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CITRUS CULTURE IN CALIFORNIA

R. E. CARYL

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B. H. Crocheron, Director, California Agricultural Extension Service.

THE COLLEGE OF AGRICULTURE
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BERKELEY, CALIFORNIA

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R. E. CARYL[1]

HISTORY AND DEVELOPMENT OF THE INDUSTRY

ALTHOUGH THE EXACT DATE of planting of the first citrus trees in California may never be known, it seems certain that the Franciscan founders of the missions introduced the first orange varieties. Apparently there is no definite record that lime or lemon varieties were included in the plantings at the missions, but probably seedling trees were grown.

The San Diego Mission, established in 1769, is known to have had in its orchards oranges which were propagated from trees at the older missions in Lower California.

The first known printed record of the occurrence of oranges in California is in the account of the visit of Vancouver to Mission San Buenaventura in November, 1793. He made note of the number of tropical and subtropical fruits growing there, including the orange and the prickly pear cactus. The sweet seedling oranges have therefore been growing in California for one hundred and fifty years or more.

The Commercial Citrus Industry.—A real interest in citrus fruit followed the planting of 6 acres of sweet seedling oranges at the Mission San Gabriel in 1804. In 1841, William Wolfskill planted the first commercial orange orchard in Los Angeles. By 1870 there were many small plantings throughout the state from San Diego to Butte County, which proved the suitability of large areas for citrus culture.

The completion of the transcontinental railroads, in 1881 and 1885, and the successful marketing of California-grown oranges on the eastern seaboard, firmly established the citrus industry and stimulated the planting of large commercial orchards. Extensive groves in the foothills of the Santa Ana River Valley and in the coast counties followed the completion of the Santa Fe Railroad in 1885.

Geographically, there are now five distinct general regions within the state where citrus-fruit varieties are commercially grown; these reach from San Diego County in the south to Glenn County in the north: (1) The coast section, comprising the southern California counties of San Diego, Orange, Ventura, and Santa Barbara, and the southwestern part of Los Angeles County, is characterized by an equable climate with cool summers, warm winters, and a relatively high atmospheric humidity

[1] Assistant Horticulturist in the Citrus Experiment Station, Riverside, California; died November 12, 1938.

due to close proximity to the Pacific Ocean. (2) The intermediate section, comprising parts of Los Angeles, Riverside, and San Bernardino counties, has hot dry summers, bright days, and cool nights. (3) The Coachella and Imperial Valley sections have very little rainfall and extremes of summer heat and dryness. (4) The central California section, in the San Joaquin Valley, includes parts of Kern, Tulare, and Fresno counties. (5) The northern California section is in the Sacramento River Valley. These last two citrus districts are climatically similar, having hot, dry air and long, clear, sunny days in summer. In spring, fall, and winter there are prolonged periods of cold days characterized by heavy dews and ground fogs. Rainfall increases as one goes north, being somewhat greater in the Sacramento River Valley than in the central California section.

In the northern sections and in the Coachella and Imperial valleys, climatic extremes tend to ripen the fruit earlier than in other parts of the state; for example, although the San Joaquin and Sacramento River valleys are from 300 to 600 miles farther north than the southern California sections, the Washington Navel oranges grown there can be marketed earlier than those from the south.

TYPES OF CITRUS FRUITS

In 1936, approximately 75 per cent[2] of the total citrus acreage was devoted to the growing of the two main orange varieties, the Washington Navel and the Valencia (see table 1). The climatic differences mentioned above influence ripening dates sufficiently so that California can make commercial shipments of oranges throughout the entire year by planting only these two varieties.[3] Because better standardization is possible under these circumstances this gives California an advantage over other districts which must use many varieties.

Next to the sweet orange in importance is the lemon, comprising 19 per cent of the total commercial citrus acreage. During the period 1930 to 1936 inclusive, plantings of the lemon increased 32 per cent as compared with 10 per cent for those of the orange. Lemon acreage in Ventura and Santa Barbara counties has doubled since 1930, with extensive plantings still being made there and in Los Angeles and San Diego counties. The coast regions are particularly well suited to the culture of the lemon, and California is the only lemon section in the United States

[2] California Coöperative Crop Reporting Service. Summary of California fruit and nut plantings acreage survey of 1936. p. 8. April, 1937. Summarized in: California Citrograph 22(7):288. 1937.

[3] Thompson, J. M. The orange industry: an economic study. California Agr. Exp. Sta. Bul. 622:1–85. 1938.

which can supply the commercial markets throughout the year. The California lemon industry is based principally on only two lemon varieties, the Eureka and Lisbon, but occasionally a few plantings of the Villafranca are made. The fruit of all varieties is generally marketed without varietal segregation, the crop being known commercially simply as "lemons."

The growth of the lemon industry as indicated by the planting of new orchards in the three different climatic areas of the state is shown in

TABLE 1

ACREAGE DEVOTED TO COMMERCIAL CITRUS FRUIT GROWING IN CALIFORNIA IN 1928 AND 1936*

Area	Oranges		Lemons		Grapefruit		Total	
	Bearing	Nonbearing	Bearing	Nonbearing	Bearing	Nonbearing	Bearing	Nonbearing
Southern California								
1928	144,699	23,064	39,538	2,942	7,692	5,143	191,929	31,150
1936	174,970	18,718	40,846	18,148	14,690	3,950	230,506	40,753
Central California								
1928	42,499	768	2,964	12	1,215	40	46,678	820
1936	37,027	3,493	1,347	166	899	42	39,273	3,701
Northern California								
1928	4,129	658	843	.....	86	.....	5,058	658
1936	2,085	1,458	506	104	48	4	2,639	1,566
Total for the state								
1928	191,327	24,490	43,345	2,954	8,993	5,183	243,665	32,628
1936	214,082	23,669	42,699	18,418	15,637	3,996	272,418	46,020

*Sources of data:
Acreage estimates of California fruit and nut crops 1927 to 1932. California State Dept. Agr. Spec. Pub. 117:19–21. 1932.
California Coöperative Crop Reporting Service. Summary of California fruit and nut plantings acreage survey of 1936. p. 8. April, 1937.

table 1. In 1928, there were 43,345 acres of bearing and 2,954 acres of nonbearing lemon orchards as compared with 42,699 and 18,418 acres of bearing and nonbearing orchards in 1936. Ventura and Santa Barbara counties each had nearly as many acres of nonbearing orchards in 1936 as those already in bearing. The lemon acreage for 1936 in the six leading counties was as follows:

County	Bearing	Nonbearing
Los Angeles	9,794	2,338
Ventura	8,630	8,334
Orange	6,519	1,169
San Bernardino	4,863	1,046
San Diego	4,533	2,147
Santa Barbara	3,027	2,971

The increase in total lemon acreage for the state from 1928 to 1936, was 14,818 acres.

Six per cent of the total citrus acreage of the state is devoted to grapefruit culture, mainly in Imperial, San Bernardino, and Riverside counties. The grapefruit seems to be better adapted than other types of citrus to the climatic extremes of the interior and desert sections, and extensive plantings have been made in those areas during the past ten years, 1927 to 1936 inclusive.

Satsuma and tangerine plantings in California are few, because of the very limited demand for this type of fruit. As a supplementary citrus fruit for the Imperial Valley, however, the tangerines are increasing in popularity, for they ripen early, are very hardy, and usually supply the November and December markets.

Limes have been planted in various sections since the early periods of the citrus industry, but because of the extreme tenderness to low temperatures of both trees and fruit, their culture has been limited to a very few nearly frostless localities. The area devoted to limes is less than 500 acres. The Mexican and Bearss varieties are commonly planted.

Other types of citrus fruits, grown as home-garden trees throughout the state, are kumquats, sweet lemons, sweet limes, Meyer lemons, citrons, and various citrus hybrids. Many citrus-fruit types make excellent ornamental plants and should become more generally known for ornamental purposes.

COMMERCIAL VARIETIES

Commercial varieties are those which produce fruit that meets the market demands, whose culture has been proved to be successful, and which can be depended upon to produce profitable crops under normal climatic and environmental conditions.

The California citrus industry is based upon only five important commercial varieties: Washington Navel and Valencia oranges, Eureka and Lisbon lemons, and Marsh (Marsh's Seedless) grapefruit.

The Washington Navel Orange.—The Washington Navel orange originated as a bud variation in a tree of the Selecta orange variety near Bahia, Brazil, and was first propagated by a Portuguese gardener in 1820. In 1868, William Saunders, of the United States Department of Agriculture, arranged for, and in 1870 secured, the importation of trees of this excellent seedless variety. Propagations were made from these and distributed to growers in California and Florida. Two of the trees were sent to Mrs. L. C. Tibbets of Riverside, California, who planted them in 1873; fruits were exhibited at the first Riverside Citrus Fair in March,

1879. These two trees, and their direct bud progenies, are the parents of nearly all of the trees of the Washington Navel orange variety now growing in California. One of the parent trees, sixty-six years old in 1939, is still growing in Riverside and produces some fruit every year.

The excellent quality of the fruit of the Washington Navel orange (fig. 1) is due to the rich flavor, seedlessness, reddish-orange color, and

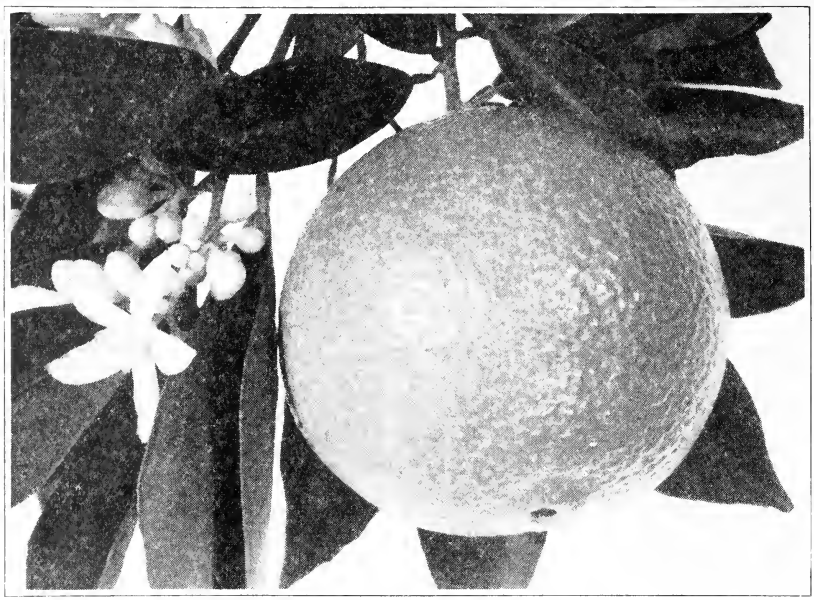

Fig. 1.—The Washington Navel orange, the standard winter orange variety in California.

smooth texture of rind, all highly desirable characteristics in a commercial citrus fruit.

The ripening period for the variety differs from year to year, according to temperature and humidity, but in general the first pickings are made during the period between November 1 and January 1.

Frequently the fruit grown in the northern and central interior sections of the state has been picked and shipped before the last part of December, at which time normal picking operations begin in the southern part of the state. It is thought that the higher temperatures and greater dryness are largely responsible for the earlier maturity in the north. The quality of the fruit of the Washington Navel is also markedly affected by the differences in the climatic environment. Cool humid summers such as are found in the coast sections usually tend to produce large fruits with thick, tough rinds, an abundance of coarse rag and

pulp, and a much lighter orange color. On the other hand, fruit produced in the hot dry interior areas, although maturing early, is sometimes lacking in the full rich flavor characteristic of the variety.

The region of optimum growth and production is generally considered to be in the intermediate section of southern California. The hot, dry summers, bright days, and cool nights tend toward the production of fruit high in quality and appearance, which surpasses even the quality of the fruit as grown in its native home near Bahia, Brazil.

During the past decade, the acreage devoted to Washington Navel and seedling oranges has decreased by approximately 6,000 acres; there were 100,532 acres of bearing and nonbearing orchards in 1928, whereas in 1936, there were 94,597 acres of bearing and nonbearing Washington Navel and seedling oranges.[4] This decrease is partly due to the fact that the Washington Navel orange must compete with the bulk of the market shipments from other orange-growing sections during the winter months. Competition is responsible for rather low prices for this variety as compared with the returns from other citrus-fruit varieties.

The Valencia Orange.—The first definitely recorded shipment of Valencia orange trees into California was made in 1876 to A. B. Chapman and George H. Smith of Los Angeles County. These trees, some of which were of the true, round strain of the Valencia orange variety, were propagated and shipped by Thomas Rivers of Sawbridgeworth, Kent, England. Other introductions of the Valencia were later made from Florida, but all have been traced to the Rivers nurseries.

Since its introduction into California in 1876, the Valencia orange (fig. 2) has become increasingly popular with both the grower and consumer and is now the leading orange variety in California. It was originally planted as a supplementary variety to the Washington Navel orange in order to meet market demands during the period when Navels were not available. Valencia oranges are harvested during the period from March to November in southern California and slightly earlier in northern districts.

The high quality, attractive color and appearance, the relatively small number of seeds per fruit, and the great vigor and hardiness of the tree have resulted in the extension of plantings in nearly all of the orange-growing districts.

As with the Washington Navel orange, there is a noticeable effect of the different climatic zones upon the fruit and tree of the Valencia orange. In the equable but humid climate of the coast section of southern

[4] California Coöperative Crop Reporting Service. Summary of California fruit and nut plantings acreage survey of 1936. p. 8. April, 1937. Summarized in California Citrograph 22(7):288. 1937.

California, both tree and fruit reach their optimum in quantity of fruit production. The trees are very large, vigorous, and hardy, and produce heavy crops with the added ability to hold the crop throughout the summer if necessary. In the intermediate sections where hot, dry summers prevail, the Valencia is likely to be seriously affected by a heavy drop

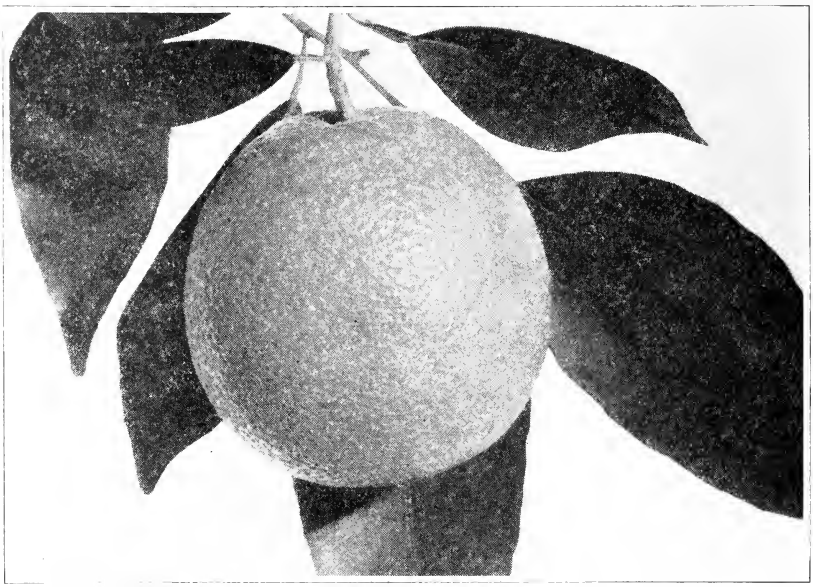

Fig. 2.—The Valencia orange, which is grown in nearly all citrus sections in California as a summer orange variety.

of fruit, caused by extreme heat; in normal years, however, very little loss occurs from this factor.

One disadvantage of the variety is its susceptibility to a drying-out of the pulp vesicles when held on the tree too long after maturity, especially in the coast districts. Another disadvantage is that after the fruit is fully ripened and colored, it has a tendency to turn back to a greenish-yellow color if it is left on the tree a long time. Both of these tendencies are apparently physiological changes which are characteristic of the variety. Even with this deterioration, "tree storage" is preferable to commercial cold storage as known at present.

The total Valencia acreage in 1928 was 112,250 acres of bearing and nonbearing orchards, whereas in 1936 there were 143,403 acres. In 1936, Orange, Los Angeles, Ventura, and San Diego counties had 88 per cent of the nonbearing Valencia-orange acreage.

The Eureka Lemon.—The Eureka lemon variety originated in Los

Angeles, California, as a seedling tree grown from seed planted in 1858. The seed was secured by a Dr. Halsey from the fruit of a box of Sicilian lemons received from a lemon market in New York City. This tree produced smooth, thin-skinned fruit which attracted the attention of citrus growers and nurserymen. In about 1880, trees were first propagated and distributed by Thomas A. Garey of Los Angeles, under the name of

Fig. 3.—The Eureka lemon, well adapted to the climate of the coastal citrus districts.

"Garey's Eureka." This was soon shortened to Eureka, under which name the variety is now being grown in all of the leading lemon-growing sections of California.

The Eureka (fig. 3) is by far the most popular commercial lemon in all the important lemon-growing sections of California, principally because of its productivity and the season in which most of its crop is produced. Although it is generally considered a spring and summer variety, the climatic extremes of the intermediate districts influence to some extent the time at which the fruit is produced. The peaks of production in the intermediate districts are from March to May and from October to December. In the coast areas, the peaks are from January to March and from June to September.

The greatest difference between the Eureka and Lisbon varieties is seen in the trees of the varieties, since the fruit is nearly identical and

almost impossible to distinguish when mixed. The trees of the Eureka are spreading, open, and of only medium vigor (fig. 4).

In general, the Eureka is best suited to the coast sections, for most of the fruit is borne on the tips of the bearing wood, and severe sunburn results from this characteristic in the hot intermediate sections. (See description of Lisbon lemon, p. 13.) Wind also causes considerable damage by scarring when the fruit is blown against twigs and leaves.

Fig. 4.—An excellent Eureka lemon orchard planted in stony, porous soil.

The Eureka is not so compatible as other citrus varieties with the average sour orange used as a rootstock. Incompatibility between rootstock and scion results in the development of a poor and overgrown bud union and usually in a short-lived tree. Because of the superiority of the sour orange as a rootstock for use where damage is likely to occur to the root system because of fungus attacks, trials are now being made at the University of California Citrus Experiment Station with sour-orange rootstocks which have proved to be more nearly compatible with the Eureka variety under commercial orchard conditions.

The Lisbon Lemon.—The Lisbon lemon came to California from Australia in two different importations sent at about the same time. In 1874, the first successful shipment was received by Mr. Sherman P. Stow and his neighbor, Mr. Ellwood Cooper, of Goleta, Santa Barbara County, California. In 1875, a small shipment of trees of this variety was received in Riverside, California, by Judge J. W. North, who turned them over to Mr. D. H. Burnham, a nurseryman of Riverside, for propagation and distribution.

In a description of the La Patera Ranch (owned by Sherman P. Stow) of Goleta, published in 1883, is the statement that the majority of the lemon trees growing there were propagated from buds secured from a

tree owned by a Mrs. Hale of Alameda, California. The history of this tree is apparently unknown, although it was about twenty years old in 1873. Since very few trees were imported from Australia by the Stows, it seems probable that the rather open type of Lisbon lemon common to Santa Barbara and Ventura counties came from the Alameda tree and that the semidense- and dense-type trees are descendants of the imported

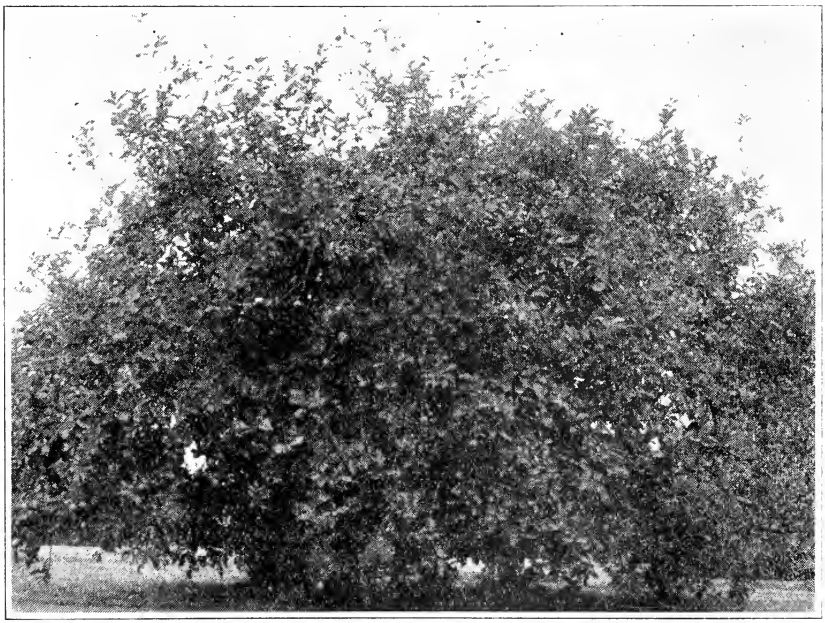

Fig. 5.—Vigorous-type Lisbon lemon tree which was planted in 1892; Chula Vista, California; photographed February, 1938.

trees from Australia. This view is supported by the fact that the denser types are more frequently found in the Riverside and Corona districts and only rarely in Ventura and Santa Barbara.

The Lisbon lemon (fig. 5) is well suited to all sections of California. It is a large, vigorous tree, dense, spreading, more or less upright, and the fruits are borne on the inside of the tree where they are well protected from sun and wind (fig. 6). The trees of the Lisbon are somewhat thornier than those of the Eureka variety. Owing to their extreme hardiness, they were not so severely injured by the cold weather of January and February, 1937, as were adjacent trees of the Eureka, nor are they so seriously affected by the extreme heat or the strong desert winds common to the intermediate sections. The Lisbon as an individual tree is usually much more productive than the Eureka, partly on account of its larger

size and bearing area. Hence, with Lisbons, fewer trees per acre should be planted than with Eurekas. Per-acre yields in judiciously planted orchards will not differ greatly.

In the coast sections, the Lisbon has fallen into some disfavor because its peak production is from January to April. Thus it is considered as a winter producer, or one-crop variety. This is not the case, however,

Fig. 6.—The Lisbon lemon variety—vigorous, productive, and suitable for planting in nearly all citrus districts.

in the intermediate sections where good production is maintained from January to May and even later in some years. With the constantly increasing number of air-conditioned packing-houses, the Lisbon may increase in popularity because of this means of holding fruit until the summer market.

Because of the great vigor and long life of the trees, many Lisbon orchards over forty, and some over fifty years of age, are still in excellent bearing condition and may be found in all lemon-growing sections, in all types of soils, and on many different varieties and species of rootstocks. It seems reasonable to suppose that the trees have had periods of decline from various causes, but they usually survive and again produce large crops. The open type of Lisbon is more subject to declines of various kinds than the denser types of the variety.

The Marsh Grapefruit.—The Marsh grapefruit, or pomelo, variety

was first planted in California by J. E. Cutter of Riverside in 1890, and the original tree is still in excellent condition and producing fair crops of fruit typical of the original strain. The variety originated near Lakeland, Florida, and was introduced by Mr. C. M. Marsh, a nurseryman of that district. The original tree was one of a grove of seedling grapefruit trees planted about 1840, all of which were killed during the freeze of 1895.

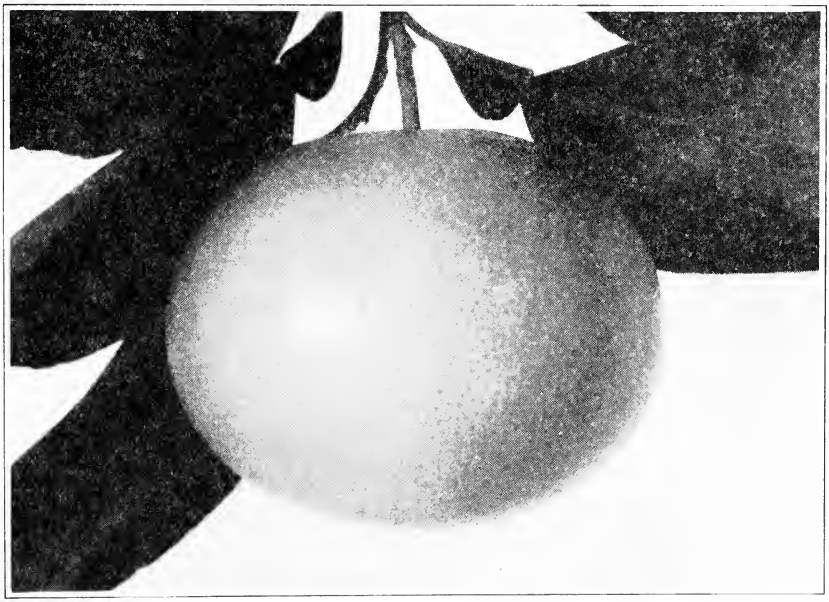

Fig. 7.—The Marsh grapefruit. The commercial variety of California and Arizona.

The commercial grapefruit industry in California is based entirely upon the Marsh variety, nearly all the trees in the state being direct descendants of the trees from the original importation from Florida made in 1890.

The popularity of the variety is due to the relative seedlessness, the form (fig. 7), and the acceptable flavor of the fruit, together with the vigor, hardiness, and productivity of the tree. In the intermediate sections, when the fruit is held on the tree until June or later, it becomes fully mature and of much better quality than when picked earlier, but in the desert sections it matures in the winter and early spring.

In 1910 there were approximately 500 acres devoted to grapefruit culture and in 1936 there were 19,633 acres, with Imperial, San Bernardino, and Riverside counties having 78 per cent of the total number of acres of bearing and nonbearing grapefruit orchards.

Under the extreme climatic conditions of the desert sections, fruit of excellent quality is usually produced. During short-crop years, however, the quality may be impaired because of the large size and very thick and puffy rinds of the fruit.

STANDARDIZATION OF VARIETIES

All citrus varieties grown in California have been found to be more or less variable, bud variations or "bud sports" being of frequent occurrence. However, most of these are inferior to the established variety in which they have arisen.

The term "standardization of varieties" means the propagation of trees by buds selected from parent trees which have been proved to be inherently superior individuals typical of the variety. In this manner, inferior strains giving rise to undesirable variations are eliminated, and inherently stable and productive strains are perpetuated, with the consequent production of orchards of uniform trees bearing heavy and superior crops of fruit. A "strain" is a group of individual trees or plants of a horticultural variety, differing from all other individuals of the variety in one or more constant and recognizable characteristics, and which are capable of perpetuation through vegetative propagation.

In old orchards, and in some younger ones propagated from carelessly obtained budwood, the standardization of the variety may be accomplished by rebudding the inferior trees with buds secured from superior individuals of the best strains. Diseased and decadent trees, as well as those seriously affected by an incompatibility between rootstock and scion, should be removed and the space replanted with young, vigorous trees. Rebudding, sometimes called top-working, is commercially successful only with healthy and vigorous trees. The time at which it should be done varies with the climate of the section in which the orchard is located, spring and fall being the preferred periods for the operation.

The replacing of inferior individual trees of poor strains or a mixture of varieties, and those affected with disease, frequently presents added cultural difficulties. These are largely brought about by the competition between the young and the old trees in the orchard for plant food, water, and sunlight. In order to keep the new trees in good health and steady growth, trees which have very vigorous-growing rootstocks should be planted; the roots of the old trees should be cut away, by subsoiling or cutting with a balling spade, to within several feet of the hole in which the young balled tree is set. The young trees should be given additional amounts of water between the regular irrigation intervals. Small amounts of well-rotted barnyard manure or other nitrogenous ferti-

lizers should be worked into the soil after the roots of the young trees have begun to grow outside the balls of the earth which came with them from the nursery.

PROPAGATION OF CITRUS VARIETIES

California citrus growers secure most of their nursery trees from professional nurserymen, many of whom propagate only the citrus varieties.

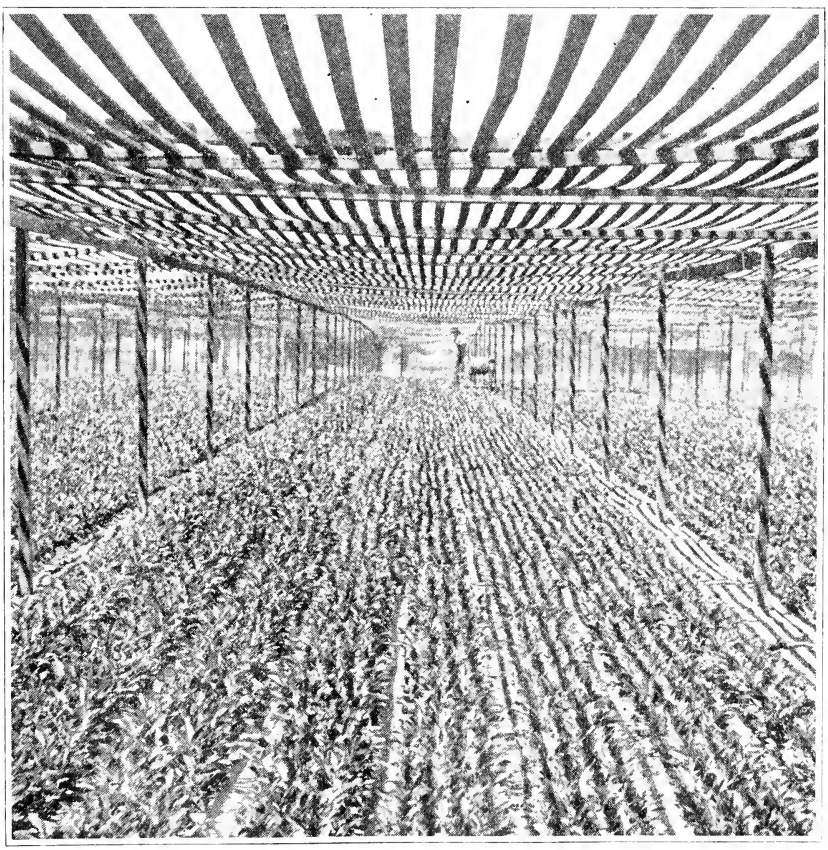

Fig. 8.—Citrus seedlings growing in beds in a typical nursery lathhouse.

It is rarely advisable for the grower to attempt to propagate his own trees unless he has had some nursery experience. The growing of these young trees is a specialized industry, and saving of time and expense usually results from the purchase of trees from a reliable citrus nurseryman; for he has carefully studied and largely overcome the many difficulties and hazards of propagation in the particular district in which he operates.

Practically all nursery trees grown in California are propagated by budding on seedling rootstocks. Seeds of the desired type are planted in the spring in carefully prepared seedbeds where they are grown for one year (fig. 8). The seedlings are then dug, sorted as to size and vigor, and all variants, hybrids, and inferior seedlings are discarded. At the age of approximately a year, the seedlings are pruned to about 8 inches and set out in nursery rows. By fall many are large enough to be budded; the smaller seedlings may be left until the following spring or fall, at which time they should be large enough for budding; if they remain small in size, or lack vigor, they should be discarded. The portion of the tree growing from the bud which has been inserted is known as the scion and the portion below this bud union as the stock.

Citrus trees may be propagated by other means such as cuttings, layers, and twig and tongue grafts, but because of the time needed to produce a tree and the rather expensive equipment necessary to grow citrus trees from cuttings, it is doubtful if any other method than budding on seedlings will ever be used for the commercial propagation of citrus in California. Apparently lemon cuttings root readily and orange cuttings with difficulty, but little is known as to the perpetuation of inherent productivity or the profitableness of a tree grown on its own roots. Trees eleven years old at the Citrus Experiment Station fail to demonstrate the practicability of propagating superior orchard trees by cuttings, this being especially true of lemons.

ROOTSTOCKS

The rootstock problem in California is one of great importance, principally because of variation within the species, the many different types of soil in which trees are grown, and the question of compatibility between the rootstock species and the commercial varieties which are budded upon them. Upon these factors and the climatic, cultural, and environmental influences, depends the success or failure of the commercial citrus orchard. The commonest citrus varieties used in California as rootstocks are the sweet and sour oranges, with occasional propagations of the grapefruit (pomelo), the Rough lemon, and the trifoliate orange (fig. 9).

The Sweet Orange.—The common round, sweet orange, *Citrus sinensis,* is perhaps the species best suited for use as a rootstock for all commercial varieties. The sweet-orange rootstock is particularly well suited to lemons and the practice of using it is increasing. Investigations now under way have demonstrated that several named varieties of sweet orange, such as the Bessie, Homosassa, Koethen, and others, produce

uniform and vigorous seedlings which are compatible with all varieties and produce smooth bud unions and large, vigorous, healthy trees. From 40 to 95 per cent of the seedlings produced from these sweet-orange varie-

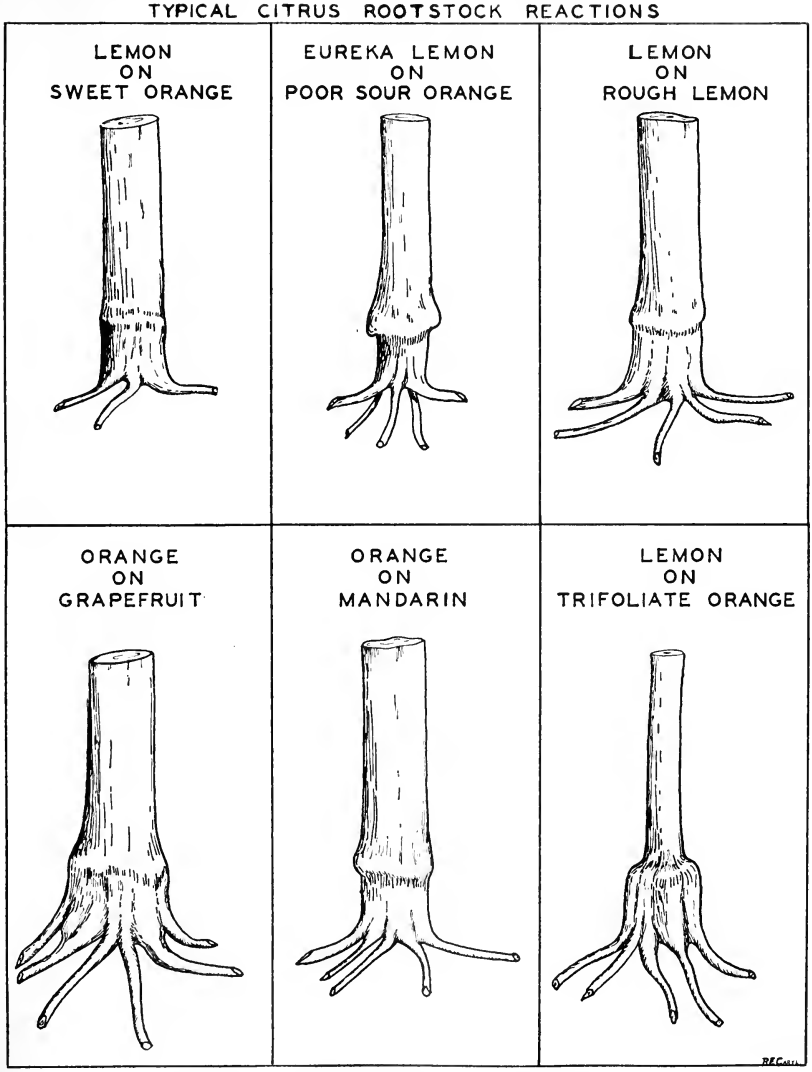

Fig. 9.—Typical citrus rootstock reactions.

ties will prove true to the parent variety. The remainder may be readily culled out in the seedbed and before budding in the nursery. The susceptibility of sweet-orange rootstock to brown-rot gummosis is its chief limitation; otherwise it might be universally used for all citrus in California.

The Sour Orange.—The sour orange, *Citrus aurantium,* has been largely used as a rootstock variety in California, principally because of its resistance to brown-rot gummosis. Sour-orange seedlings are from 75 to 85 per cent apogamic, or true to type. This rootstock is especially favored for grapefruit.

As shown in figure 9, the Eureka lemon is frequently incompatible with the common Florida strains of sour-orange seedlings, but more vigorous varieties of lemons may be budded on them, usually with satisfactory results, especially if the trees are to be grown on light, well-drained soils. Named varieties such as the Brazilian, Rubidoux, and the Standard sour oranges give little evidence of incompatibility even with the Eureka lemon and apparently transmit the desired characteristics of the parent variety to the seedling progenies.

The Grapefruit.—The grapefruit, or pomelo, *Citrus paradisi,* has been used as a rootstock in California citrus propagation occasionally in the past and more frequently during the last few years. Its use is still in an experimental stage, and rather conflicting results have been reported from the various citrus districts. The seedlings are apt to be extremely variable and must be culled severely before budding, since only about 60 per cent transmit the parent characteristics. In experimental trials where the trees were propagated with buds from the same parent tree, citrus trees budded on grapefruit rootstocks have proved less productive than trees on either sweet- or sour-orange rootstocks. As a rootstock for citrus trees, the grapefruit should be used with considerable caution, since there is some doubt regarding its commercial value.

The Rough Lemon.—In Florida the Rough lemon, *Citrus limonia,* has been used as a rootstock for citrus varieties for many years. Its use has been largely confined to the light, sandy, droughty soils of the "ridge section" of that state, where it is the only stock that has proved satisfactory. Because of its vigor, the Rough-lemon rootstock causes both tree and fruits to grow rapidly and tends to produce very large trees and fruits with thick, coarse rinds, insipid flavor, and poor color and quality.

As a rootstock for commercial citrus varieties for planting in California, the Rough lemon cannot be recommended, largely because of lack of experience with it under the many variations of climate and soil conditions in this state. It is undoubtedly one of the most vigorous rootstocks known, but its vigor is probably detrimental to the quality of the fruit. Valencia orange trees on Rough-lemon roots are considered by many people to be prone to produce more granulated fruits than are normally found.

The Trifoliate Orange.—The trifoliate orange, *Poncirus trifoliata,* has

been used to some extent as a rootstock in the past, but because of its dwarfing tendencies is not suited for use with most of the species and varieties of citrus grown in commercial orchards. As a rootstock for ornamental varieties of citrus and for home-orchard trees where small size is desired, the trifoliate orange is still used by some nurserymen. It is one of the hardiest of all varieties and transmits its characteristics, particularly slow growth and small size, to varieties budded on it. The

TABLE 2

COMPARATIVE YIELDS OF TWELVE-YEAR-OLD (1939) EUREKA AND LISBON LEMON TREES ON VARIOUS ROOTSTOCKS, VENTURA COUNTY

Rootstock	Eureka lemon trees				Lisbon lemon trees			
	Rootstock strains tested	Number of trees tested	Relative yield*		Rootstock strains tested	Number of trees tested	Relative yield*	
			1st 5 years	6th to 8th year			1st 5 years	6th to 8th year
Sweet orange.....	5	64	100	100	5	49	100	100
Sour orange.....	3	44	80	81	3	40	93	89
Mandarin orange..	4	39	79	86	2	30	78	81
Rough lemon.....	1	15	108	78	1	15	99	67
Grapefruit.....	3	30	72	72	3	33	90	84
Sampson tangelo..	1	15	99	91	1	15	88	80

* The relative yields of the Eureka and Lisbon lemons are not directly comparable. Comparisons should be made within columns and not across columns.

Valencia orange, however, seems to be an exception, for this variety has done well in some sections when budded on trifoliate-orange rootstocks.

Hybrid Varieties.—The Sampson tangelo (tangerine crossed with grapefruit) and the Morton citrange (sweet orange crossed with trifoliate orange) are hybrid varieties which are giving considerable promise as rootstocks for the commercial citrus varieties, but they cannot be recommended as yet because of a lack of propagating material and insufficient experience with them under orchard conditions.

Choice of a Rootstock.—The Citrus Experiment Station at Riverside is conducting a long-time experiment on citrus rootstocks for oranges, lemons, grapefruit, and mandarins.

The only progress report published so far deals with the responses of lemons. Table 2 which is prepared from this progress report[5] shows the summary of the average annual yield per tree of Lisbon and Eureka lemon trees budded on different rootstock varieties.

From the experience of commercial citrus orchardists and from care-

[5] Batchelor, L. D., and H. J. Webber. Progress report of lemon rootstock experiments. California Citrograph 24:160–61, 190–91. 1939.

fully planned experimental plots with trees grown on the different rootstock species, a few general suggestions may be made as to rootstock suitability for the varied conditions in California citrus-growing sections.

The sweet orange, when used as a rootstock, is best adapted to soils ranging from light to medium sandy loams, or loams which are underlain with gravel and have good drainage. In heavy clay loams and adobes, the sweet-orange roots are susceptible to root diseases and may be seriously damaged by poor drainage.

The sour orange is hardy and resistant to disease; it has a deep taproot system which enables it to grow under a wide range of soil conditions. It is well adapted as a rootstock to all citrus varieties, with the possible exception of some strains of lemons. The sour orange is well adapted for use as a rootstock for grapefruit planted in the desert sections. Here basin irrigation is the usual method of applying water. Under such conditions, it is advisable to use a rootstock such as the sour orange, which is less likely to be killed by gummosis. Most of the grapefruit orchards in California, as well as in Texas and Arizona, are propagated on sour-orange rootstocks.

CHARACTERISTICS OF GOOD CITRUS TREES

Before purchasing trees of any citrus variety, a grower should assure himself of the following very important points:

1. The tree should be typical of the variety and of a strain which has proved to be comparatively free from both persistent and intermittent variations. For example, the corrugated strains of any variety are persistent variations, and the Hart's Tardiff strain of the Valencia orange, as grown in California, shows intermittent variation, for the fruit may be nearly perfect one year and as high as 75 per cent off-type the next.

2. The tree, particularly the scion, should have inherent vigor and not a forced vigor due to the rootstock, as in the case of the Valencia budded on Rough lemon.

3. The tree should be disease-resistant, both as to scion and rootstock; above all, it should not be a carrier of any known disease or virus such as psorosis (see discussion of this disease, p. 45), which is transmitted through the bud to the young tree. There is no known remedy for psorosis, but the trouble may be prevented by propagation of disease-free parent trees.[6]

[6] The nursery inspection service of the California Department of Agriculture inspects and certifies parent trees free from psorosis virus. Reliable nurserymen now sell trees propagated from certified parents at a small advance in price.

4. The progeny trees should be potentially productive. The better nurserymen select buds only from trees known to produce good crops of high-quality fruit.

5. There should be compatibility between stock and scion as evidenced by a smooth bud union.

6. The prospect of long, productive tree life is of extreme importance to the citrus grower. Although there are many factors which influence the life and productivity of a citrus tree, its longevity depends to a great extent upon the vigor of the parent strain of the scion variety and of the individual seedling rootstock on which it is grown.

Good young nursery trees of the Washington Navel orange have a drooping habit of growth, few suckers, large dark-green leaves, and frequently flowers with anthers devoid of pollen. Valencia orange nursery trees are usually larger than the Navel trees and a little more upright; the flowers have pollen in the anthers.

Eureka lemon trees in the nursery are almost entirely lacking in thorns and are erect and open in growth characteristics; the leaves are large and dark green in color. Young Lisbon lemon trees are more upright, with many large thorns on the trunk and small thorns on the new growth; the leaves are narrower, more pointed, and of a much lighter yellowish green than those of the Eureka lemon variety.

Marsh grapefruit trees have vigorous upright growth which gradually spread, a few thorns, and large, dark-green leaves with large-winged petioles.

LOCATING AND PLANTING THE CITRUS ORCHARD

Location.—The selection of the site for a citrus orchard will depend to some extent upon the variety to be grown, but in general the most important factors to be considered are: a satisfactory quality and kind of soil which has good underdrainage and freedom from hardpan and alkali; an adequate supply of good water; and relative freedom from frosts and severe winds.

Soil.—The largest citrus areas are located on recent alluvial soils, all of which have excellent underdrainage, are fairly fertile, easily cultivated, free from accumulations of injurious alkali, and are especially well adapted to the growing of citrus fruits. Other types of soil may contain hardpan or plow sole and may be difficult to irrigate and cultivate, although some of them produce orchards of a high degree of excellence and productivity. Citrus trees are extremely susceptible to alkali injury and should never be planted on land that is even slightly alkaline.

Water Supply.—California citrus districts are located in areas which are partially dependent upon irrigation for their water supply, and the source of the water for this purpose is of primary importance. Areas dependent upon water from wells have frequently had to deepen the wells and install larger and more powerful pumps during periods of drought or because of the increased number of orchards planted in the district. Many orchards have been seriously injured by irrigation water containing high amounts of salts or alkali. A permanent and adequate supply of water reasonably free from salts is of fundamental importance. The cost of such water delivered to the orchard should not be excessive. Poor water conditions should be carefully investigated before plantings are made, since remedies are expensive and frequently difficult to carry out.

Frost Damage.—The possibility of frost damage is also a major consideration in the selection of the orchard site. The severe freezes of 1913, 1922, and 1937, as well as the lighter freezes of 1924 and 1932, give evidence of the frost damage which may occur in supposedly frost-free areas. The lemon-orchard site should be in a relatively frost-free area, since both tree and fruit are more tender than those of the orange varieties. Frost hazard depends upon local topography, the path of prevailing winds or minor air currents, and other local factors. The location of orchards of the various citrus varieties in any area is necessarily based largely on local experience as to climatic suitability.

Wind Damage.—At certain seasons of the year, severe damage to citrus orchards occurs rather frequently from the hot, dry, desert winds. Areas directly in the path of these winds should not be planted to citrus orchards unless effective windbreak protection is provided. (See discussion of windbreaks, p. 42). Observations made in certain sections after severe dry winds indicate that those orchards which are irrigated with salty water are more severely injured than near-by orchards which have a source of suitable water for irrigation purposes.

Preparation of the Land.—No particular treatment is ordinarily necessary for good virgin soils other than the clearing away of native brush and the removal of rocks and other debris (fig. 10). If the land has previously grown grain crops, in order to improve the tilth and fertility of the soil, a green-manure crop should be grown to be plowed under as soon as the young trees are planted.

Rolling land is now rather generally planted on the contour. Formerly the practice was to scrape off the high spots to fill the lower areas, but this should be avoided as much as possible in order to maintain an even depth of top soil in all parts of the orchard. Scraped areas frequently produce small, stunted trees and unprofitable areas in an orchard. Some

leveling may be necessary of course in laying out the contour rows to allow for the proper flow of irrigation water, but this type of work should be reduced to the minimum.

Since citrus trees are usually planted in the spring, deep plowing followed by thorough cultivation should be done as soon as the winter rains are over in order to provide suitable conditions of soil tilth for the young trees. Fall plowing followed by a winter covercrop, previous to planting, is of great value in the initial preparation of the soil.

Fig. 10.—Two-year-old lemon orchard planted in stony soil, showing a portion of the rock removed from 5 acres before planting.

Since the young trees will need water as soon as they are set, the irrigation system should be installed before planting begins, or adequate facilities should be provided for watering from tank wagons the first year or two.

Planting the Trees.—In California, citrus trees are usually planted from early spring to early summer. Trees planted during the period from March to May inclusive continue their growth with but a slight check, and new growth is sufficiently hardened by the time cold weather begins to permit them to withstand low temperatures with a minimum amount of frost damage.

The most convenient planting plan for all citrus orchard operations is the square system. When the contour system is used, the rows should be straight in at least one direction unless the contour of the land is too steep or irregular. The hexagonal system has been used to some extent in the older citrus sections because more trees can be put on an acre;

however, trees planted in this manner soon grow together, causing a possible increase in the expense of orchard operations.

Distances at which the trees are planted depend upon the variety, type of soil, rootstock, and climatic influences, since each of these has an important effect upon the size of the mature tree. The usual placing for oranges and grapefruit is in rows from 22 to 24 feet apart, with the trees 20 to 24 feet apart in the rows; lemon trees are planted in rows from 22 to 26 feet apart, the trees being from 18 to 22 feet apart in the rows.

Fig. 11.—Two-year-old (double-planted) orchard of oranges and grapefruit, one variety to be removed when trees begin to interfere.

When grown on the same type of soil and on the same or comparable rootstocks, Eureka lemon trees need much less space than either Lisbons or Villafrancas, and Washington Navel orange trees need less than the Valencia orange or the Marsh grapefruit. These points should be carefully considered before deciding upon the planting distances (fig. 11). For heavy crop production per acre, however, it is essential either to have large trees or to have them planted rather close together. Double planting is the usual practice now in order to increase yields the first few years. The extra trees should be removed when crowding occurs. The double planting may be mixed or of one variety.

The orchard site should be surveyed in order that stakes may be accurately set to mark the spots in which the trees are to be planted. The use of the planting board, usually 4 feet long with a notch cut at the center and one at each end, aids in planting the tree accurately. The center notch of the board is placed over the marking stake, and pegs are

driven into the ground at the notches in the ends of the board. The center stake and board are then removed, the end pegs remaining as guides for the digging of the hole and the planting of the tree.

Fig. 12.—Young lemon tree wrapped with newspaper as protection against frost and sun.

The hole is dug from 2 to 3 feet in diameter and to a depth equal to the length of the ball of earth containing the root system of the tree. In digging the hole, the top soil should be kept separate and used in refilling the space between the ball and the sides of the hole.

When the hole has been dug, the planting board is placed over it so that the planting pegs fit in the end notches; the balled tree is then placed in the hole, the trunk of the tree being set in the center notch of the board. The bud union of the tree should stand at the same level above the orchard soil as in the nursery, but it should be planted a little shallower to allow for the settling of the tree. The hole is then nearly filled with top soil, which should be lightly tamped around the roots or ball of the tree. Finally, the string holding the burlap sacking to the ball is cut, and the flaps are turned down and covered with a few shovelfuls of soil.

Planting should begin at the upper end of the row so that water may be applied immediately. If after irrigation it is found that trees are either too high or too low, they should be lowered or raised before the ball of earth becomes incorporated with the orchard soil.

The trunks of the young trees should be wrapped with newspapers (fig. 12), or with other types of tree protectors, to prevent sunburn or other injury to the tender bark during their first year of growth.

In soils which have previously been planted to citrus, brown-rot gummosis may be present and seriously injure young citrus trees unless great care is taken in planting them properly. As a precaution against brown-rot gummosis, young citrus trees are often planted on slight mounds or even on low ridges in order to keep their lateral roots at or near the surface of the ground. The trunks and top lateral roots may be treated with a thin wash or paste of bordeaux mixture. Irrigation water should be kept away from the trunks, since the brown-rot fungus thrives in moist soils. This will be difficult during the first few irrigations, but if the trees have been properly planted and treated, very little, if any, infection will occur. Brown-rot gummosis is further discussed on page 45.

FERTILIZATION

Needs of California Soils.—The fertilization of citrus orchard soils in California is of vital importance. Because of the great variation in the soils of the different citrus-growing sections, soil improvement is almost an individual orchard problem, except that orchard experience and careful fertilization experiments indicate the general necessity of the addition of nitrogen and usually organic matter, and that practically all soils in the citrus districts are amply supplied with available phosphorus and potassium.

Organic matter, as found in the soil, consists chiefly of the more or less decomposed remains of plants, such as straw, leaves and roots of previous crops, and manure. Very small amounts of such materials are found

naturally in most California soils. This is because the native vegetation of the lower arid valleys was originally sparse, and produced a relatively small amount of organic matter to be contributed to the soil, and also because high soil temperatures cause rapid organic-matter losses.

Organic matter in citrus soils in California is chiefly valuable as a source of nitrogen: it is the only fraction of the soil in which nitrogen is stored. Another benefit from its use lies in an improved physical condition of the soil and increased rate of water penetration.

In fertilization practices, available nitrogen is secured for the soil from both organic and inorganic sources. Since nitrate nitrogen is derived from the decomposition of the organic matter in the soil by bacteria and other microörganisms, the citrus grower may increase his potential supply of nitrates by growing covercrops, or by adding organic manures such as the cereal straws, alfalfa hay, bean straw, and animal manures. Inorganic materials, such as the nitrate and ammonium compounds, are used either alone or in combination with organic materials. Successful citrus growing requires constant attention to the problem of soil fertility. Hence the importance of adding nitrogen and organic matter to California citrus soils cannot be overemphasized.

Soil Analyses.—Chemical analyses of the soil in citrus orchards are usually considered of little value. This is in part due to the variability of California soils and the difficulty of securing a representative sample typical of the whole grove. Furthermore, many elements may be present in a form unavailable to plants, and, although the chemist can easily determine the total amount of mineral elements in the soil, no test has as yet been devised which will determine the availability of all the nutrient materials. The composition of the soil solution affects the growth of the plants, of course, but the growth of the plants also affects the soil solution. The most important consideration in the grower's knowledge of his soil is the availability of the plant foods, or nutrient materials in solution, at the proper stage or growth period. As is pointed out in Circular 235, "At those periods when the plant needs to draw most heavily on the nutrients, adequate supplies must already be dissolved in the soil solution, or be capable of entering into solution with sufficient rapidity. Thus the rate at which the soil solution is replenished with plant foods as they are withdrawn by the plant is the vital question."[7]

It is therefore of little interest to determine the total amounts of the plant-food elements present in the whole soil mass.

[7] Hoagland, D. R. Soil analyses and soil and plant interrelations. California Agr. Exp. Sta. Cir. 235:1–7. 1922. (Out of print.)

See also: Hoagland, D. R. Fertilizer problems and analysis of soils in California. California Agr. Exp. Sta. Cir. 317:1–18. 1939.

Organic Manures.—The principal organic fertilizers used in California citrus orchards are animal manures, alfalfa hay, and bean and cereal straws.

When the grower purchases these materials for use in citrus orchards, he should know their chemical composition and also their freedom from weed seeds, dirt, and an undue amount of moisture. Their value and cost should be determined by the nitrogen and organic-matter content. Table 3 gives typical chemical analyses of the bulky organic materials commonly used in the fertilization of citrus orchard trees.

TABLE 3

TYPICAL ANALYSES OF BULKY ORGANIC MATERIALS

(Average analyses of materials used by Citrus Experiment Station, Riverside, California, except as otherwise noted)

Material	Per cent nitrogen	Per cent organic matter	Per cent phosphoric acid	Per cent potash
Dairy manure (fresh)	0.50	22.60	0.24	1.00
Feedyard manure	1.35	48.73	0.51	2.77
Poultry manure no 1*	2.50	60.00	2.50	1.20
Poultry manure no. 2*	1.60	50.00	1.25	0.90
Hog manure*	1.60	52.00	2.10	1.01
Sheep manure*	1.60	50.00	1.50	1.50
Alfalfa hay	2.63	83.79	0.56	1.85
Alfalfa straw	1.50	82.00	0.30	1.50
Lima-bean straw	1.20	78.30	0.30	1.50
Barley straw	0.70	86.00	0.20	2.10
Cotton hulls	1.20	80.00	0.50	4.00

* Data from:
Wahlberg, Harold E. Fertilization of citrus trees (adapted to Orange County conditions). Agricultural Extension Service of the University of California and the United States Department of Agriculture cöoperating. (Mimeo.) 1936.

The composition and value of animal manures varies according to the kind of animals and their feed as well as the conditions under which the materials are collected and stored. Manures secured from dairies usually average from 0.50 per cent to 1.25 per cent nitrogen.

Since most bulky manures are relatively low in nitrogen, they should be supplemented by the addition of inorganic nitrogenous materials.

In the past, alfalfa hay has been used extensively as a source of both nitrogen and organic matter: alfalfa hay has an average nitrogen content of 2.0 to 2.6 per cent for the better grades and from 1.0 to 1.5 per cent for the lower grades. But good clean hay is usually too expensive as compared with some other types of fertilizer materials. Weeds, especially Bermuda grass and foxtail grass, are a serious adulterant of the lower grades of alfalfa hay. Moreover, many citrus-orchard soils are apparently unsuited to the use of alfalfa hay, other types of fertilizer materials having given much better results.

Bean straw is commonly secured from either lima-bean or black-eye-bean fields but is usually applied to the orchards nearest the source, or returned to land on which the crop was grown. The average nitrogen content varies from 1.0 to 1.5 per cent with a relatively high percentage of organic matter. These straws are high in potash but low in phosphoric acid and are valuable mainly as a source of nitrogen and organic matter. Care should be used in the purchase of bean straws because of the amount of weed seeds which they usually contain and the danger of introducing morning-glory into the grove. Benefits derived from the use of such straws may be largely nullified by the expensive eradication measures necessary for the control of morning-glory, puncture vine, and other noxious weeds. The expense of weed eradication should be charged against the fertilizer material which introduced the weeds into the orchard.

Recent years have seen the increased use of the cereal or grain straws, such as barley, oats, and wheat, as sources of bulky organic fertilizer material for citrus orchards. In many types of soil these materials are giving even better results than either alfalfa hay or the bean straws, especially when used in combination with some cheap source of inorganic nitrogen such as an ammonium or nitrate compound.

Organic materials are probably best applied in the fall of the year, before the planting of the winter covercrop and installation of the irrigation furrows. But if disked into the soil before serious loss from wetting and drying-out occurs, the various types of manure may be applied at any time during the year. The amount of nitrogen to add may be determined by an analysis of the material applied to the soil. Since grain straws may have somewhat more than twice as much organic matter as dairy or barnyard manure, but a smaller amount of nitrogen, more nitrogenous material should be added to the straw than would normally be used to supplement barnyard manure. When the ratio between the organic matter and nitrogen is approximately 20 to 1, the organic matter will decay rapidly, and the beneficial effects of the application will take place sooner than if decay requires a longer period. If grain straw is not properly supplemented with a nitrogenous fertilizer, too much organic matter may be applied, with resultant denitrification of the soil and injury to the trees.

Peat has been used extensively as a manure substitute in some sections adjacent to a local supply, but the grower should not put more than a nominal value on this material.[8] Although tree prunings, sawdust and

[8] For further information regarding the use of peat as manure, see:
Burd, John S. Peat as a manure substitute. California Agr. Exp. Sta. Cir. 203:1–10. 1918. (Out of print; may be consulted at many city and county libraries in California.)

shavings, and other coarse and slowly decomposing materials contribute slightly to the humus content of the soil, they should not be used in large amounts or too often. Cornstalks are similar to straw but decompose even more slowly. They are of value as a source of organic matter. Cotton bollies decompose more rapidly than any of the foregoing materials and supply both organic matter and nitrogen.

Inorganic Materials.—Of the many kinds of inorganic materials commonly used as fertilizers in California citrus orchards, those which are a source of nitrogen are of the greatest value.

At the present time, commercial ammonium sulfate is in general use as a source of nitrogen. It contains about 20 per cent nitrogen, some of which is immediately available to roots in the top few inches of soil; most of the nitrogen, however, must be changed into nitrate nitrogen before becoming available to the roots lying deeper in the soil. The use of covercrops in combination with ammonium sulfate is frequently a successful practice. The covercrop takes up the nitrogenous fertilizer in the surface soil, and the nitrates are later made available through the decomposition of the covercrop. In many cases, the use of ammonium sulfate alone has proved satisfactory.

Ammonium sulfate is at present one of the cheapest sources of nitrogen available and has in general been responsible for as good yields as the more expensive source of nitrogen. The former objection that it leaves a residue of sulfate which results in an acid condition of the soil, although well established from the soils of eastern states, seems to be of doubtful applicability in California. The natural alkaline nature of California soils, and also of most sources of irrigation water, may be depended upon to counteract any potential acidity; hence it does not seem probable that an acid condition of the soil harmful to citrus trees will result from prolonged use of reasonable amounts of this fertilizer.

Sodium nitrate and calcium nitrate contain about 16 per cent nitrogen and are excellent supplementary sources of this element when used in combination with deep-rooted covercrops, manure, or organic matter. Both materials have the advantage of being immediately available to citrus trees. For lemon groves in light soils, either one of these fertilizers may be applied before the February and June growth periods. In February, small amounts may be spread well over the surface of the ground, to be carried into the root zone by rains. In June, the material should be put in the bottom of the irrigation furrows; otherwise it will not be carried to the root zone.

Nitrogenous fertilizers applied to citrus orchards in the irrigation water have given satisfactory results for many years in the different

citrus-growing sections of California. By this method, the chemical concentrates are dissolved and thoroughly diluted in the water as it enters the irrigation furrows. Various simple, efficient, and inexpensive applicators for such fertilizers are used and have proved to be satisfactory in maintaining a reasonably uniform concentration of fertilizer in the water. The distribution of fertilizer in the orchard is not so uniform as by hand or mechanical application and is less satisfactory for ammonia or ammonium salts than for nitrates.

Effect of Time of Application.—The time of the year at which fertilizer materials are applied to the soil has very little effect on the production of citrus trees. As far as their nutrient value is concerned, fertilizer materials may be applied at any time. But the soil type and the climatic or environmental conditions surrounding the grove have some effect in determining the time of application. In most citrus districts, manures may be applied to the soil at any time during the year, whenever they can be purchased the cheapest. One of the commonest practices is to apply them in the fall before the planting of the winter covercrop or installation of the winter irrigation furrows. Since manures are comparatively slow in decomposing, they must be applied several weeks before the nitrates become available for use by the trees. If quickly available inorganic sources of nitrogen are applied to neglected groves before the fall growth period, new growth which might be damaged or lost during the frosts of the winter months may be forced out.

There is very little reason for making more than one application of any material during the year, except possibly in the case of easily leached materials applied to loose, open soils. The application of manure in the fall, with the addition of a quickly available source of nitrogen near the end of the rainy season before growth starts in the spring, is one of the commonest and most successful fertilizer practices.

Amount of Nitrogen Necessary.—The determination of the amount of nitrogen that is necessary for the production of profitable crops of citrus fruits is a complicated but important problem and must usually be worked out by the individual grower for his own particular conditions. In years of fair prices and with trees twenty years old or more, 200 to 300 pounds of actual nitrogen per acre per year can be used profitably. If half of the nitrogen is derived from manure and half from an inorganic source, and 300 pounds of nitrogen per acre are applied, it would be necessary to apply approximately 7½ tons of manure and 750 pounds of an inorganic fertilizer containing 20 per cent nitrogen per acre. This amount should give satisfactory results in orchards of full-bearing age and keep the trees in good health.

Trees which receive little or no nitrogen usually have a yellowish-green color, the leaves become small, blossoms are scarce with no vitality, and there is very little fruit. The addition of as little as 50 pounds of nitrogen per acre has resulted in a greatly increased crop and a healthy appearance. Amounts of nitrogen above 300 pounds per acre should be used with care in most citrus districts, since larger amounts may prove to be unprofitable.

Zinc Deficiency.—For many years citrus trees in California orchards have been affected with mottle-leaf, and various types of experiments have been conducted in an attempt to remedy or control the condition. Mottle-leaf has now almost completely disappeared as the result of experiments in the application of zinc compounds to the leaves in the form of dusts and sprays.[9] Apparently the effect of an application of zinc to the trees controls the mottled condition for two to three years, the period depending upon the total amount of zinc applied and upon the climatic conditions at the time of application. In some sections dusts are satisfactory, but sprays are more suitable for all conditions and varieties.

Soil Amendments in California Citrus Soils.—Probably no citrus soils exist in California which will be materially benefited by the application of lime as a source of fertilizer or for use as a corrective for supposedly acid soil conditions. Soil studies made over a period of many years by several different agencies have failed to find a California citrus soil deficient in lime. There are natural lime compounds in the soils, and in many instances these are constantly increased by the irrigation waters.

Other soil amendments such as sulfur and gypsum have not been found to be necessary for citrus soils.

Phosphates in California Citrus Soils.[10]—Soil studies made in all of the principal citrus-growing areas of southern California indicate that most soils in these areas contain sufficient phosphate for the needs of citrus trees. The phosphate, with the possible exception of that in calcareous types of soil, is in a readily available state. Previous fertilizer practices in these citrus soils may also have resulted in an accumulation of phosphate which is in a somewhat more available form than that natively present in the soil. The use of manure as one of the principal sources of nitrogen and organic matter adds phosphates and potash in sufficient quantity to equal a complete mixed fertilizer with an average nitrogen-phosphate-potash content in about the proportion of 10 : 7 : 20.

[9] For a more complete discussion of mottle-leaf, see:
Parker, E. R. Experiments disclose more facts on zinc control of mottle-leaf. Citrus Leaves 18(4):5–6, 20. 1938.

[10] Chapman, H. D. The phosphate of southern California soils in relation to citrus fertilization. California Agr. Exp. Sta. Bul. 571:1–22. 1934.

The use of phosphate in nine field trials with citrus trees located in different types of soils, and for periods ranging from five to twenty years, has in no case resulted in significantly increased yields. In orchards which have been fertilized in the past with chemicals containing phosphates and with animal manures, a sufficient amount of phosphate has accumulated in the root zone to supply the trees for many years, making the addition of phosphates to such citrus soils unnecessary.

Potassium in California Citrus Soils.—As in the case of the phosphates, California soils usually contain sufficient quantities of potassium for satisfactory tree growth. Only preliminary studies have been made on the increases in water-soluble potash due to fertilization with materials containing this element. These investigations indicate that a movement of potash comparable to that of the phosphates has taken place in the upper part of the soil, especially in the surface 3 feet, and that a marked increase in water-soluble potash has followed the moderate application of fertilizers containing potassium. Most bulky organic materials commonly used as fertilizers contain as much potash as nitrogen, or even more (table 3). Thus, as with the phosphates, sufficient amounts of potash are apparently applied through the use of manure to make the application of chemicals containing additional potash unnecessary.

COVERCROPS

The general use of winter covercrops in citrus orchards in California has aided in the maintenance and the increase of soil fertility, in the prevention of soil erosion in the winter, in the conservation of the nutrient materials in the soil, in the breaking up of plow soles, and in the general improvement of the physical condition of the soil. Some growers feel that a covercrop is a disadvantage during the winter months because of a somewhat lower temperature and also possible interference with orchard-heating operations. There is, however, very little difference in the minimum temperatures of the atmosphere 3 feet or more above the ground in orchards with and without covercrops.

In most sections, the advantages of the use of covercrops far outweigh the disadvantages. The beneficial effects of the use of a covercrop in combination with fertilization have been clearly shown in numerous experiments conducted in groves located on a wide range of soil types. There has generally been an increase in yield where nitrate of lime, nitrate of soda, manure, or a "complete" fertilizer has been applied in combination with a winter covercrop. The positive advantage shown when any one of these materials has been used with a covercrop is a yield increase from

6 to 40 per cent over that obtained with the same fertilizer applied without a covercrop.

Species in common use for covercrops at the present time are the mustards, *Melilotus indica,* malva, and native or introduced weeds.

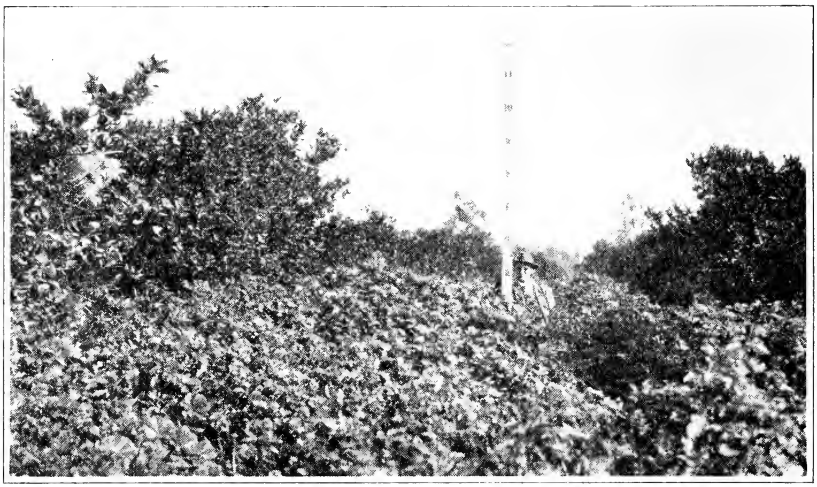

Fig. 13.—White mustard (*Brassica alba*) used as a covercrop in a citrus orchard.

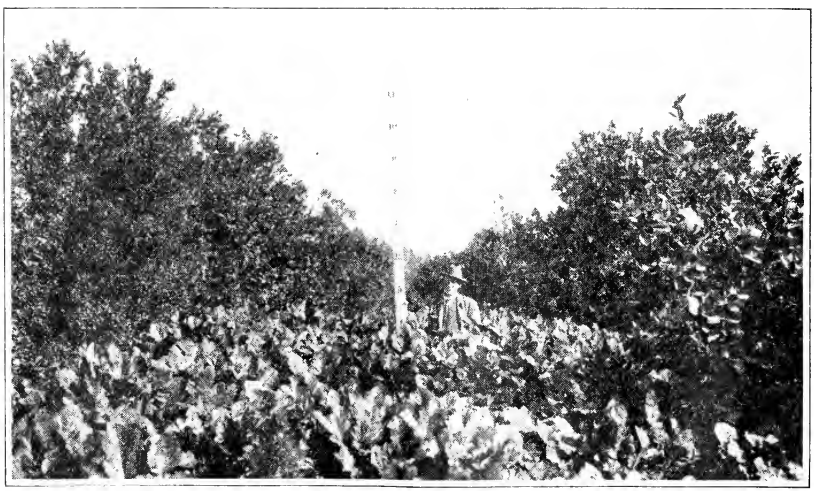

Fig. 14.—Brown mustard (*Brassica nigra,* cult.) used as a covercrop in a citrus orchard.

The mustards commonly used are white (common yellow) mustard (*Brassica alba*), shown in figure 13, and brown (red) mustard (*Brassica nigra,* cult.), shown in figure 14. The white mustard grows rapidly and

makes an excellent covercrop but has a hollow stem, which makes it intolerant of tramping. Its use should therefore be avoided where picking and heating crews frequent the grove during the winter. Brown mustard has a solid stem and will usually recover from tramping and continue upright growth. Since the seed does not have to be raked or harrowed into the soil, the method of planting is by sowing 5 or 6 pounds of seed per acre after the irrigation furrows have been installed.

Melilotus indica is used either alone or in combination with either of the mustards.

Malva is frequently a volunteer covercrop in many sections during the winter and because of its deep taproot is very beneficial in penetrating and opening up plow soles.

Other weeds, such as pigweed and purslane, are commonly found in citrus orchards and, if not allowed to compete with the trees for water and nutrients, may be considered as summer covercrops and sources of organic matter. The water supply is the limiting factor in the use of summer covercrops. Where water can be applied as needed, such plants as the weeds and cowpeas (*Vigna sinensis*) may be grown to supplement the soil fertility.

The use of summer covercrops is the accepted practice in the Imperial Valley and other desert sections. Sesbania (*Sesbania punicca*), a tall legume producing a large amount of organic matter and adapted only to hot climates, is commonly used.

Winter covercrops should be turned under while they are still in a green and succulent condition or as soon as possible after the latter part of February. They should never be plowed under when the soil is either too dry or too wet, because this results in a poor incorporation of the green tops with the soil, slow decay, and subsequent unsatisfactory soil conditions. Again, covercrop plants may have remained standing in the orchard too long before plowing; thus, they have reached full maturity, have become hard and dry, and are very slow to decay. Misusing a covercrop in either of these two ways may make it an actual detriment rather than an asset.

INTERCROPPING YOUNG ORCHARDS

In those coast sections having rich soil, abundant water supply, and a relatively high atmospheric humidity, the growing of vegetable crops between the rows of young citrus orchard trees has proved to be a successful practice during the first four or five years after planting of the trees. Lima beans and lettuce are the two principal vegetable intercrops grown, although flowers, many kinds of garden-vegetable varieties, and

small fruits, such as strawberries and the bush berries, are occasionally grown.

In the interior sections this practice has usually been found undesirable owing to the higher summer temperatures, the low humidity, and limited water supply.

For best results, the practice of intercropping should not be carried beyond the fifth or sixth year in any climatic district. When intercrops are planted, care must be taken to provide and maintain suitable conditions for the trees at all times.

CULTIVATION

The common method of cultivation in California citrus orchards is to disk the soil as soon as possible after the winter rains, usually in the latter part of February or first part of March. Subsequent cultivation is done with a disk or spring-tooth harrow after every second or third irrigation until the sowing of the winter covercrop in the fall. During the past ten years, there has been less cultivation than formerly. A moderate use of the spring-tooth harrow or disk after each irrigation or after every second irrigation is necessary in the drier sections, where competitive summer weed growth should be kept down unless water is available for its use. For the majority of citrus soils, it is probably best to reduce cultivation to the minimum.

In irrigated orchards, a hard and impervious layer known as "plow sole" frequently develops a few inches below the surface, and in some soils this is serious enough to retard the penetration of irrigation water. Plow sole was formerly thought to be caused by plowing and cultivating repeatedly at the same depth, but this is probably only one of the factors causing its formation. The usual type of plow-sole condition may be made a less serious handicap to irrigation by the application of organic matter which is worked into the soil, and by growing covercrops which have taproot ed plants, as, for example, mustard or malva. Mechanical means of control should be avoided as much as possible because of the injury to the root systems of the trees. Cultivation of the soil only when in good condition and the beneficial results of reduced cultivation practices will aid in preventing the formation of plow soles.

Mulching.—The practice of mulching with organic matter has been generally discarded by citrus growers except in groves planted on terraces or very steep hillsides. Severe damage has occurred to citrus trees in the past where mulching with straw under the trees has attracted rodents which injured the bark and roots of the trees. It is an expensive and relatively undesirable practice and is rarely used.

IRRIGATION

Citrus trees growing in California are in an entirely artificial environment, since most of the species are natives of the warm, humid areas of the tropics and subtropics. They are also evergreen trees and require soil moisture at all times, although their requirements differ during the seasons. The citrus-growing areas of California are in semiarid regions in which the natural rainfall is insufficient for the needs of the trees and is largely confined to the winter months. Irrigation is therefore necessary throughout the entire period of little or no rainfall. The water requirements of mature citrus trees range from 18 to 48 acre-inches annually, including the rainfall. This amount depends largely upon the age of the trees and upon the soil, climate, and environmental influences. The time and frequency at which water should be applied to the soil, and the interval between applications of water, depend upon many variable factors, but irrigation methods may be established for each climatic zone and soil type.

Moisture conditions for satisfactory growth are usually maintained for from 4 to 8 weeks after the last winter rain, after which time irrigation becomes necessary. Available moisture must be maintained at all times in the first 4 feet of soil, since the majority of the feeding roots may actually be in the first 2 or 3 feet. Overirrigation must be avoided with certain heavy soils and with those where soil drainage is slow, especially in the coast climatic zone. Two or three irrigations a year may be sufficient under such extreme conditions. Injury to the trees may be avoided by determining moisture conditions through the use of a soil tube or auger and by withholding further applications of water from those portions of the soil which remain wet from one irrigation to another.

Irrigation practices have been improved during the last few years by systematic soil-moisture observations, and the interval between irrigations and amount of water to be applied are now largely governed by these observations. The use of a soil tube or auger to test the soil for the amount of water present at various depths should be a regular practice by all growers, since definite information can thus be obtained about the condition of the soil and its effect upon the trees. The core of soil removed by the tube or auger will indicate the moisture content below the surface and will show the proper amount of water to be added to maintain satisfactory moisture conditions in the root zone.

Methods of Irrigation.—Irrigation systems and methods of application in common use in the various citrus-growing sections are the straight furrow, the contour furrow, the basin, the contour basin, and the sprink-

ler systems.[11] All of these types are generally supplied with water from underground cement pipe or steel main pipelines. A few open-flume systems are still in use in some of the older sections but are gradually being replaced with more efficient types of equipment.

In the straight-furrow system, from four to eight furrows are made between each two rows of trees, and the water is led into the furrows from the hydrant at the head of the row. The length of the run depends to a

Fig. 15.—Irrigation by contour furrows. (From Ext. Cir. 16.)

large extent upon the type of soil, but runs of 300 feet or less are preferable to longer runs. The water is usually run through to the end of the furrow and the valves in the hydrant adjusted so that there will be little, if any, runoff of water at the lower end. The length of time required for satisfactory penetration of water into the root zone varies from 2 to 72 hours, with an average of approximately 24 hours for the various types of soil.

On rolling land, contour furrows are much more efficient than straight furrows (fig. 15).

In very light sandy soils, the basin or check systems are used, with a

[11] For further information regarding these systems, water measurement, etc., see:

Huberty, M. R., and J. B. Brown. Irrigation of orchards by contour furrows. California Agr. Ext. Cir. 16:1–16. Revised 1932. (Out of print; may be consulted at many libraries that have on file copies of the publications of the College of Agriculture at the University of California.)

Brown, J. B. The contour check method of orchard irrigation. California Agr. Ext. Cir. 73:1–19. 1933.

Christiansen, J. E. Measuring water for irrigation. California Agr. Exp. Sta. Bul. 588:1–96. 1935.

large head of water. The water is usually run to the lowest basin first and then worked back until finally the first or highest basin is filled. An improvement on this system has been developed during the past few years and is known as the contour-check system. This has the advantage of supplying nearly equal amounts of water to all parts of the orchard and has given excellent results in the hot interior valleys which have fine sandy soil.

The overhead-sprinkler type of irrigation is in use in a few sections but has not proved generally satisfactory when used over a period of years. An improvement on the overhead system has been made in recent years by placing the sprinkler heads on low, portable standards fed by water from a rubber garden hose. These sprinklers throw the water over the square between four trees, very little water being thrown high enough to get on the trees. The entire line is moved after sufficient water has been applied, and there are usually enough hose lines and sprinklers so that the whole grove is irrigated in a reasonable length of time.

PRUNING

The practice of pruning citrus trees in California has at present been reduced to the minimum. Severe pruning has been found to be detrimental to the tree and is a cause of reduction of the crop and stimulation of the growth of suckers or water-sprouts. Pruning of the orange varieties should consist only of the removal of dead wood, broken or interfering branches, and poorly placed suckers. This should be done annually on young trees. It is usually unnecessary to prune older trees for this purpose except every second or third year; operating expenses are thus reduced and the quantity of and returns for the fruit increased. Because lemon trees are much more vigorous than orange trees, they may need more frequent pruning.

There are many different types of pruning, each type being suitable for use in some district but not in others. For this reason, the grower should observe in his own district the results of pruning demonstrations and experiments which are being carried out by his neighbors or by the staff of the Agricultural Extension Service. This type of demonstration when carried on for at least three years will serve as a reliable guide to enable the grower to decide upon the best pruning system for use in his orchard.

Experiments in the pruning of severely frost-damaged citrus trees have been carried on after every freeze (fig. 16). Recommendations for the general treatment of frozen trees usually suggest the advisability of doing no pruning for six months or a year after the freeze. The extent of

Fig. 16.—Lemon trees frozen in February, 1937, and pruned during the following summer; photographed February, 1938. Pruning so soon after the frost has forced considerable water-sprout growth. This grove is adjacent to that shown in figure 17.

Fig. 17.—Badly frozen lemon trees unpruned one year after freeze of February, 1937; photographed February, 1938. (The heaters were installed after the freeze.) The delay in pruning the injured wood has encouraged the growth of fruit wood, and the trees are better prepared for crop production than those shown in figure 16.

the damage will be known by that time, and unnecessary pruning be avoided. Figure 17 shows the better recovery of lemon trees as a result of delaying pruning for a year after the freeze.

Excessive pruning and the various new radical pruning systems which are introduced periodically by well-intentioned but uninformed persons should be carefully avoided.

FROST PROTECTION

Since nearly all citrus districts are subject to occasional frosts, some means of protecting the trees and fruit may prove advisable.

The method of heating orchards in most general use at the present time is the burning of oil in orchard heaters of various designs and capacities. These heaters have given partial satisfaction for many years and are now undergoing improvement, particularly in regard to the amount of heat generated and reduction in smokiness.[12]

WINDBREAKS

Permanent windbreaks are an essential feature of citrus-growing areas which are in the direct path of the hot, dry winds originating in the desert regions, particularly in the intermediate sections.

Windbreaks are also planted near the coast because they are of benefit in maintaining a warmer and more even temperature during the winter months and at times in the spring when fogs and strong coast winds are frequent.

The most suitable tree for use as a windbreak in nearly all districts is the blue gum (*Eucalyptus globulus*), shown in figure 18. This is a very hardy variety, attains a great height, and is not so brittle and so easily broken in severe winds as other species of eucalyptus.

The young eucalyptus seedlings are planted on the windward side of the orchard, usually in a single row and 5 feet apart in the row. The results from planting double rows of trees have not been entirely satisfactory, and many old windbreaks have been thinned to a single row. By planting only at right angles to the direction of the damaging wind, the formation of air pockets is avoided.

When the young trees are two years old, alternate trees are usually cut

[12] Types of equipment used throughout the citrus districts for heating purposes are described in detail as to cost of operation, efficiency, and suitability in the following publications, which may usually be secured from local libraries, from the files of the County Agricultural Agents, or from the branches of the University of California:

Schoonover, W. R., F. A. Brooks, and H. B. Walker. Protection of orchards against frost. California Agr. Ext. Cir. 111:1–70. 1939.

Schoonover, W. R., and F. A. Brooks. The smokiness of oil-burning orchard heaters. California Agr. Exp. Sta. Bul. 536:1–67. 1932.

back to 3 feet to induce branching and filling in of the lower part of the windbreak.

The effective range of a windbreak composed of trees of blue gum is approximately 5 feet of orchard for each foot of height of the windbreak. Accordingly, a row of trees 60 feet in height will protect approximately 300 feet of orchard. One row of trees should therefore be planted for every 330 feet in areas where wind damage is severe.

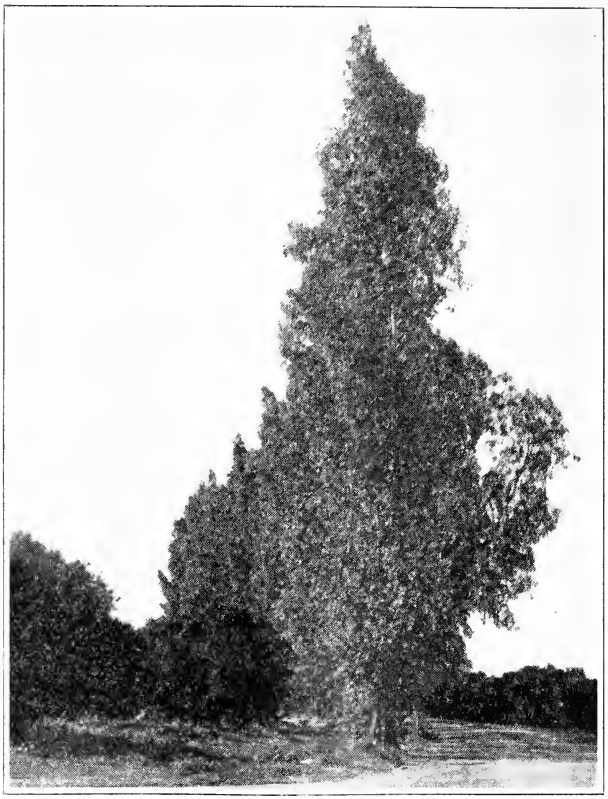

Fig. 18.—Eucalyptus windbreak protecting citrus trees from desert winds in the interior section of southern California.

The blue gum is a surface feeder and has been objected to because it retards the growth of the first few rows of citrus trees. This root competition may be largely eliminated by cutting the roots of the windbreak trees with a subsoil plow or special root cutters often enough to prevent the growth of large roots, and by placing an extra amount of manure or other nutrient material on the feeding area of the rows of citrus trees adjacent to the windbreak.

Monterey cypress (*Cupressus aphylla*) has been used in the past as a windbreak tree because it is less injurious to the citrus tree than the blue gum. It has lately proved to be short-lived, however, on account of the attack of an insect which burrows between the wood and bark of the tree and thus girdles and destroys the tree (fig. 19). Various species of native California cypress are being grown experimentally to determine

Fig. 19.—Old cypress windbreak dying from attack of bark beetles.

the degrees of resistance or immunity to the attack of these bark beetles, so that eventually a long-lived cypress windbreak tree may be developed.

Many investigations have been carried on to determine the cause and effect of the damage done by the desiccating desert winds. After a bad "norther," there are frequently many dead twigs and smaller branches to which dead and scorched leaves are still attached. Twigs from which the leaves have been detached by the direct effect of the wind usually remain alive. In the case of twigs on which the dead leaves remain, however, the water-carrying tissues of the twigs become clogged with gum, and the twig dies. The minimum amount of damage of this kind is usually found in groves protected by suitable windbreaks and in which the best cultivation and irrigation practices have been followed.[13]

[13] For further information on wind damage, see:

Reed, H. S., and E. T. Bartholomew. The effects of desiccating winds on citrus trees. California Agr. Exp. Sta. Bul. 484:1–59. 1930. (Out of print; may be consulted at libraries.)

DISEASES, INSECTS, AND OTHER PESTS[14]

Citrus orchards in California are subject to many injurious diseases, insects, and other pests. The trees, leaves, bark, fruit, and roots may be affected by the same diseases or insects at the same time, or any part may be affected singly.

Most of these troubles can be controlled by proper treatment at the right time. Because of the great number of diseases and insects attacking citrus orchards, the grower should consult his local county agricultural commissioner, the county farm advisor, or the divisions of the University of California Citrus Experiment Station at Riverside, California.

Psorosis.—Psorosis, or scaly bark, has recently been shown to be a virus disease, the only known method of transmission being by propagation. When a tree, otherwise suited as a desirable source of budwood, is found to have psorosis either in the systemic or localized form, it should be considered as a probable source of the disease and no budwood should be taken from it. Treatment of serious cases of psorosis has not proved satisfactory and usually a tree should be removed as soon as it becomes unprofitable. The first stage of the disease often responds to treatment, but since the complete eradication of the disease may apparently be achieved by the propagation of disease-free nursery stock, this seems a better method of attack.

Brown-Rot Gummosis.—Brown-rot gummosis is a serious fungus disease which attacks the roots, trunk, branches, and fruit of citrus trees and is especially prevalent during winters of abundant rainfall. The effect of the disease upon the tree is manifested by the exudation of a gummy substance from the affected parts. These may be large or small in extent, according to the severity of the attack. The spread of the disease may be checked by cutting away the outer bark and scraping the brown areas in the cambium layer until healthy white wood is found. The wound should be painted with a bordeaux paste of the consistency of paint, made by stirring together in water bordeaux powder and one-half as much hydrated lime by weight. Fruit attacked by brown rot decomposes rapidly and falls to the ground, where it is a source of further injury to tree and fruit. Before the winter rains, the tree should be

[14] For further information on citrus diseases, insects, and pests, see the following publications:

Fawcett, H. S. Citrus diseases and their control. 2d ed. 656 p. McGraw-Hill Book Company, Inc., New York, N. Y. 1936.

Quayle, Henry J. Insects of citrus and other subtropical fruits. 583 p. Comstock Publishing Co., Inc., Ithaca, N. Y. 1938.

Quayle, H. J., and Walter Ebeling. Spray-fumigation treatment for resistant red scale on lemons. California Agr. Exp. Sta. Bul. 583:1–22. 1934.

sprayed with bordeaux mixture to a height of 3 or 4 feet above the ground. Weeds or soil near the skirts of the trees should also be thoroughly sprayed. If cyanide fumigation is to be done within the year, a more dilute mixture composed of 1 pound copper sulfate, ½ pound hydrated lime, and ⅓ pound blood-albumin spreader, to 100 gallons of water should be substituted for the bordeaux mixture as a spray for brown rot.

Miscellaneous Diseases.—Spotting of citrus fruits is caused by the breaking of the oil cells in the rind by careless handling, especially when the fruit is wet. This type of injury, which appears as light grayish scars on the surface of the fruit, is noted on fruits on the tree after severe windstorms which have whipped the fruit against twigs and thorns.

Symptoms of excessive amounts of chlorides in the soil are usually observed first in the leaves. The tips and margins of the leaves become yellow or brown and in extreme cases defoliation occurs. Excessive amounts of sulfates and bicarbonates stunt the growth of the trees and make the leaves chlorotic. All citrus, but especially lemons, are susceptible to these alkali salts. The condition may sometimes be remedied by leaching with alkali-free water, but the situation is often complicated. A grower confronted with such a situation should consult the farm advisor or write to the College of Agriculture for further assistance.

Scale Insects.—The scale insects are at present the most serious of the many pests attacking citrus orchards. Of these, the red and black scales cause the greatest amount of damage. The general and most satisfactory method of control for use in all districts is fumigation with hydrocyanic acid gas. In some sections both spray and fumigation are needed for the control of a resistant red scale on lemons.

Miscellaneous Pests.—Mealybugs, cottony cushion scale, and other citrus insect pests are nearly, if not entirely, controlled by their natural insect enemies.

Snails as citrus-orchard pests may be controlled by using poison bait. The county agricultural commissioner should be consulted for recommendations and for laws on the use of poisons.

Weeds.—The usual method of weed control for citrus orchards is cultivation. Serious infestations of morning-glory and Bermuda grass can be controlled fairly successfully by cultivation at frequent intervals. Morning-glory roots are storage reservoirs for large amounts of plant food, and this food supply can be entirely exhausted by never allowing any green leaves to appear above the ground.

Small patches of morning-glory have been satisfactorily controlled with carbon disulfide, or by repeated spraying with orchard-heater oil.

Care must be used when handling carbon disulfide, because it is highly inflammable and explosive. It must not be placed near the drip of the trees because it kills roots of citrus as well as those of morning-glory. There is a type of inexpensive applicator available for it which has given satisfaction in the control of oak-root fungus and small patches of noxious weeds. This applicator is shoved into the ground to the desired depth. The liquid is then measured from the reservoir into a small glass bottle attached to the lower side of the reservoir and by a series of valves is discharged at the desired time into the inside of the pipe which has been shoved into the ground. The pipe is then withdrawn and the hole filled with soil to prevent the rapid escape of the carbon disulfide gas.

If Bermuda grass can be plowed, spring-tooth-harrowed, raked, and burned, two such operations during the summer will nearly eradicate it from between the rows of trees in citrus orchards; but if it gets under the trees, the only satisfactory method of control is constant handwork with a hoe.

PICKING CITRUS FRUITS

The harvesting of citrus fruits is one of the most important of the many handling operations to which they are subjected. The care with which they are picked determines their length of life and the condition in which they reach the markets. Very slight skin punctures, bruises, clipper cuts, and careless handling or dropping into boxes cause losses because molds and fungi enter the tissues at such places and cause decay of the entire fruit. Many years of intensive study and carefully conducted experiments in picking and handling citrus fruits have proved that decay is increased by careless handling of the fruit in the grove, packing-house, and in transit to the markets.

Picking is usually carried on by carefully trained picking crews under the direction of an experienced picking foreman employed by the grower's association. The owner of the small grove rarely harvests his own fruit, for only the large operator has his own picking crews.

COST OF PRODUCTION[15]

During the past few years, there has been an increased interest in the cultural costs of producing oranges and lemons in California. The California Citrus League has conducted these studies for a long period and

[15] For more detailed studies of the economic aspects of citrus production, see:
Shultis, Arthur. Citrus enterprise-efficiency studies in southern California. California Agr. Exp. Sta. Bul. 620:1–65. 1938.
Wallschlaeger, F. O. Orange and lemon yields in 1935 highest on record of Citrus League. California Citrograph 22:14. 1936.

on a large acreage. This work is also being carried on by the county farm advisors in coöperation with growers in their districts. Special studies are being made with profitable, unprofitable, and average groves in the citrus-growing areas. Detailed information can be secured by growers from their local county farm advisors for cost-of-production figures in groves similar to their own and in their own locality.

The keeping of cost-account records is of extreme importance to citrus growers. Each grower should be informed at all times as to the cost of producing his crop. The successful grower of the future will be the one who can keep his production costs at the minimum, for the increased plantings of the past few years will tend toward the production of larger supplies of fruit in the near future, with the prospect of probable lower returns to the grower. The cost-of-production studies suggest many ways for the lowering of certain types of fixed and fluctuating charges, but the effectiveness of these reductions is largely in the hands of the grower himself.

Citrus-fruit growing in California, thousands of miles from the large market centers, is a complex and specialized industry in which the grower, to be successful, must have a great amount of foresight and energy and a genuine personal interest in the many important details which mean the difference between profit and loss for himself and the citrus industry.