semi-Tropical Planter, June, 1887.

"Bahia or Washington Navel Orange." Rpt. U. S. Dept. Agr., 1886, p. 267.

"History of the Washington Navel Orange." U. S. D. A. Yearbook, 1887, p. 640.

"History of the Introduction of the Washington Navel." Rural New Yorker, June, 1899.

Coit, J. Eliot. "The History of the Washington Navel or Bahia Orange." Calif. Cultivator, April 18, 1912.

Chapman, C. C. "Introduction of the Australian Navel." History of Orange County, 1911, p. 74.

Reasoner, P. W. "The Navel Oranges in Florida." American Garden, April, 1888, p. 135.

Mills, J. W. "Origin of the Golden Nugget Navel Orange." Calif. State Bd. Hort. Rpt. 1902, p. 256.

Taylor, W. A., and Gould, H. P. "The Thomson Orange." U. S. D. A. Yearbook, 1911, p. 436.

Hume, H. H. "The Surprise Navel Orange." Proc. 29th Am. Pom. Soc. 1905, p. 169.

Earle, S. F. "The Navel Orange in Cuba." Calif. Cultivator, Jan. 1, 1914.

Saunders, Wm. "History of Hart's Late or Hart's Tardiff Orange." U. S. D. A. Yearbook, 1887, p. 640.

[Anon.] "Origin of the Valencia Late Orange." Pacific Rural Press, Sept. 18, 1909, p. 180.

Williams, P. F. "The Satsuma Orange." Alabama Exp. Sta. Bul. 157, 1911.

Taber, G. L. "The Satsuma Orange." American Garden, 1890, p. 590.

Saunders, Wm. "The Satsuma Orange." U. S. D. A. Yearbook, 1887, p. 638.

McFarland, J. Horace. "The Satsuma Orange." American Garden, 1890, pp. 268, 590.

Carney, J. L. "History of the Parson Brown Orange." Florida Grower, Oct. 4, 1913, p. 10.

Webber, H. J. "The Rustic Citrange." U. S. D. A. Plant Industry Circular, 1907.

Shinn, C. H. "The Japanese Oranges." American Garden, 1890, p. 333.

Koethen, E. L. "The Jaffa Orange in California." Calif. Cultivator, March 6, 1913.

Hume, H. H. "Oneco Mandarin Orange." Proc. 28th Am. Pom. Soc. 1903, p. 248.

Close, F. "The Sour Orange and its Product." Pacific Rural Press, Feb. 18, 1888, p. 149.

Lelong, B. M. "Varieties of the Orange." Calif. State Bd. Hort. Rpt. 1888, p. 33.

"Orange Varieties Popular in California." Pacific Rural Press, June 16, 1888, p. 521.

[Anon.] "Thomson's Improved Navel Orange." Pacific Rural Press, Vol. 41, p. 525, May 30, 1891.

[Anon.] "Navel Oranges." Pacific Rural Press, April 14, 1883, p. 326.

[Anon.] "The Lue Gim Gong Orange." Calif. Cultivator, June 5, 1913, p. 694.

Van Deman, H. E. "Onshiu or Satsuma Orange." Pacific Rural Press, April 7, 1888, p. 317.

[Anon.] "Onshiu, a Fine Japanese Orange." Pacific Rural Press, Feb. 12, 1887, p. 125.

[Anon.] "Canton Hybrid Orange Better Than Onshiu." Pacific Rural Press, June 18, 1887, p. 538.

[Anon.] "The Satsuma, a Fine Japanese Orange." Pacific Rural Press, Feb. 16, 1889, p. 152.

Berger, H. "Oranges in Japan." Pacific Rural Press, Sept. 10, 1882, p. 206.

Parsons, S. B. "The Sweet Seville Orange." U. S. D. A. Yearbook, 1877, p. 565.

[Anon.] "The Lue Gim Gong Orange." Proc. 32d Am. Pom. Soc. 1911, p. 172.

TAYLOR, W. A. "The Lue Gim Gong Orange." U. S. D. A. Yearbook, 1913, p. 109.

Breeding Oranges

SWINGLE, W. T. "Citrus Trifoliata in Relation to Citrus Culture." Proc. 32d Session Am. Pom. Soc. 1911, pp. 218–21.

SMITH, C. B. "Improving the Orange by Selection." 37th Calif. Fruit Grow. Convention, 1910, p. 100.

PAINE, C. R. "Variation in the Branches of the Navel Orange." Calif. Cultivator, July 6, 1911, p. 4.

[Anon.] "Do Different Buds on the Same Orange Tree Produce Like Fruit?" Calif. Cultivator, March 13, 1913.

BELLING, J. "Polyembryony of the Orange." Florida Sta. Rpt. 1908, p. cix.

MILLS, J. W. "Improvement of the Orange." Rpt. Calif. State Bd. Hort. 1902, p. 255.

Insects Affecting Oranges

HUBBARD, H. G. "Insects Affecting the Orange." U. S. D. A. Div. of Entomology, 1885.

ASHMEAD, W. H. "Orange Insects." Jacksonville, Fla., 1880.

SASSCER, E. R. "The Cork-colored Orange Tortricid." Journal Econ. Ent., June, 1911, p. 297.

GANDARA, GUILLERMO. "Enfermedades y Plagas Del Naranjo." Mexico. Sec. de Fomento. Callejon de Bettemitas, No. 8, 1910.

JONES, P. R., and HORTON, J. R. "The Orange Thrips." U. S. D. A. Bureau of Entomology, Bul. 99, part 1, 1911.

QUAYLE, H. J. "The Orange Tortrix." Journal Econ. Ent., Oct. 1910, p. 401.

HERRERA, A. L. "The Morelos Orange Worm." Journal Econ. Ent. 1908, No. 3, pp. 169–74.

[Anon.] "Trypeta Ludens in Mexico." Calif. State Hort. Com. 1905.

MOULTON, DUDLEY. "The Orange Thrips." U. S. D. A. Bureau of Ent. Tech. Series, No. 12, part VII, 1909.

Comstock, J. H. "The Angular-Winged Katydid On Orange." U. S. D. A. Rpt. Sec. of Agr. 1880, p. 249.

Dew, J. A., and Wolf, F. A. "The Satsuma Orange, Its Insect Pests and Diseases." Bul. 1, Insecticide Dept. Van Antwerp's Seed Store, Mobile, Ala.

Orange Diseases

Reed, J. H. "Black Rot of the Navel Orange." Calif. Cultivator, Vol. XVII, No. 11, p. 160, 1901.

Pierce, N. B. "Black Rot of Navel Orange." Calif. Cultivator, Vol. XVII, No. 12, p. 181, 1901.

"Black Rot or Navel Rot of Orange." Bot. Gaz. Vol. 33 (1902), No. 3, pp. 234–5.

Fawcett, H. S. "Black Rot of the Navel in Florida." Florida Exp. Sta. Rpt. 1911, p. lx.

Amundsen, E. O. "Black Rot of the Navel Orange." Calif. State Com. Hort. Monthly Bul., Vol. 2, No. 5, May, 1913.

Fawcett, H. S. "Stem End Rot of the Oranges." Florida Exp. Sta. Rpt. 1911, 1912.

"Diplodia Rot of Oranges." Florida Exp. Sta. Rpt. 1911.

"Three Fungus Enemies of Orange Trees." Proc. Am. Pom. Soc. 1911, p. 190.

"The Scaly Bark Disease of the Orange." Florida Exp. Sta. Rpt. 1907, p. xliii.

"Orange Scab or Verrucosis." Florida Exp. Sta. Rpt. 1911.

Curtiss, A. H. "The Prevention of Orange Rust." Florida Exp. Sta. Bul. 2, 1888.

Webber, H. J. "Sooty Mold of the Orange and Its Treatment." U. S. D. A. Div. Veg. Phys. & Path. Bul. 13, 1897.

Powell, G. H. "The Decay of Oranges While in Transit from California." U. S. D. A. Plant Ind. Bul. 123, 1908.

Smith, R. E. "The Soft Spot of Oranges." Bot. Gaz. Vol. 24 (1897), No. 2, pp. 103–4.

Messenger, C. B. "Orange Dropping and Its Causes." Calif. Fruit Grower (1896), No. 19, pp. 450–1.

WEBBER, H. J. "Melanose of the Orange." Florida Farmer and Fruit Grower, 7 (1896), p. 419.

UNDERWOOD, L. M. "Diseases of the Orange in Florida." Journal of Mycology, Vol. VII, No. 1, Sept. 10, 1891, p. 63.

SCRIBNER, F. L. "Orange Leaf Scab." U. S. D. A. Rpt. 1886, p. 120.

SMITH, R. E. "Brown Spot of the Orange." Calif. Exp. Sta. Bul. 203, 1909, p. 47.

COIT, J. ELIOT. "The Brown Spot of the Navel Orange." Proc. Soc. Hort. Sci. 1910, p. 62.

GALLOWAY, B. T. "Gum Disease or Foot-Rot of the Orange." U. S. D. A. Div. Bot. Bul. VIII, 1889, pp. 51–4.

SMITH, R. E., and SMITH, E. H. "Orange Diseases." In Calif. Sta. Bul. 218, 1911.

The Lemon

HOLT, L. M. "Lemon Culture for Profit." Proc. Pom. Soc. of Southern Calif. 1892, p. 30.

POWELL, G. H. "The American Lemon Industry." U. S. D. A. Yearbook, 1907.

POWELL, G. H., and CHASE, E. M. "Italian Lemons and Their By-Products." U. S. D. A. Plant Industry, Bul. 160, 1909.

[Anon.] "History of the Lemon Rate Case." Calif. Cultivator, Aug. 29, 1912.

POWELL, G. H., and WALLSCHLAEGER, F. O. "The California Lemon Industry." Citrus Protective League, Bul. 9, Jan. 1913.

POWELL, G. H. "The Italian Lemon Industry." Citrus Protective League Circular 10, Jan. 1913.

[Anon.] "Cost of Producing Lemons in California." Citrus Protective League, Brief of Facts Presented to Ways and Means Committee of Congress. Jan. 20, 1913.

CHENEY, A. S. "The Lemon Industry in Sicily." U. S. Consular Rpt. 1908.

WORKS, J. D. "The Tariff on Lemons." Speech in U. S. Senate, July 24, 1913.

GARCELON, G. W. "Fifteen Years with the Lemon." Calif. State Board of Hort. Pamphlet, 1891.

NEWCOMER, E. J. "Italian Lemon Culture." Calif. Cultivator, May 29, 1913.

KIMBALL, F. A. "Lemon Culture and Lemon Curing." Rpt. Calif. State Bd. Hort. 1888.

CONGER, O. H. "Lemon Culture." Rpt. Calif. State Bd. Hort. 1889.

TENNEY, W. A. "Ventura Lemon Culture." Overland Monthly, Vol. 60, pp. 150–7, 1905.

FERRARI, E. "Extensive Bibliography of the Lemon." Bol. Abor. Ital. 5 (1909), pp. 145–80.

LELONG, B. M. "Varieties of the Lemon." Calif. State Bd. Hort. Rpt. 1888, p. 39.

KIMBALL, F. A. "Lemon Culture." Proc. Am. Pom. Soc. 1897, pp. 95–9.

BLANCHARD, N. W. "The Lemon and Its Treatment." Pacific Rural Press, Vol. 39, p. 378, 1890.

TEAGUE, C. C. "Curing and Shipping Lemons." Calif. Fruit Grower, July 11, 1903.

ALLEN, W. J. "Curing the Lemon." Dept. Agr. New South Wales, Farmers' Bul. 47, 1912.

HARWOOD, N. S. "Growing American Lemons." World's Work, Vol. 5, pp. 3315–22, April, 1903.

TYLOR, A. R. "Gray Mold of Lemons." Calif. Cultivator, Feb. 1, 1912.

SMITH, R. E., and SMITH, E. H. "Brown Rot of the Lemon." Bot. Gaz. Vol. 42, pp. 215–21, Sept. 1906.

SMITH, R. E. "Brown Rot of the Lemon." Calif. Exp. Sta. Bul. 190, 1907.

FAWCETT, H. S. "Tear Staining of Lemons." Calif. Com. Hort. Monthly Bul., June, 1913, p. 560.

"Two Fungi as Causal Agents in Gummosis of Lemon Trees in California." Calif. Com. Hort. Monthly Bul., Aug. 1913.

"Treatment for Gummosis of Lemon Trees." Calif. Cultivator, July 24, 1913.

Smith, C. O. "Black Pit of Lemon." Phytopathology, Vol. III, No. 6, Dec. 1913.

Rolfs, P. H. "Lemon Scab." Florida Grower, June 6, 1914.

The Lime

Watts, Francis. "Lime Cultivation in the West Indies." Imp. Dept. Agr. for West Indies, Pamphlet No. 72, pp. 136, 1913.

Nicholls, H. A. A. "The Lime." In Chapter VI, "Text-Book of Tropical Agriculture."

[Anon.] "The Lime Tree and Its Products." Nature, Vol. 79, p. 22, 1908.

Timehri. "The Lime Industry of Dominica." 1883.

Tempany, H. A., and Jackson, T. "Lime Industry of Antigua." West Indian Bulletin, Vol. 12.

[Anon.] "Feeding and Manurial Value of Lime Skins." Agricultural News, Vol. 11, p. 288.

Ballou, H. A. "Notes on Lime Cultivation." West India Bul., Vol. 11, p. 93.

Brooks, A. J. "Development of the West Indian Lime Fruit." West Indian Bul., Vol. 12, p. 506.

Sands, W. N. "British West Indian Limes in New York." West Indian Bul., Vol. 11, p. 153.

Jones, G. A. "The Keeping Qualities of Lime Juice." Agricultural News, Vol. 11, p. 180.

Watts, F., and Jones, J. "Citrate of Lime and Concentrated Lime Juice." West Indian Bul., Vol. 9, p. 159.

Mandarin Oranges

Hume, H. H. "The Mandarin Orange Group." Florida Exp. Sta. Bul. 66, 1903.

Shinn, C. H. "The Japanese Oranges." The American Garden, Vol. 11, pp. 333–6, June, 1890.

WESTER, P. J. "Mandarin Orange. The Situation in the Citrus Districts of Batangas." Phil. Agr. Rev., Vol. 6, pp. 125–30, March, 1913.

The Pomelo

LELONG, B. M. "The Pomelo in California." Calif. State Bd. Hort. Rpt. 1894, p. 63.

BAKER, C. F. "The Grapefruit in Southern California." Rpt. Proc. 39th Calif. Fruit Grow. Convention, 1911, p. 81.

HUME, H. H. "Pomelos." Florida Exp. Sta. Bul. 58, 1901.

BOYLE, H. H. "Notes on Siamese Pomelos." Phil. Agr. Rev., Vol. VII, No. 2, Feb. 1914.

BAKER, C. F. "Siamese Seedless Pomelos." Am. Breeders Mag., Vol. IV, No. 4, Dec. 1913.

[Anon.] "Siamese Seedless Grapefruit." U. S. Daily Consular and Trade Rpt., Aug. 28, 1911, p. 925.

HARRISS, H. "Grapefruit." Bul. Dept. Agr., Jamaica, n. s., Vol. 2, No. 6, Jan. 1913, p. 166.

BOYLE, H. H. "The World's Best Pomelo." Phil. Agr. Rev., Vol. 5, No. 11, Nov. 1912, p. 614.

WARD, C. W. "The Grapefruit Game and How to Play It." Outdoor World and Recreation, Vol. 48, No. 3, Feb. 1913.

MOTT, J. "The Pomelo, Shaddock, or Grapefruit." American Garden, Vol. 11, p. 715, Dec. 1890.

MORRIS, D. "Grapefruit and Shaddocks." Garden and Forest, Vol. 9, 1896, p. 163.

HUME, H. H. "Anthracnose of the Pomelo." Florida Exp. Sta. Bul. 74, 1904.

The Kumquat

HUME, H. H. "The Kumquats." Florida Exp. Sta. Bul. 65, 1902.

[Anon.] "Citrus Japonica." Pacific Rural Press, March 5, 1887, p. 205.

CHAPIN, L. P. "Kumquats." Good Housekeeping, Vol. 52, pp. 479–81, April, 1911.

The Citron

Ferrari, E. "History and Relationships of the Citron." Atti. R. 1st Incoragg. Napoli, 6. ser. 7 (1909), p. 21. Contains a good bibliography of Citron.

Richardson. "A Chapter on Citron." Pacific Rural Press, March 31, 1883, p. 284.

Calhoun, J. J. "California Should Grow Citron." Orchard and Farm (San Francisco), April, 1913.

[Anon.] "The Home of the Citron." Rural Californian, March, 1905, p. 91.

[Anon.] "Citrous in Mogador." Gardeners' Chronicle, 1884, 2, p. 601.

[Anon.] "Citron of Commerce." Pacific Rural Press, Vol. 39, p. 244, March 8, 1890. (Fruiting at Riverside.)

[Anon.] "Citron." Pacific Rural Press, Vol. 40, p. 352, Oct. 25, 1890.

Sturtevant, E. L. "Citron." Mem. Tor. Bot. Club, Vol. 1, No. 4, p. 158, 1890.

[Anon.] "The Troon or Tabernacle Citron." Gardeners' Chronicle, Nov. 8, 1885, p. 601.

Wickson, E. J. "Candied Citron." Pacific Rural Press, Nov. 2, 1907, p. 275.

REFERENCES TO LITERATURE DEALING WITH THE CITRUS FRUITS IN GENERAL

Miscellaneous References

Ferrarius, J. B. "The Hesperides." 1646.

Macfayden. "Citrus of Jamaica." In Hooker's Bot. Misc., Vol. 1, p. 295, 1830.

Targioni, D. A. "Citrus Fruits." Journal Hort. Soc., London, Vol. 9, p. 171, 1855.

GALLESIO. "History of the Citrus." English translation in appendix to "Orange Culture," by T. W. Moore.

DE CANDOLLE, A. "Origin of the Citrus Fruits." In "Origin of Cultivated Plants."

[Anon.] "Citrus Culture in Foreign Lands." U. S. D. A. Yearbook, 1886, pp. 693–703.

SIMMONS, P. L. "Products of the Orange Family." In "Tropical Agriculture," p. 438, 1877.

WHITE, W. N. "The Orange Family." In "Gardening for the South," New York, 1868.

HART, E. H. "Citrus Fruits." In Thomas' "American Fruit Culturist," various editions.

HENDERSON, PETER. "Citrus." In "Handbook of Plants," New York, 1889.

KLEE, W. G. "Citrus Fruits." U. S. D. A. Div. Pom. Bul. 1, 1887.

DAVIS, G. W. "A Treatise on the Culture of the Orange and Other Citrus Fruits." Jacksonville, Fla., 1881.

DOWNING, A. J. "The Orange Family." In "Fruits and Fruit Trees of America," New York, 1849.

GOFF, E. S. "Citrus Fruits." In "Lessons on Commercial Fruit Growing," Madison, Wis., 1902.

REASONER, P. W. "Orange, Pomelo, Lemon, etc." U. S. D. A. Div. Pom. Bul. 1, 1887.

JONES, J. W. "On the Culture of the Genus Citrus." Gardener's Chronicle, April 20, 1844.

BONAVIA, E. "Oranges and Lemons of India." London. 2 vols.

WICKSON, E. J. "California Citrus Industry." Proc. 32d Meeting Am. Pom. Soc., 1911, pp. 245–54.

ROEDING and WOOD. "Citrus Fruits in California." Los Angeles, 1913.

COOK, A. J. "California Citrus Culture." Calif. State Com. Hort. 1913.

CALL, A. F. "The Culture of Citrus Fruits." Calif. Cultivator, Feb. 5, 1914, and continued in subsequent numbers.

BOYNTON, S. S. "Citrus Culture in Northern California." Pacific Rural Press, Vol. 41, p. 32, Jan. 10, 1890.

CHUBB, O. P. "The Future of California Citrus Fruit." Pacific Rural Press, April 28, 1888, p. 371.

HOLT, L. M. "The Future of Citrus Culture in California." Pacific Rural Press, June 2, 1888, p. 482.

HOLMES, E. W. "California Citrus Fruit Growing." Pacific Rural Press, March 31, 1883, p. 279.

RUDISILL, H. J. "Limits of Profitable Citrus Culture." Pacific Rural Press, Feb. 25, 1888, p. 159.

COIT, J. E., and CONDIT, I. J. "Citrus Fruits." The text for a series of 24 lessons given as a correspondence course by University of California, Sept. 1913.

CHAPMAN, C. C. "The Citrus Industry in Orange County, California." In "History of Orange County," 1911, p. 71.

MILLS, J. W. "Citrus Fruit Culture." Calif. Exp. Sta. Bul. 138, 1902.

LELONG, B. M. "Citrus Culture in California." Calif. State Bd. Hort. 1888.

LELONG, B. M. "Culture of Citrus Fruits in California." Calif. State Bd. Hort. 1902.

WICKSON, E. J. "The Orange, Lemon, Lime, etc." In "California Fruits, and How to Grow Them," San Francisco, 1913.

WOOD, W. R. "Citrus Fruits in the San Joaquin Valley." Rural Californian, March, 1909, p. 80.

CHAPMAN, C. C. "Details of Citrus Culture." Calif. State Com. Hort. Monthly Bul., Vol. 2, Nos. 2 and 3, 1913.

COIT, J. E. "The University of California Citrus Experiment Station." Calif. State Com. Hort. Monthly Bul., Vol. 1, No. 9, p. 685, 1912.

WHITNEY, J. D. "The Possibilities of the Central California Citrus Country." Pacific Rural Press, May 18, 1912, p. 461.

COIT, J. E. "Citrus Culture in the Arid Southwest." Arizona Exp. Sta. Bul. 58, 1908.

Hume, H. H. "History of the Citrus in Florida." Rpt. Am. Pom. Soc. 1907, p. 128.

"Citrus Fruits and their Culture." Jacksonville, Fla., 1904.

"Cultivation of Citrus Groves." Florida Exp. Sta. Bul. 69, 1904.

Harcourt, H. "Culture of Citrus Fruits in Florida." In "Florida Fruits and How to Raise Them," Louisville, 1886.

Bushway, R. H. "Citrus Culture in Texas." Proc. 32d Meeting Am. Pom. Soc. 1911, pp. 65–9.

Potts, A. T. "Experiments on Citrus Fruits." Texas Exp. Sta. Bul. 148, 1912.

Waschka, S. A. "Citrus Fruits, Report of Progress." Texas Exp. Sta. Bul. 118, Feb. 1909.

Hume, H. H. "Citrus Fruits in Texas." Texas State Dept. Agr. Bul. 3, Nov. 1909.

Rolfs, P. H. "Culture, Fertilization, and Frost Protection of Citrus Groves in the Gulf States." U. S. D. A. Farmers' Bul. 542, July 9, 1913.

"Sites, Soils, and Varieties for Citrus Groves in the Gulf States." U. S. D. A. Farmers' Bul. 538, May, 1913.

"Citrus Fruit Growing in the Gulf States." U. S. D. A. Farmers' Bul. 238, 1906.

Swingle, W. T. "Hardy Citrus Fruits for the Cotton Belt." Georgia State Bd. Ent. Bul. 33, 1910.

Stubbs, W. C., and Morgan, H. A. "The Orange and Other Citrus Fruits from Seed to Market." Louisiana Exp. Sta. Special Bul. 1893.

Higgins, J. E. "Citrus Fruits in Hawaii." Hawaii Exp. Sta. Bul. 9, 1905.

Wester, P. J. "Citriculture in the Philippines." Phil. Bureau of Agr. Bul. 27, 1913.

"The Situation in the Citrus District of Batangas." Phil. Agr. Review, Vol. 6, No. 3, March, 1913.

Kinman, C. F. "Citrus Fruits in Porto Rico." Porto Rico Exp. Sta. Report, 1912, p. 23.

"Report on Citrus Fruits in Porto Rico." Porto Rico Exp. Sta. Report, 1911.

MILLIS, J. M. "Citrus Fruit Culture." Bul. Dept. Agr. Jamaica, 1903, pp. 161–8.

IKEDA, T. "Citrus Fruits in Japan." In "Fruit Culture in Japan," p. 28.

GEORGESON, C. C. "Citrus Fruits of Japan." The Am. Garden, Vol. 12, No. 9, 1891.

COOK, S. A. "Citrus Culture in Victoria." Journal Dept. Agr. Victoria, 1913.

PRESCOTT, E. E. "Citrus Fruit Culture." Dept. Agr. Victoria, Bul. 7, 1911.

"Citrus Fruit Culture." Journal Dept. Agr. Victoria, Vol. 9, pp. 371 and 515.

MEYER, F. N. "Citrus Fruits in China." In Bulletin on plant explorations in China, U. S. D. A. Plant Industry Bul. 204, 1911.

SERCY, C. DE. "Nouveau Traite des Orangers et Citronniers." Paris, 1692.

ALIÑO, B. G. "Trabado Completo del Naranjo." Valencia, 1893.

MAYLIN, A. "Manual Practico Para el Cultivo del Naranjo." Valencia, 1905.

PALMER, G. L. "Citrus Culture in Sicily." Florida Grower, Nov. 15, 1913.

MAY, D. W. "Shade in Citrus Culture." Porto Rico Hort. Soc. Rpt. 1912, p. 44.

"Windbreaks for Citrus Fruits." Porto Rico Hort. Soc. Rpt. 1912, p. 36.

CALL, A. F. "Work Stock for Citrus Orchards." Calif. Cultivator, Feb. 19, 1914.

TRABUT, "L'Oranger en Algerie." Gov. Gen. de L'Algerie, Bul. 44, 1908.

Propagation, Stocks, Scions

WOOD, W. "Selection of Seed an Important Factor in Laying the Foundation for a Citrus Orchard." Rpt. 37th Calif. Fruit Growers' Convention, 1910, p. 25.

WEBBER, H. J. "The Reproduction of The Orange from Seed." Gardeners' Chronicle, Ser. 3, 19 (1896), Nos. 496 and 497.

"Methods of Propagating the Orange and Other Citrus Fruits." U. S. D. A. Yearbook, 1896, p. 471.

[Anon.] "Planting Citrus Seed." Rural Californian, June, 1910, p. 193.

MORRIS, O. M. "Seed from Frozen Oranges Viable." Calif. Cultivator, Feb. 20, 1913, p. 234.

HENDRICKSEN, H. C. "Propagation and Marketing of Oranges in Porto Rico." Porto Rico Exp. Sta. Bul. 4, 1904.

AUSTIN, C. F. "Propagation of Citrus Fruits." Cuba Exp. Sta. Los Vegas, Circular 24, 1906.

LELONG, B. M. "Propagation of Citrus Trees from Seed." Calif. State Bd. Hort. 1892.

BALDRIDGE, M. "Propagation of Orange Trees." Calif. State Bd. Hort. Rpt. 1888.

[Anon.] "The Greatest Citrus Nursery in the World." Pacific Rural Press, May 11, 25, June 8, 1907.

SWINGLE, W. T. "Inarching Young Hybrid Citrus Seedlings." Georgia State Bd. Ent. Bul. 33, p. 42.

ROBERTSON, G. R. "The Art of Budding Citrus." Calif. Cultivator, Aug. 24, 1911, p. 170.

TEAGUE, R. M. "Budding Citrus Trees." Calif. Cultivator, March 20, 1913.

COIT, J. E. "Pedigree *versus* an Official Seal for Citrus Nursery Stock." Calif. Cultivator, May 23, 1912, p. 644.

KIZANO, M. "Effect of Stock on Color of Kumquats." U. S. D. A. Bureau Plant Ind. Bul. 207, p. 15, S. P. I. No. 26568.

ALLEN, W. J. "Effect of Stock on Valencias' Turning Green Again." Agr. Gazette, New South Wales, May 2, 1911, p. 417.

COOK, S. A. "Citrus Root-stocks in Victoria." Journ. Dept. Agr. Victoria, 1913, Vol. XI, part 6.

SWINGLE, W. T. "The Limitation of the Satsuma Orange to Trifoliate Orange Stock." U. S. D. A. Bureau Plant Ind. Cir. 46, Dec. 1909.

BONNS, W. W. "Results of Experiments with Citrus Root-stocks." Calif. Cultivator, Dec. 25, 1913.

TABER, G. L. "Citrus Trifoliata *versus* Sour Orange as a Stock." Exp. Sta. Record, Vol. XIV, p. 441, 1902.

CUTTER, J. E. "Citrus Stocks — Sour *versus* Sweet." Proc. Pom. Soc. South. Calif. 1892, p. 13.

VAN DEMAN, H. E. "Relative Merit of the Various Stocks for the Orange." U. S. D. A. Div. Pom. Bul. 4, 1891, p. 21.

[Anon.] "Influence of Lemon Stock on Quality of Oranges." Calif. Cultivator, Feb. 23, 1911 and continued in subsequent numbers.

BERNARD, A. "Citrus Triptera as a Grafting Stock." Revue Horticole, Vol. 80, p. 140, 1908.

SWINGLE, W. T. "Citrus Trifoliata in Relation to Citrus Culture." Proc. Am. Pom. Soc. 1911, p. 218.

WOLF, F. A. "A Field Method for Distinguishing between Certain Orange Stocks." Alabama Exp. Sta. Circular 17, July, 1912.

WICKSON, E. J. "Citrus Trifoliata in California." Pacific Rural Press, June 20, 1907.

Citrus Breeding

WEBBER, H. J. "Complications in Citrus Hybridization caused by Polyembryony." Bot. Gaz. Vol. 29, 1900, p. 141.

"New Citrus Fruit Creations of the Department of Agriculture." U. S. D. A. Yearbook, 1904, p. 221.

"New Citrus and Pineapple Productions." U. S. D. A. Yearbook, 1906, p. 329.

"Present Status of Citrus Breeding." Proc. Am. Pom. Soc. 1907, p. 5.

SWINGLE, W. T. "Some New Citrus Fruits." Am. Breeders' Mag. Vol. IV, No. 2, 1913.

SWINGLE, W. T. "Citrus Breeding Experiments." In article on Crop Improvement. U. S. D. A. Plant Ind. Circular 116, 1913.

"Variation in First Generation Hybrids (Imperfect Dominance): Its Possible Explanation through Zygotaxis." IV Conference Internat. de Genetique, Paris, 1911, pp. 381–394.

WHITE, O. E. "Swingle on Variation in F 1 Citrus Hybrids and the Theory of Zygotaxis." Am. Nat., Vol. 48, No. 567, 1914.

SHAMEL, A. D. "A Study of the Improvement of Citrus Fruits through Bud Selection." U. S. D. A. Plant Ind. Circular 77, 1911.

"A Study of Bud Selection in Citrus Fruits." Proc. 39th. Calif. State Fruit Growers' Convention, 1911, p. 89.

"Breeding Citrus Fruits." Calif. State Com. Hort. Monthly Bul. Vol. 1, No. 9, p. 441, 1912.

"Good and Bad Oranges and Orange Trees." Pacific Rural Press, June 13 and 20, 1914.

"Bud Selection in Citrus Fruits." Pacific Rural Press, Jan. 31, 1914.

VAILE, R. S., and REED, F. "Citrus Breeding Discussions." Calif. State Hort. Com. Monthly Bul. Vol. 1, No. 9, p. 479, 1912.

NORTON, J. H. "Variations in the Productivity of Citrus Trees." Calif. Cultivator, March 6, 1913.

WICKSON, E. J. "Improvement of Citrus Fruit Varieties." Am. Breeders' Assoc. Rpt. 1907, Vol. 3, p. 271.

BABCOCK, E. B. "The Improvement of Citrus Fruits." University of Calif. Journal of Agr. Vol. 1, No. 7, Feb. 1914.

VAILE, R. S. "Improvement of Citrus Stock through Bud Selection." Pomona Calif. Journ. Econ. Bot. Vol. 1, Sept. 1911.

KRAUS, E. J. "Bud Variation in Relation to Fruit Markings." Oregon Crop Pest and Hort. Rpt. 1913, p. 71.

COIT, J. E. "The Relation of Asexual or Bud Mutation to the Decadence of California Citrus Orchards." Proc. 37th Calif. State Fruit Growers' Convention, 1910, p. 32.

COIT, J. E. "Budding Wood." Calif. Cultivator, Apr. 25, 1912.

HARTIN, E. H. "The Ultimate Orange." Pacific Rural Press, Vol. 40, Aug. 16, 1890, p. 140.

BARRETT, O. W. "Natural Citrus Hybrids." Phil. Agr. Rev. Vol. 5, No. 6, p. 334, 1912.

EMERSON, R. A. "The Possible Origin of Mutations in Somatic Cells." Am. Nat. Vol. 47, p. 375, 1913.

SAVASTANO and PARROZZANI. "Some Natural Hybrids of Citrus Fruits." Annals Royal Italian Station of Agr. and Fruit Culture, Vol. 1, 1911. Also contains a bibliography of European citrus literature.

SAVASTANO, L. "Nomadic Albinism in some Orange Trees." Annals Royal Italian Station Agr. and Fruit Culture, Vol. 1, 1911.

KERNER and OLIVER. "Citrus Bizzaria a Graft Hybrid." In "Nat. Hist. of Plants," Vol. 2, p. 569.

TRABUT, DR. "L'Hybridation des Citrus: Une Nouvelle Tangerine 'La Clementine.'" Revue Horticole, 1902, p. 232.

ANDRE, ED. "Oranger Hybride de Montanbau." Revue Horticole, 1905, p. 243.

Citrus Soils and Root Systems

REED, J. H. "Penetration of Orange Tree Roots." Calif. Cultivator, 14 (1900), No. 21, pp. 321–3.

"Root Systems in the Orange Orchard as Affected by Irrigation, Cultivation, and Fertilization." Pacific Rural Press, 61 (1901), No. 1, pp. 4–5.

LIPMAN, C. B. "Humus Discussion, Cover Crops." Calif. Cultivator, Dec. 4, 1913.

"Essentials in the Management of California Soils." Calif. Com. Hort. Monthly Bul. Vol. 3, No. 1, Jan. 1914.

"The Use of Lime and Gypsum on California Soils." Calif. Exp. Sta. Circular 111, 1913.

CALL, A. F. "How to Handle Citrus Soils." Calif. Cultivator, Feb. 5, 1914.

HILGARD, E. W. "Acidity of the Root Sap of Citrus Trees." Calif. Exp. Sta. Rpt. 1895–97, pp. 181–3.

HILGARD, E. W. "Marly Subsoils and the Chlorosis or Yellowing of Citrus Trees." Calif. Exp. Sta. Circular 27, 1906.

"Hardpan and Cultivation." Calif. Exp. Sta. Report, 1898–1901, p. 149.

CHASE, E. "Investigation of Citrus Subsoils." Proc. 37th Calif. State Fruit Growers' Convention, 1910, p. 61.

LOUGHRIDGE, R. H. "Alkali Tolerated by Oranges." Calif. Exp. Sta. Bul. 133, 1901, p. 17.

PAINE, C. R. "Soil Treatment in Citrus Orchards." Calif. Cultivator, March 6, 1913.

BRISTOL, W. M. "Sand on Heavy Citrus Soils." Calif. Cultivator, March 6, 1913.

MILLS, J. W. "The Use of Dynamite in Orchard Planting." Calif. Cultivator, Nov. 20, 1913, p. 500.

Irrigation

LOUGHRIDGE, R. H. "Distribution of Water in the Soil in Furrow Irrigation." U. S. D. A. Office Exp. Sta. Bul. 203, 1908.

ETCHEVERY, B. A. "The Selection and Cost of a Small Pumping Plant." Calif. Exp. Sta. Circular 117, 1914.

"Irrigation and Cultivation of Orchards." Dept. Agr. British Columbia, Victoria, Bul. 44, 1912.

WICKSON, E. J. "The Water Needs of Citrus Trees." U. S. D. A. Farmers' Bul. 116, 1900.

TAIT, C. E. "Cost of Irrigating Citrus Fruits." Pacific Rural Press, June 3, 1911.

"Irrigation of Citrus Orchards." U. S. D. A. Office Expt. Sta. Bul. 236, 1911.

KRITZER, W. H. "Definitions and Equivalents for Irrigation and Hydraulic Computations." Pacific Rural Press, July 27, 1912, p. 28.

ADAMS, F. "Irrigation Resources of California and their Utilization." U. S. D. A. Office Exp. Sta. Bul. 254, 1913.

WHITNEY, D. J. "Overhead Irrigation in the Citrus Grove." Pacific Rural Press, July 13, 1912.

WOEHLKE, W. V. "The Water Savers." The Outlook (New York), March 25, 1910, Vol. 94, p. 659.

WALLACE, T. C. "Irrigating Oranges." Pacific Rural Press, Oct. 31, 1908, p. 276.

FORBES, R. H. "Irrigating Citrus Trees in Alkali Soil." Arizona Exp. Sta. Bul. 44, 1902, p. 171.

KOETHEN, E. L. "Irrigation, the Citrus Growers' Catechism." Pacific Fruit World, May 20, 1911, p. 4.

STANLEY, F. M. "Irrigation of Citrus Groves." Florida Grower, May 17, 1913.

Fertilization

HILGARD, E. W. "Fertilizers for California Orange Trees." Pacific Rural Press, Nov. 7, 1908, p. 294.

WEBBER, H. J. "Fertilization of the Soil as Affecting the Orange in Health and Disease." U. S. D. A. Yearbook, 1894, pp. 193–202.

COLBY, G. E. "Ingredients withdrawn from the Soil by Citrus Fruits." Exp. Sta. Record, Vol. 5, pp. 5–89.

"Effect of Fertilizers on Fruit of Navel Oranges." Calif. Exp. Sta. Rpt. 1895, pp. 172–7.

FLOYD, B. F. "Problems in Citrus Nutrition." Florida Exp. Sta. Rpt. 1911.

WRIGHT, GEORGE. "Fertilizing Citrus Fruits." Calif. Cultivator, Oct. 30, 1913.

WEBBER, H. J. "Fertilizer Experiments with Citrus Fruits." Calif. Cultivator, Dec. 11, 1913.

CALL, A. F. "Fertilizing California Citrus Orchards." Calif. Cultivator, Feb. 19, 1914, p. 228.

PAINTER, E. O. "Fertilizers for Citrus Fruits." Proc. 32d Session Am. Pom. Soc. 1911, pp. 54–9.

MURTADO, D. J. "Fertilizing Oranges in Spain." Calif. Cultivator, Dec. 4, 1913.

CHAPMAN, A. C. "Fertilization of Orange Orchards." Calif. State Bd. Hort. Rpt. 1888, p. 150.

WALLACE, T. C. "Fertilizing Orange Orchards." Pacific Rural Press, Nov. 7, 1908.

BLAIR, A. W. "Experiments on Citrus Fertilization." Florida Exp. Sta. Rpt. 1911.

WICKSON, E. J. "Oranges and Potash." Pacific Rural Press, Nov. 20, 1909, p. 323.

HILGARD, E. W. "Effect of Citrus Culls on Soil." Calif. Cultivator, June 6, 1912.

ROBERTSON, G. R. "Citrus Culls as a Fertilizer." Calif. Cultivator, June 15, 1911, p. 208.

Cover-Crops and Green Manuring

GOEZE, E. "Early Green Manuring of Oranges." Gardeners' Chronicle, July 27, 1867, p. 785.

DAVY, J. B. "Lupines for Green Manuring in California." Calif. Agr. Exp. Sta. Rpt. 1897–98, p. 203.

MCKEE, R. "Orchard Green Manure Crops in California." U. S. D. A. Plant Ind. Bul. 190, 1910.

MESSENGER, C. B. "Buckwheat for Humus." Calif. Cultivator, June 4, 1914, p. 680.

CALL, A. F. "Green Crops in the Citrus Orchard." Calif. Cultivator, Feb. 12, 1914, p. 196.

WATERBURY, G. W. "Cover-Crops in Citrus Orchards." Calif. Cultivator, Jan. 15, 1914.

MERTZ, W. M. "Citrus Cover-Crops." Calif. Cultivator, Jan. 8, 1914, p. 36.

GERALDSON, G. "Green Manuring." Calif. Cultivator, Oct. 5, 1911, p. 314.

LIPMAN, C. B. "Green Manuring in California." Calif. Exp. Sta. Circular 110, 1913.

"The Function of Cover-Crops." Orchard and Farm (San Francisco), Jan. 1914, p. 201.

ADAMSON, J. E. "Cover-Crops for Citrus Fruit." Pacific Rural Press, Sept. 20, 1913.

NORTON, J. H. "Citrus Cover-Crops." Calif. Cultivator, Jan. 27, 1910.

KOETHEN, E. L. "The Best Citrus Cover-Crop." Pacific Fruit World, June 17, 1911.

WHITNEY, D. J. "Advantages of Alfalfa in Orchards." Pacific Rural Press, Dec. 13, 1913.

LIPMAN, C. B. "Citrus Cover-Crops." Proc. 39th Calif. State Fruit Growers' Convention, 1911, p. 124.

PIPER, C. V., and MCKEE, R. "Vetches." U. S. D. A. Farmers' Bul. 515, 1912.

Varieties — Botany

SWINGLE, W. T. "Eremocitrus, a New Genus of Hardy Drouth-Resistant Citrous Fruits from Australia." Journ. Agr. Research, Vol. 2, No. 2, May, 1914.

SWINGLE, W. T., and KELLERMAN, MAUDE. "Citropsis, a New Tropical African Genus Allied to Citrus." Journ. Agr. Research, Vol. 1, No. 5, 1914.

"Citrus Ichangensis, A Promising, Hardy New Species from Southwestern China and Assam." Journ. Agr. Research, Vol. 1, No. 1, Oct. 10, 1913.

PARISH, S. B. "Botanic View of the Orange." Proc. 37th Calif. Fruit Growers' Convention, 1910, p. 21.

ANDRE, ED. "Oranges Monstrueuses." Revue Horticole, 1900, p. 423.

[Anon.] "Ringing Oranges." Scientific American, Dec. 14, 1912, p. 515.

CUTTER, J. E. "Varieties of Citrus Fruits." Calif. State Bd. Hort. Rpt. 1894, p. 250.

LELONG, B. M. "New Varieties of Citrus Fruits." Calif. State Bd. Hort. 1891.

[Anon.] "New Citrus Varieties." Pacific Rural Press, Vol. 41, p. 21, Jan. 10, 1891.

Chemistry — Judging

COLBY, G. E. "Analyses of California Oranges." Calif. Exp. Sta. Bul. 93, p. 6, 1891.

"Analyses of California Oranges and Lemons." Calif. Exp. Sta. Rpt. 1893–94, pp. 240–56.

"Comparison of Shipping Navel Oranges from Northern, Southern, and Middle California." Calif. Exp. Sta. Rpt. 1898–1901, p. 244.

"Composition of Citrus Culls." Calif. Exp. Sta. Rpt. 1898, p. 259.

PICKELL, J. M., and EARLE, J. J. "Analyses of Oranges." Florida Exp. Sta. Bul. 17, 1892.

COLLISION, S. E. "Sugar and Acid in Oranges and Grapefruit." Florida Exp. Sta. Bul. 115, 1913.

HENRY, A. M. "The Chemical Composition of Florida Oranges." Florida Dept. Agr. Quar. Bul. Vol. 23, No. 2, April, 1913.

ROSE, R. E. "Immature Citrus Fruit." An. Rpt. Florida State Chemist, Dec. 31, 1913.

"Report of Commission Appointed to prepare Immature Citrus Fruit Standard." Florida Dept. Agr. Quar. Bul. Vol. 22, No. 4, Oct. 1, 1912.

"Analyses of 280 Samples of Oranges." Florida State Chemist, Aug. 15, 1912.

"Immature Citrus Fruit: Laws, Rules, and Regulations." Published by state printer, Florida. Not dated.

"When is an Orange Mature and Wholesome?" Address before Assoc. Am. Food, Drug and Dairy Officials, Portland, Maine, July 16, 1914.

"Details of the Acid Test Law in Florida." Florida Grower, Sept. 13, 1913.

"Florida Green Fruit Law in Detail." Florida Grower, Aug. 23, 1913.

BAHADUR, RANA. "Composition of Fibrous Part of Japanese Orange." Univ. Tokyo, Col. Agr. Bul. Vol. VII, No. 1, 1906.

SOUTHERST, W. F. "Sugar Content of Oranges." Calif. Cultivator, May 18, 1911, p. 612.

BANCROFT, A. L. "Where is the Orange the Sweetest?" Pacific Rural Press, July 8, 1911, p. 25.

VAN DEMAN, H. E. "Judging Citrus Fruits." Proc. Am. Pom. Soc. 1889, p. 145.

HUME, H. H. "Judging Citrus Fruits." Citrus Fruits and their Culture, p. 155, 1903.

"Judging Citrus Fruits." Proc. 23d Session Am. Pom. Soc. 1891, pp. 152–6.

CUTTER, J. E. "Scale for Judging Citrus Fruits." Calif. State Com. Hort. Rpt. 1889, p. 365.

[Anon.] "Judging Citrus Fruit." Rural Californian, Dec. 1910, p. 364.

SHAMEL, A. D. "Rules for Judging Citrus Fruits." Calif. Cultivator, May 15, 1913. (See also June 5, 1913, p. 694 for judging trees in the orchard.)

[Anon.] "Citrus Standard Score Card." Pacific Rural Press, Jan. 10, 1914, p. 42.

Pruning

COIT, J. E. "The Pruning of Citrus Trees." Calif. Cultivator, Oct. 21, 1913.

ENGLEHARDT, J. P. "The Pruning of the Washington Navel Tree." Proc. 37th Calif. State Fruit Growers' Convention, 1910, p. 97.

PAINE, C. R. "Pruning to Improve the Orange." Proc. 28th Calif. State Fruit Growers' Convention, 1903, p. 169.

"Orange Pruning." Calif. Cultivator, Jan. 22, 1904, p. 75.

"Renovation of the Orange Tree by Systematic Pruning." Proc. 37th Calif. State Fruit Growers' Convention, 1910, p. 28.

"Pruning out the Australian Type." Calif. Cultivator, May 16, 1912.

"Systematic Pruning of the Orange Tree." Calif. Cultivator, May 16, 1912.

WHITNEY, D. J. "A Change in Orange Pruning." Pacific Rural Press, Aug. 3, 1912.

"Pruning Navels — Wild Wood." Pacific Rural Press, Jan. 17, 1914.

WHITNEY, D. J. "Right Pruning and Novel Quality." Orchard and Farm (San Francisco), May, 1914, p. 2.

CALL, A. F. "Pruning Citrus Trees." Calif. Cultivator, Feb. 12, 1914, p. 197.

SALLE, J. W. "Pruning Citrus Trees." Calif. State Bd. Hort. Rpt. 1888, p. 211.

LITTLE, F. A., and RUMSEY, C. E. "Pruning Citrus Trees." Rural Californian, March, 1909, p. 84.

WILLIAMS, E. A. "The Pruning of Citrus Trees." Rural Californian, March, 1910, p. 89.

TOWT, C. W. "Citrus Tree Surgery." Univ. Calif. Journ. Agric. Oct. 1913.

BRISTOL, W. M. "Pruning the Orange." Pacific Rural Press, May 29, 1909.

WALLACE, T. C. "Pruning Orange Trees." Pacific Rural Press, Nov. 14, 1908.

KOETHEN, E. L. "Propping Citrus Trees." Pacific Rural Press, Oct. 26, 1907.

STILES, H. C. "Lemon Pruning in California." American Garden, Jan. 1891, p. 47.

WILLIAMS, E. A. "Hints on Pruning Orange Trees." Pacific Rural Press, March 12, 1910.

LEFFINGWELL, C. W., Jr. "Pruning the Lemon Tree." Calif. Cultivator, No. 13, 1900, pp. 193, 199, and 200.

ALLEN, R. C. "Pruning the Lemon Tree." Pacific Rural Press, Vol. 60 (1900), No. 13, p. 197.

LEWIS, E. S. "Shaping Lemon Trees." Calif. Cultivator, Aug. 28, 1913, p. 198.

COIT, J. E. "Dressings for Wounds of Citrus Trees." Calif. Cultivator, Feb. 13, 1913.

"Pruning Frosted Citrus Trees." Calif. Exp. Sta. Cir. 100, June, 1913.

HODGES, R. E. "Delayed Pruning Saved Frosted Citrus Trees." Pacific Rural Press, July 11, 1914.

Curing — Storing — Sweating — Packing

TEAGUE, C. C. "Curing and Marketing Lemons." Proc. 28th Calif. State Fruit Growers' Convention, 1903, p. 63.

SIEVERS, A. F. and TRUE, R. C. "Keeping Quality of Lemons." Pacific Rural Press, June 19, 1909.

"Some Factors Affecting the Keeping Qualities of American Lemons." U. S. D. A. Plant Ind. Cir. 26, 1909.

"A Preliminary Study of the Forced Curing of Lemons as Practiced in California." U. S. D. A. Plant Ind. Bul. 232, 1912.

HART, J. H. "Precooling of Perishable Freight." Engineering Mag., Vol. 36, pp. 288–9, 1908.

STUBENRAUCH, A. V. "The Relation of Handling to Decay in Calif. Navel Oranges in 1910–11." U. S. D. A. Plant Ind. July 13, 1911.

CALL, A. F. "Sweating Citrus Fruit." Calif. Cultivator, March 5, 1914, p. 292.

WILLIAMS, L. B. "The Coloring of Oranges and Lemons by the Sweating Process." Proc. 37th Calif. State Fruit Growers' Convention, 1910, p. 104.

BIGELOW and GORE. "The Ripening of Oranges." Journ. Am. Chem. Soc. Vol. XXIX, No. 5, May, 1907.

"Coloring Green Oranges." Ruling No. 133 U. S. Board of Food and Drug Inspection.

CONGAR, et al. "Lemons, Picking and Curing." Pacific Rural Press, Jan. 2, 1886.

[Anon.] "Packing Citrus Fruits." Pacific Rural Press, Jan. 21, 1888, p. 43.

[Anon.] "Rules for Grading California Oranges." Am. Pom. Soc. Proc. 1907, p. 109.

ALLISON, L. R. W. "The Precooling Plant of the Santa Fe Railway." The Railway and Eng. News, May 11, 1912.

CALL, A. F. "Time to Pick Citrus Fruits." Calif. Cultivator, Feb. 19, 1914, p. 229.

TEMPLE, W. C. "Preparing Citrus Fruits for Market." Proc. 32d Session Am. Pom. Soc. 1911, pp. 77–83.

HAIZLIP, W. T. "Forms for Packing-House Bookkeeping." Florida Grower, Oct. 18, 1913.

NEWCOMER, E. J. "Methods of Handling Citrus Fruits in Seville." Calif. Cultivator, Nov. 6, 1913.

NEWLIN, J. A. "Tests of Packing Boxes of Various Forms." U. S. D. A. Forest Service, Cir. 214, 1913.

HOSFORD, G. W. "Coöperation in the Handling of Lemons in California." Cornell Countryman, Vol. 11, No. 7, 1913, p. 209.

HUME, H. H. "Packing Citrus Fruits." Florida Exp. Sta. Bul. 63, 1902.

LELONG, B. M. "Packing Oranges." Rpt. Calif. State Bd. Hort. 1889, p. 141.

[Anon.] "A Model Citrus Packing-House." Florida Grower, March 29, 1913.

CALL, A. F. "Packing Citrus Fruits." Calif. Cultivator, March 12, 1914, p. 324.

STUBENRAUCH, A. V., and DENNIS, S. J. "The Precooling of Fruit." U. S. D. A. Yearbook, 1910.

WORKS, J. D. "Details of Packing Lemons and Placing Them in the Cars." Speech before U. S. Senate, July 24, 1913.

Marketing, Organization, Statistics, Tariff

COOK, O. G. "Transportation of Citrus Fruits." Proc. Am. Pom. Soc. 1911, p. 98.

DWINELLE, C. H. "Notes on Keeping Quality of California Oranges." Pacific Rural Press, June 14, 1884, p. 435.

POWELL, G. H. "Coöperation in the Handling and Marketing of Fruit." U. S. D. A. Yearbook, 1910.

STUBENRAUCH, A. V., et al. "Factors Governing the Successful Shipment of Oranges from Florida." U. S. D. A. Bul. 63, March 28, 1914.

CALL, A. F. "Marketing Citrus Fruit." Calif. Cultivator, March 12, 1914.

COIT, J. E. "Shipping Green Oranges." Calif. Cultivator, June 18, 1914.

"The Marketing of Frosted Citrus Fruit." Decision No. 150, U. S. Board of Food and Drug Inspectors.

WORKS, J. D. "History of the California Fruit Growers' Exchange; Its Methods and Legal Status." Speech in U. S. Senate, July 24, 1913.

BARRETT, O. W. "The Valencia Orange Trade." Philippine Agr. Rev. Feb. 1913, Vol. VI, No. 2.

[Anon.] "Prices Received for Florida Citrus Fruits Averaged by Seasons." Florida Grower, June 7, 1913.

PHILLIPS, T. H. "Methods of the California Citrus Union." Pacific Rural Press, Aug. 17, 1907.

WOODFORD, B. A. "Organized Citrus Fruit Marketing." Proc. 39th Calif. Fruit Growers' Convention, 1911, p. 85.

"California Fruit Growers' Exchange and Its Relation to the Citrus Fruit Industry." Proc. 40th Calif. State Fruit Growers' Convention, 1912, p. 40.

POWELL, G. H. "Organization of the California Citrus Fruit Industry." U. S. D. A. Yearbook, 1910, p. 405.

"California Fruit Growers' Exchange." Calif. Cultivator, March 13, 1913.

"Report of Fruit Growers' Exchange for 1912." Monthly Bul. Cal. State Hort. Com. Vol. 11, No. 11, Nov. 13, 1913, p. 721.

WHITNEY, D. J. "Working Methods of Citrus Coöperation." Orchard and Farm, May, 1914, p. 5.

"The Cost of a Central California Orange Grove." Pacific Rural Press, Aug. 10, 1912.

WALLSCHLAEGER, F. O. "The World's Production and Commerce in Citrus Fruits and Their By-Products." Citrus Protective League, Bul. 11, 1914.

Tait, C. E. "The Cost of the Producing Citrus Fruits." U. S. D. A. Office of Exp. Sta. Bul. 236, 1911.

Powell, G. H. "The Cost of Producing Oranges in California." Citrus Protective League, 1912.

[Anon.] "Protection for Home Grown Oranges and Lemons." Pac. Rural Press, Vol. 39, p. 249, March 8, 1890.

[Anon.] "The Citrus Tariff — Brief of Facts." Citrus Protective League, 1908.

Adams, S. H. "The Lemon and the Tariff." McClure's Mag. Vol. 36, pp. 353–60, Jan. 1911.

[Anon.] "Tariff and Lemons." Outlook, Vol. 92, pp. 337–8, June 12, 1909.

[Anon.] "Reasons Why the Tariff Should not be Removed on Lemons." Overland, Vol. 59, pp. 258–9, March, 1912.

By-Products

Chace, E. M. "Italian Lemons and Their By-Products." U. S. D. A. Plant Ind. Bul. 160, 1909.

Cheney, A. S. "Citrus By-Products Manufacture in Sicily." U. S. Consular Rpt. 1908.

Bioletti, F. T. "Vinegar from Orange Culls." Calif. Cultivator, Jan. 30, 1913.

Cruess, W. V. "Making Orange Vinegar." Calif. Cultivator, Oct. 30, 1913.

"Utilization of Waste Oranges." Calif. Exp. Sta. Bul. 244, 1914.

Skinner, L. B. "Orange Culture in Florida." (Discussion of Juice Bottling), Proc. Am. Pom. Soc. 1911, p. 70.

Stubenrauch, A. V. "Uses of Citrus Fruits." Good Housekeeping, Vol. 54, pp. 103–8, Jan. 1912.

[Anon.] "What Can Be Made of Orange Peel." Scientific American, Vol. 84, p. 88, Feb. 9, 1901.

[Anon.] "Canned Lemons and Lemon Juice." Pacific Rural Press, March 14, 1885, p. 225.

[Anon.] "Orange Flower Cultivation in France." Gardeners' Chronicle, April 11, 1914, p. 253.

[Anon.] "The Distillation of Orange Flowers at Grasse." Journ. Royal Soc. of Arts, June 23, 1911, p. 807.

[Anon.] "Essential Oils of the Orange." Jamaica Bot. Dept. Bul. N. S. 2 (1895), No. 9, pp. 177–80.

GUILLEN, G. J. "Productos Oftenidos de la Naranja." Barcelona, 1891.

PENZIG, O. "Chimica Fisiologica delle Auranciaele." Annali di Agricoltura, Rome, 1887, p. 265.

DUNBAR, P. B., and BIGELOW, W. D. "The Acid Content of Fruits." Science, Oct. 31, 1913, p. 639.

[Anon.] "Orange Wine." Bol. Quin. de la Camera de Com. de la; Asuncion, Paraguay, June 20, 1904.

WATTS, F. "The Lime Juice Industry of the West Indies." Imp. Dept. Agr. West Indies. Pamphlet No. 72, 1913.

FRAZER, R. "Canning Valencia Bitter Oranges." Calif. Cultivator, May 16, 1912, p. 613.

LELONG, B. M. "Method of Making Citric Acid." Rpt. Calif. State Bd. Hort. 1889, p. 146.

BAUSKETT, F. N. "How Lemon Oil is Made." Scientific American, Vol. 101, p. 372, Nov. 20, 1909.

[Anon.] "Process of Preserving Citron in Brine." "World's Production of Citron." U. S. Consular Rpts. Jan. and March, 1909.

RABAK, F. "The Production of Volatile Oils and Perfumery Plants in United States." U. S. D. A. Bureau Plant Ind. Bul. 195, 1910.

BARRETT, O. W. "A New Branch of the Citrus Industry." Phil. Agr. Rev. Vol. 5, No. 8, Aug. 1912.

[Anon.] "Orange Marmalade." Pacific Rural Press, March 29, 1884, p. 298, and Apr. 26, 1884, p. 401.

[Anon.] "Citronella Grass." U. S. D. A. Bureau Plant Ind. Plant Inventory No. 31, 1914, p. 54.

KLEE, W. G. "Lemon Grass of India." Calif. Exp. Sta. Rpt. 1887, p. 129.

GHIRLANDA, D. C. "Sopra una malattia riscontrata nei frutti del citrus Aurantium." Pisa Soc. Tos. di Scienze Nat. Processi Verboli, Vol. XXII, No. 4, 1, 1913.

Frost Fighting — Frost Injured Fruit

REED, J. H., HOLMES, KOETHEN, ZUMBRO and MARTIN. "Report of Committee on Frost Protection." In "Culture of the Citrus in Calif." (Lelong), p. 155, 1902.

MITCHELL, A. J. "Effects of Low Temperature on Citrus Trees and Fruits." Monthly Weather Rev. Vol. 38, No. 1, 1910.

BONNEMEYER, B. "The Cold Wave and the Citrus Industry." Monthly Weather Rev. Vol. 39, No 1, 1911.

ADAMSON, J. E. "Frost Fighting at Pomona." Monthly Weather Rev. Vol. 40, No. 7, 1912.

WEBBER, H. J. "Effect of Freezes on Citrus in Florida." U. S. D. A. Yearbook, 1895, p. 159.

CULBERTSON, J. D. "Protecting the Limoneira from Frost." Calif. Cultivator, Dec. 11, 1913.

"Frost Protection in the Limoneira Lemon Orchards." Monthly Bul. Calif. State Com. Hort. Vol. III, No. 1, Jan. 1914.

TEAGUE, C. C. "Frost Protection." Monthly Bul. Calif. State Com. Hort. Vol. 1, No. 9, 1912, p. 434.

NICHOLS, C. "Frost Fighting on The Limoneira Ranch." Univ. Calif. Journ. Agr. Vol. 1, No. 1, April, 1913.

"Frost Fighting Equipment in Citrus Orchards." Calif. Cultivator, Feb. 26, 1914, p. 259.

COIT, J. E. "The Protection of Citrus Trees from Frost Injury." Citrus Protective League, Cir. 6, Feb. 23, 1912.

"Preliminary Test of Cloth Covers for Reducing Radiation." Calif. Cultivator, May 9, 1912.

BUTTERWICK, O. C. "Root Pruning as Frost Protection." Florida Agriculturist, No. 18, p. 280, 1899.

ONDERDONK, G. "Dormant Orange Trees and Winter Injury." Texas State Dept. Agr. Bul. 18, 1911.

WOODBRIDGE, T. R. "Orchard Heating Costs." Pacific Rural Press, May 24, 1913, p. 588.

WHITNEY, D. J. "Frost and Northern California Oranges." Pacific Rural Press, Nov. 29, 1913.

[Anon.] "Electric Orchard Heaters." Pacific Fruit World, Vol. 37, No. 17, Dec. 1912.

MEAD, T. L. "A Frost Proof Orange Orchard." Country Life in America 7 (1905), No. 4, p. 367.

RICHARDSON BROS. "Cost and Result of Orchard Firing." Calif. Cultivator, Feb. 27, 1913, p. 260.

MERRILL, G. E. "The Freeze and Frost Fighting." Pacific Rural Press, Feb. 22, 1913.

WHITNEY, D. J. "Overhead Irrigation and Frost." Pacific Rural Press, Jan. 25, 1913.

MCADIE, A. D. "Frost Fighting Methods, History and Progress." Pacific Rural Press, May 4, 1912.

WEBBER, H. J. "Advice to Citrus Growers after 1913 Freeze." Pacific Fruit World, Feb. 1, 1913.

SMITH, F. J. "Coöperation in Frost Prevention." Calif. Cultivator, May 9, 1912, p. 584.

CALL, A. F. "The Relation of Frost Protection to the Citrus Industry." Calif. Cultivator, May 9, 1912, p. 588.

LEFFERTS, D. C. "Alcohol for Separation of Frosted Fruit." Calif. Cultivator, May 9, 1912, p. 583.

ADAMSON, J. E. "Elimination of Frosted Fruit." Pacific Rural Press, May 10, 1913, p. 541.

"Government Definition of Frozen Oranges." Pacific Rural Press, Feb. 1, 1913, also Decision No. 150, U. S. Board Food and Drug Inspection.

MANN, C. W. "Keeping Quality of Citrus Fruit Treated to Eliminate Frosted Fruit." Calif. Cultivator, May 9, 1912, p. 582.

BIOLETTI, F. T. "Experiment to Determine the Condition of Cell Walls of Frozen Oranges." Calif. Exp. Sta. Rpt. 1897–98, p. 184.

Insect Pests

GOSSARD, H. A. "The Cottony Cushion Scale." Florida Exp. Sta. Bul. 56, 1901.

KELLOM, J. H. "Resin Spray and Its Effects on Citrus Trees." Rpt. Calif. State Bd. Hort. 1889, p. 420.

QUAYLE, H. J. "Citrus Fruit Insects." Calif. Exp. Sta. Bul. 214, 1911.

"The Purple Scale." Calif. Exp. Sta. Bul. 226, 1912.

"The Black Scale." Calif. Exp. Sta. Bul. 223, 1911.

"The Red or Orange Scale." Calif. Exp. Sta. Bul. 222, 1911.

"Red Spiders and Mites of Citrus Trees." Calif. Exp. Sta. Bul. 234, Nov. 1912.

"Locomotion of Certain Young Scale Insects." Journ. Econ. Ent. June, 1911, p. 301.

WOODWORTH, C. W. "The Red Spider of Citrus Trees." Calif. Exp. Sta. Bul. 145, 1902.

GOSSARD, H. A. "The White Fly." Florida Exp. Sta. Bul. No. 67, 1903.

WOODWORTH, C. W. "The White Fly in California." Calif. Exp. Sta. Circular 30, 1907.

"White Fly Eradication." Calif. Exp. Sta. Circular 32, 1907.

CARNES, E. K. "Practical Work in Combating the Citrus White Fly." Proc. 23d Calif. Fruit Growers' Convention, 1907, p. 133.

BERGER, E. W. "White Fly Conditions in 1906; the Use of the Fungi." Florida Exp. Sta. Bul. 88, 1907.

YOTHERS, W. W. "Spraying for White Flies in Florida." U. S. D. A. Bureau Ent. Circular 168, 1913.

BERGER, E. W. "White Fly Studies in 1908." Florida Exp. Sta. Bul. 97, 1909.

"Investigations of the White Fly." Florida Exp. Sta. Rpt. 1908.

MORRILL, A. W. "The White Fly Enemies of Citrus." Arizona Hort. Com. Circular 13, Jan. 18, 1910.

DAY, C. A., WOOD, WM., et al. "Citrus Scales and Their Treatment." Proc. 23d Calif. Fruit Growers' Convention, 1907, p. 163.

NEULS, J. D. "The Use of Flour Paste in Lime-Sulfur Solutions in the Control of Citrus Red Spiders." Monthly Bul. Calif. State Com. Hort. June, 1913, p. 557.

VAILE, R. S. "Citrus Mealy Bugs." Calif. Cultivator, Feb. 27, 1913.

MARLATT, C. L. "Scale Insects and Mite Enemies of Citrus Trees." Scientific American Sup. Vol. 52, pp. 21494–7.

SEVERIN, H. P. "The Introduction, Methods of Control, Spread and Migration of the Mediterranean Fruit Fly in the Hawaiian Islands." Monthly Bul. Calif. State Hort. Com. Vol. 1, No. 9, p. 558, 1912.

ESSIG, E. O. "Plant Lice Affecting Citrus Trees." Monthly Bul. Calif. State Hort. Com. Vol. 1, No. 7, 1912, p. 282.

FAWCETT, H. S., and BURGER, O. F. "Spraying and the Citrus Purple Scale." Florida Exp. Sta. Press Bul. 183, Feb. 3, 1912.

MARLATT, C. L. "Scale Insects and Mites of Citrus Trees." U. S. D. A. Farmers' Bul. 172, 1903.

TOWER, W. V. "Insects Injurious to Citrus Fruits and Methods for Combating Them." Porto Rico, Exp. Sta. Bul. 10, 1911.

SEVERIN, H. P. "Life History of the Mediterranean Fruit Fly in Hawaii." Journ. Econ. Ent. Vol. 6, Oct. 1913.

MILLS, J. W. "Poisoning Grasshoppers on Orange Trees." Calif. Cultivator, May 14, 1914, p. 606.

Fumigation

MORSE, F. W. "The Use of Gases Against Scale Insects." Calif. Exp. Sta. Bul. 71, June 12, 1887.

"The Use of Hydrocyanic Acid Against Scale Insects." Calif. Exp. Sta. Bul. 73, Aug. 27, 1887.

COQUILLETT, D. W. "Report on Gas Treatment for Scale Insects." U. S. D. A. Report 1887, pp. 123–142.

MORSE, F. W. "Experiments on the Cause and Avoidance of Injury to Foliage in the Hydrocyanic Gas Treatment of Trees." Calif. Exp. Sta. Bul. 79, May 5, 1888.

COQUILLETT, D. W. "Supplementary Report on the Gas Treatment for Scale Insects." Insect Life, Vol. 1, pp. 41–42.

"Report on Various Methods for Destroying Scale Insects." U. S. D. A. Report 1888, pp. 123–133.

"Hydrocyanic Acid Treatment for Scale Insects." Insect Life. Vol. 1, p. 286.

"The Use of Hydrocyanic Gas for the Destruction of the Red Scale." Insect Life, Vol. II, pp. 202–207.

LELONG, B. M. "Improved Fumigating Apparatus." Rpt. Calif. State Bd. Hort. 1890, pp. 469–472.

CRAW, ALEX. "Gas Treatment for Destroying Scale Insects upon Citrus Trees." Rpt. Calif. State Bd. Hort. 1893–94, pp. 105–109.

WOODWORTH, C. W. "Orchard Fumigation." Calif. Exp. Sta. Bul. 122, Jan. 1899.

"Fumigation Dosage." Calif. Exp. Sta. Bul. 152, 1903.

"Fumigation Scheduling." Calif. Exp. Sta. Circular 50, 1910.

"Dosage Tables." Calif. Exp. Sta. Bul. 220, 1911.

"A New Leakage Gauge." Calif. Exp. Sta. Circular 75, 1912.

MORRILL, A. W. "Fumigation for Citrus White Fly." U. S. D. A. Bureau of Ent. Bul. 76, 1908.

MORRILL, A. W. and YOTHERS, W. W. "Preparations for Winter Fumigation for the Citrus White Fly." U. S. D. A. Bureau of Ent. Circular 111, 1909.

WOGLUM, R. S. "Investigation of the Use of Hydrocyanic Acid Gas in Fumigating Citrus Trees." Proc. 34th Calif. State Fruit Growers' Convention, May 1, 1908, p. 103.

"Fumigation of Citrus Trees." U. S. D. A. Bureau of Ent. Bul. 90, part 1, 1911.

"The Value of Sodium Cyanide for Fumigation Purposes." U. S. D. A. Bureau of Ent. Bul. 90, part 2, 1911.

"An Improved Fumigation Generator." Calif. Cultivator, Aug. 7, 1913, p. 126.

"The Fumigation of Citrus Trees." Calif. Cultivator, Sept. 11, 1913.

McDonnell, C. C. "Chemistry of Fumigation with Hydrocyanic Acid Gas." U. S. D. A. Bureau of Ent. Bul. 90, part 3, 1911.

Schoene, W. J. "The Influence of Temperature and Moisture on Fumigation." New York (Geneva) Exp. Sta. Tech. Bul. 30, 1913.

Bache, R. "Fumigation of Citrus Fruit Orchards." Technical World, Vol. 16, p. 209, Oct. 1911.

Diseases

Smith, R. E., and Smith, E. H. "Citrus Diseases." In Calif. Expt. Sta. Bul. 218, June, 1911.

Swingle, W. T., and Webber, H. J. "Diseases of Citrus Fruits in Florida." U. S. D. A. Vegetable Phys. and Path. Bul. 8, 1896.

Hume, H. H. "Some Citrus Troubles." Florida Exp. Sta. Bul. 53, 1900.

McAlpine, D. "Fungus Diseases of Citrus Trees in Australia." Melbourne, Nov. 1899.

Fawcett, H. S. "Citrus Diseases." Fla. Exp. Sta. Rpt. 1908.

"Scaly Bark of Citrus." Fla. Exp. Sta. Bul. 98, 1909.

"Citrus Scab." Fla. Exp. Sta. Rpt. 1909.

"Bucksin of Citrus Fruits." Fla. Exp. Sta. Rpt. 1909.

"Relation of Wither-tip to Scaly-Bark." Fla. Exp. Sta. Rpt. 1909.

"Webber's 'Brown Fungus' of the Citrus Whitefly." Science, N. S. Vol. 31, No. 806, p. 912, 1910.

"Silver Scurf of the Orange." Fla. Exp. Sta. Rpt. 1910.

"Citrus Scab or Verrucosis." Fla. Exp. Sta. Rpt. 1910.

"Stem End Rot of Oranges and Pomelos." Fla. Exp. Sta. Rpt. 1910.

"Scaly Bark or Nail Head Rust." Fla. Exp. Sta. Rpt. 1910.

Fawcett, H. S. "Scaly Bark or Nail Head Rust of Citrus." Florida Exp. Sta. Bul. 106, 1911.

"Stem End Rot and Gummosis." Fla. State Hort. Soc. Proc. 1911, p. 41.

"Stem End Rot of Citrus Fruits." Fla. Exp. Sta. Bul. 107, 1911. and Burger, O. F. "A Gum Inducing Diplodia of Peach and Orange." Mycologia, Vol. III, No. 3, May, 1911.

"A Variety of Cladosporium Herbarum on Citrus Aurantium in Florida." Phytopathology, Vol. 1, No. 5, 1911.

"The Cause of Stem End Rot of Citrus Fruits." Phytopathology, Vol. 2, No. 3, June, 1912.

"Citrus Gumming in Florida." Fla. Exp. Sta. Rpt. 1912.

"Citrus Galls." Monthly Bul. Calif. State Com. Hort. Vol. 1, No. 13, Dec. 1912, p. 937.

"Citrus Scab." Monthly Bul. Calif. State Com. Hort. Vol. 1, No. 11, Oct. 1912, p. 833.

"Two Fungi as Causal Agents in Gummosis of Lemon Trees in California." Monthly Bul. Calif. State Hort. Com. Vol. 2, No. 8, Aug. 1913.

Smith, R. E. "Mottled-Leaf of Citrus Trees." Calif. Cultivator, May 25, 1911.

Thomas, E. E. "A Preliminary Report of a Nematode Observed on Citrus Roots and Its Possible Relation with the Mottled Appearance of Citrus Trees." Calif. Exp. Sta. Circular 85, Feb. 1913.

Vaile, R. S. "Citrus Nematode." Annual Rpt. Ventura County Hort. Com. 1913.

Cobb, N. A. "Citrus Root Nematode." Jour. Agr. Research, Vol. II, No. 3, June, 1914.

Thomas, E. E. "The Nematode Worm on the Roots of Citrus Trees." Calif. Cultivator, July 9, 1914, p. 28.

Kellerman, K. F., and Wright, R. C. "Relation of Bacterial Transformations of Soil Nitrogen to Nutrition of Citrus Plants." Journ. Agr. Research, Vol. 2, No. 2, May, 1914.

GILE, P. L. "Relation of Calcareous Soils to Pineapple Chlorosis." Porto Rico Exp. Sta. Bul. 11, 1911.

FLOYD, B. F. "Frenching, Yellow Spotting, Die-Back, and Melanose of Citrus." Fla. Exp. Sta. Rpt. 1910.

"Yellow Spotting of Citrus Groves." Fla. Exp. Sta. Rpt. 1909.

HILGARD, E. W. "Marley Subsoils and the Chlorosis or Yellowing of Citrus Trees." Calif. Exp. Sta. Circular 27, 1906.

COIT, J. E. "Mottled-Leaf of Citrus not Spread by Budding." Calif. Cultivator, Jan. 18, 1912, p. 68.

SNOWDEN, R. R. "Magnesia-Lime Chlorosis of Citrus Trees." Calif. Cultivator, Aug. 11, 1910.

LIPMAN, C. B. "Chlorosis of Citrus Trees and the Physical Condition of the Soil." Calif. Cultivator, June 1, 1911.

"Poor Nitrifying Power of Soils a Possible Cause of Mottled-Leaf and Die-Back of Lemons." Science, N. S. Vol. 39, No. 1011, pp. 728–730, May 15, 1914.

COIT, J. E. "Exanthema or Die-Back of Citrus Trees." Calif. Cultivator, March, 12, 1914.

ESSIG, O. E. "Exanthema or Die-Back of Citrus Trees." Pomona College Journal of Econ. Bot. Vol. 1, No. 2, May, 1911.

BRITTLEBANK, C. C. "Exanthema of Orange Trees in Australia." Journ. Agr. Victoria, July, 1912, p. 401.

TENNY, L. S. and HOSFORD, G. W. "The Decay of Florida Oranges while in Transit and on the Market." U. S. D. A. Plant Industry Circular 19, 1908.

STEVENS, H. E. "Melanose and Stem End Rot." Florida Grower, Nov. 1, 1913.

"Citrus Melanose." Fla. Exp. Sta. Rpt. 1912.

FLOYD, B. F. "Experiments with Citrus Die-Back." Fla. Exp. Sta. Rpt. 1912.

"Melanose of Citrus." Fla. Exp. Sta. Rpt. 1911.

COBB, N. A. "Alternarias of Citrus." Dept. Agr. New South Wales, Misc. Pub. 666, 1904.

Floyd, B. F., and Stevens, H. E. "Melanose and Stem End Rot." Florida Exp. Sta. Bul. 111, 1912.

Savastano, L. "Leforne teratoligiche del fiore e frutto degli Agrumi." Agricoltura Portici, Vol. IV, 1884.

Grossenbacher, J. G. "Experiments on the Decay of Florida Oranges." U. S. D. A. Plant Ind. Circular 124, 1913.

Hedges, F., and Tenney, L. S. "A Knot of Citrus Trees Caused by Sphæropsis tumefaciens." U. S. D. A. Bureau Plant Ind. Bul. 247, 1912.

Stevens, H. E. "Citrus Canker." Fla. Exp. Sta. Bul. 122, March, 1914.

Rolfs, Fawcett, and Floyd. "Diseases of Citrus Fruits." Florida Exp. Sta. Bul. 108, 1911.

Clausen, R. E. "A New Fungus Concerned with Wither-tip of Varieties of Citrus Medica." Phytopathology, Vol. 2, No. 6, Dec. 1912.

Rolfs, P. H. "Wither-tip and other Diseases of Citrus Trees and Fruits." U. S. D. A. Plant Ind. Bul. 52, 1904.

Cook, M. T., and Horne, W. T. "Wither-tip." Cuba (Santiago de Los Vegas) Bul. 9, 1908.

Smith, R. E. "Wither-tip." Calif. Cultivator, July 27, 1911.

Essig, E. O. "Wither-tip and Its Treatment." Calif. Cultivator, May 25, 1911.

"Wither-tip of Citrus Trees." Pom. Col. Journ. Econ. Bot. Feb. 1911.

Rolfs, P. H. "Fall Dropping of Citrus Fruits." Fla. Exp. Sta. Press, Bul. 60, Oct. 15, 1906.

"Citrus Bloom Dropping." Fla. Exp. Sta. Press, Bul. 84, March 9, 1908.

Floyd, B. F. "Experiments on Die-Back of Citrus." Fla. Exp. Sta. Rpt. 1909.

Home, W. T. "Root Rot of Citrus Trees." Proc. 37th Calif. Fruit Growers' Convention, 1910, p. 93.

Rolfs, P. H., and Fawcett, H. S. "Fungus Diseases of Scale

Insects and White Fly." Florida Exp. Sta. Bul. 94, 1908.

COIT, J. E. "Blemishes of Citrus Fruits." Proc. 39th Calif. State Fruit Growers' Convention, 1911, p. 22.

BUTLER, O. "A Study on Gummosis of Citrus and Prunus, with Observations on Squamosis and Exanthema of Citrus." Annals of Botany, Vol. 25, No. 97, Jan. 1911, p. 107.

COOK, M. T. "Diseases of Citrus Fruits." In "Diseases of Tropical Plants," pp. 116–30, 1913.

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