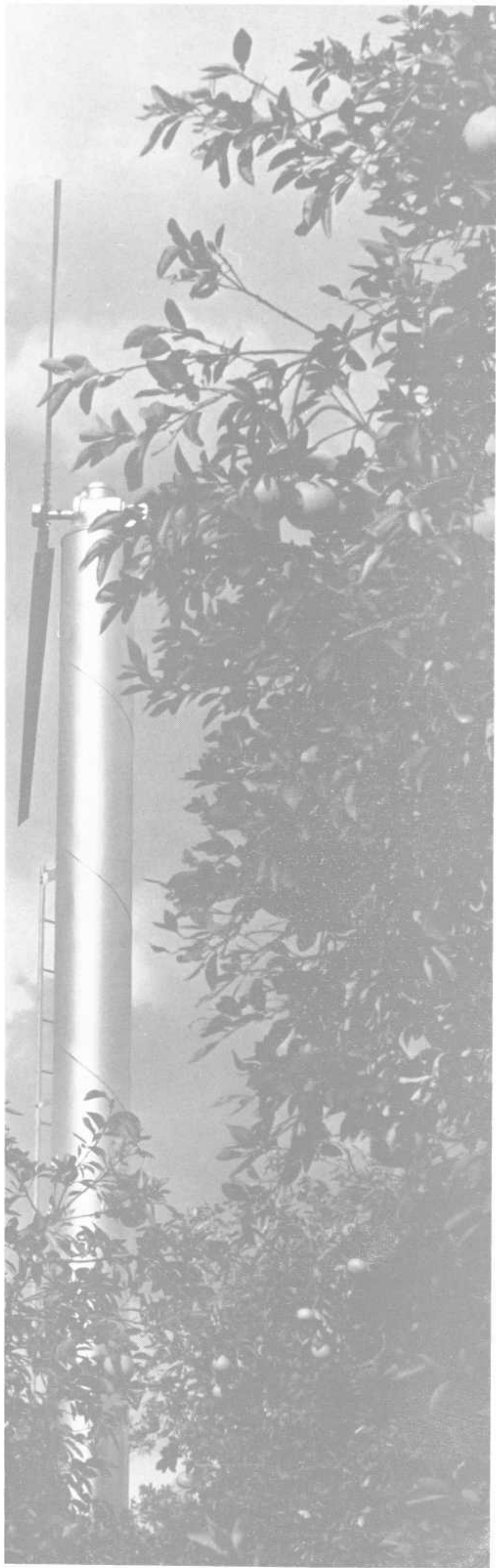
Commercial Citrus Production In Arizona



Special Report No. 7

Agricultural Experiment Station
and
Cooperative Extension Service

The University of Arizona

Summary

Establishing a Young Grove

New Plantings should be made in the warmer parts of the Salt River Valley where at least five acre feet of good quality water is available per year and on the Yuma Mesa and Wellton-Tacna area, where Colorado River water is available. Grade the land to a uniform slope before planting trees.

Varieties which are produced only in the west and marketed as fresh fruit offer the greatest promise of profitable future returns. Confine new plantings to oranges and tangerine type fruit.

Rootstocks best adapted are Rough lemon on the sandy Yuma Mesa soils and sour orange on sandy loam and clay loam soils.

Budwood selected from virus disease free trees will avoid future disease problems. Nucellar Valencia and Washington Navel budwood is available and provides the best source of healthy trees.

Space trees according to variety and soil type. Closely spaced "hedge-row" planting for oranges offers promise of greater income per acre.

Management of a Mature Grove

Irrigate by wetting the soil according to the usage of water by the tree. Trees use about six times more water in July than they do in January. Wet subsoils thoroughly at least once each year.

Occasionally observe the depth of water penetration with a soil tube. Tensiometers may be used as a guide for timing irrigations.

Cultivate by thoroughly disking all weeds and cover crops in October and irrigate thoroughly in November so that the soil is bare and firm to reduce freeze damage during the winter. Disk in the spring and summer after the cover crops are two to four feet high.

Non-tillage, using herbicidal spray materials, provides as satisfactory tree growth as do cover crops — with marked advantages for close spaced plantings of young trees.

Fertilize with the cheapest form of commercial nitrogen. Apply from one-half to four pounds of actual nitrogen per tree during the winter spring and summer depending upon soil type, tree condition and variety. In non-silted Yuma Mesa soils, manure or phosphorus is required in addition to nitrogen.

Protect against freezing by maintaining healthy, strong trees and by irrigating during freezing weather. Do not cultivate between November 10 and February 20.

Wind machines provide protection and are economically feasible in certain groves. Supplemental heat from orchard heaters will be required during severe freezes.

Remove low producing and diseased trees from old groves and replant with healthy ones. Soil fumigation before planting may improve growth.

Control citrus thrips by applying insecticides after blossom petals drop in the spring, according to local recommendations.

(See inside back cover for complete table of contents.)

Commercial Citrus Production In Arizona

By R. H. Hilgeman

and D. R. Rodney

Department of Horticulture

The University of Arizona

There are 28,850 acres of citrus in Arizona. This respresents a gain of about 41 percent during the past 11 years. Major changes in the location of new groves and in the varieties planted have taken place. Citrus acreage in the Yuma area has increased. In the Salt River Valley, groves have been removed more rapidly than replanted so that the area has decreased. Varieties have changed.

The 10,000 acres of grapefruit present in 1949 have decreased to about 5,600 acres in 1960 so that it now represents only 19 percent of the total. While both the Washington Navel and Valencia orange acreage has increased substantially, the most spectacular growth has been in lemons which increased from 807 to 6,890 acres.

Commercial citrus production in Arizona began with the planting of about 500 acres of oranges in the Salt River Valley by development companies between 1893 and 1895. A considerable part of this acreage was destroyed by the 1913 freeze.

During the following twelve-year period there was a gradual increase in acreage. Stimulated by very profitable returns from these groves, the largest plantings of over 18,000 acres were made from 1925 to 1934. These groves constitute the major portion of the present bearing commercial acreage of citrus in the state. This was followed by a period of unfavorable fruit prices that discouraged new plantings so only about 1,200 acres were planted between 1940 and 1948.

In the Salt River Valley, between 1949 and 1960 the sub-division of groves chiefly in the North Phoenix-Camelback district, has reduced the total citrus area from 18,548 to about 13,900 acres (Table 1). Bearing older acreage has decreased more than this because approximately 2,500 acres have been replanted within the period. New plantings have been confined chiefly to Washington Navel and Valencia oranges. Also, about 200 acres have been planted or topworked to the Kinnow mandarin.

In the Yuma area during the same period, citrus has increased from 1,954 to 14,878 acres. The acreage of all varieties has increased. However, the major increases have occurred in lemons and Valencia oranges which now account for about 80 percent of the total acreage. Since lemons come into high production early, the amount of fruit harvested in this area is increasing rapidly each year.

TABLE 1.—ACREAGE OF PRINCIPAL CITRUS VARIETIES

	Salt River Valley		Yuma	
	1949	1960	1949	1960
Grapefruit (white)	9031	4300	1031	1343
Grapefruit (red)	137	400	3	731
Valencia orange	3669	3500	469	6177
Navel orange	3095	3250	23	258
Sweet orange	1743	900	3	174
Lemon	629	1100	178	5790
Tangerines	234	500	22	300
Lime and Misc.	10	10	5	105
Totals	18,548	13,960	1954	14,878

1949—Data from Arizona Citrus: mimeographed; cooperative; Bureau of Agri. Econ., Arizona Agr. Expt. Sta. and Desert Grapefruit Industry Committee.

1960—Yuma: Data from Yuma County Agriculture Extension Service Survey.

1960—Salt River Valley: Based on acreage reported to Grapefruit, Orange, and Lemon Marketing Administrative Committees and estimates from packing house records.

Areas of Citrus Production

Citrus production is concentrated in two general areas in the State, the Salt River Valley and the Yuma Mesa.

Salt River Valley

The Salt River Valley citrus area consists of five separate districts situated in the warmer zones near the low mountains which irregularly border the valley (Figure 1-A, B,C,D, *and E*).

District A

A small acreage is irregularly planted north and west of Glendale. The soils vary from deep sandy loam to silty clay loam. Low salinity water is obtained from deep wells owned by the grove operators. Temperatures very from moderately cold in the lower areas to very warm near the mountains on the north part of the district. Valencia oranges and lemons can be grown successfully in the warmer portions. Most of the new acreage has been planted in this district.

District B

The Phoenix-North Central district is rapidly being subdivided into home sites so that citrus production is less each year. The soils are principally deep sandy loam or clay loam types, but near the mountains gravelly calcareous sandy loams occur and stony areas are present.

The part of the district below the Arizona Canal obtains low salinity water from the Salt River Valley Water Users Association. The parts above the canal obtain water from deep wells some of which contain excessive amounts of boron. Most of the district is more subject to freeze injury than the other districts so that Valencia oranges and lemons should not be planted.

District C

The South Mountain district is a rather narrow strip along the base of the Salt River Mountains. The soil is principally calcareous gravelly sandy loam, sometimes shallow and underlaid with caliche. Gravity water from the Salt River is supplemented with variable amounts of well water of higher salinity so that the total soluble salts in the water delivered varies from 400 to 1,300 ppm. Moderate salt injury to leaves frequently occurs after prolonged use of the water with the higher salt content.

The district is generally warm, particularly the higher portions where Valencia oranges and lemons are successfully grown. Washington Navel orange production has generally been less satisfactory in this district than in the others.

District D

The chief commercial area of old trees at present is the Mesa district situated in Lehi Valley and on the mesa northeast of the city of Mesa. Fertile clay loam and gravelly or stony sandy loam soils of varying depth are present. The largest part of the district is supplied with slightly saline water from the Roosevelt Conservation District. Water delivery is frequently limited during the summer.

During the first years after the trees were planted in this area (1928-1937) no serious freezes occurred and the trees made excellent growth. Although in recent years freezes have occurred, the district may still be classified as warm. The highest producing Washington Navel orange trees in the state are grown in this district.

District E

The Chandler Heights district comprises a compact group of groves in a 2-square-mile area about 12 miles southeast of Chandler. The soil is friable light sandy loam. A limited quantity of low salinity water is obtained from deep wells.

Large differences in temperature occur between the upper and lower portions of the district. The warmer upper portion is satisfactory for lemon production. The lower portion is suitable for tangerines and Washington Navel oranges.

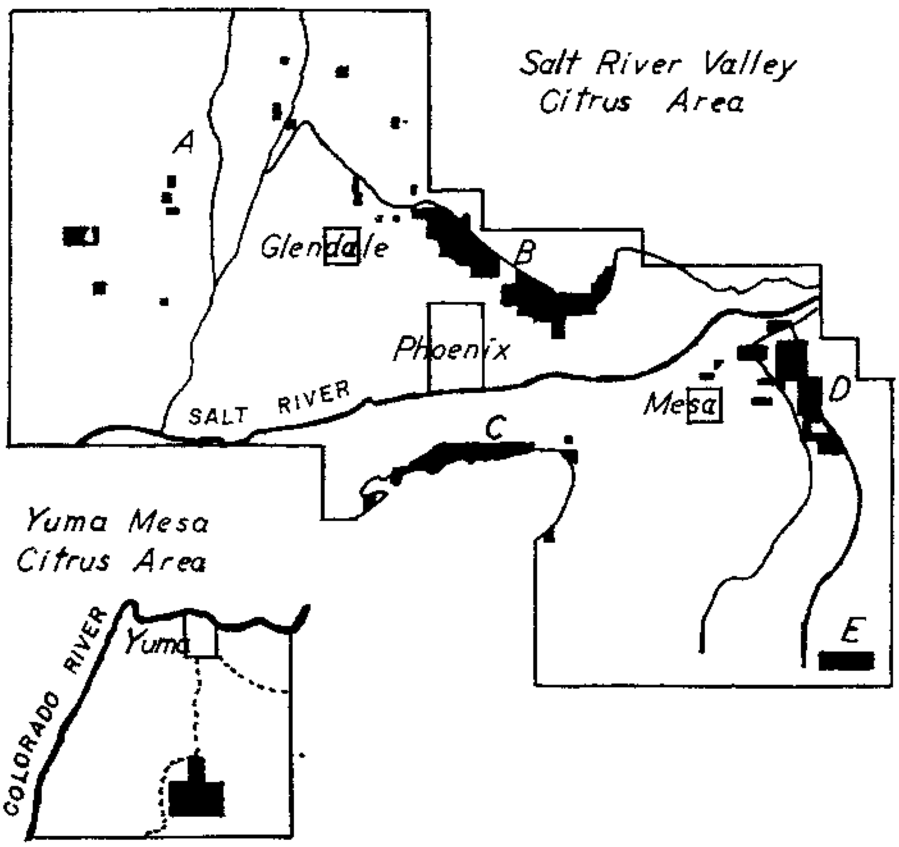


FIGURE 1.—Citrus producing areas in Arizona are indicated by the dark portions on the map. Districts in the Salt River Valley (A through E) are explained in the text.

Yuma Mesa

The Yuma area consists of a rather flat mesa, situated about eight miles south of the city of Yuma (Figure 1). The native soil is a deep, very fine sand, containing small quantities of silt. In the older sections of the district, the original soil is overlaid with silt deposited over a period of many years when the irrigation water contained river silt. Nitrogen is deficient and the virgin soil with no silt accumulation is apparently deficient in available phosphorus.

Ample quantities of water which

contain about 850 ppm. total salts are available from the Colorado river. Temperatures average about four degrees warmer than in the Salt River Valley area, and the trees have suffered less damage from freezes than those in any other region in the Arizona or California desert.

The yields of Washington navel oranges are low, but Marsh grapefruit yields are higher than those in any other desert area. The production of lemons and of Valencia oranges has been generally satisfactory.

Citrus Varieties and Their Commercial Value

Oranges, grapefruit, and lemons growing in the desert areas develop a deeper orange or yellow color, have a thicker peel, and tend to contain less juice and more soluble solids than they do when grown in the more humid areas of Texas and Florida. Since the peel is thick and weather conditions are usually dry during picking, the fruit normally is not subject to serious decay when marketed. It is highly satisfactory for export.

The present outlook for citrus in the United States indicates that larger amounts will be produced during the next ten-year period than ever before. Experience in the past has shown that Arizona growers cannot make a reasonable profit upon canned single strength or concentrated juice in competition with that from Florida or Texas. Consequently, a profitable industry must be based upon the sale of fresh fruit.

Certain varieties of oranges produced in Arizona regularly sell above Florida and Texas oranges marketed at the same time. New plantings should be confined to these varieties with the object of selling the major part as fresh fruit. Such plantings would be confined chiefly to the Washington Navel and Valencia orange, and several varieties of tangerines. Lemons are in this category, but because lemon acreage in Arizona and California has rapidly increased during the past 10 years a surplus of fruit with accompanying low prices is in prospect so that further planting does not appear advisable at this time.

Orange Varieties

Washington Navel

The chief advantage of this variety is its early maturity which allows it to be picked between November 15 and December 15, although it has not reached its maximum quality at this time (Fig. 2). Characteristically, it has a deep orange color and a moderately thick peel. The juice is high in soluble solids and low in acid (15:1 ratio) with a rich, pleasing flavor. It must be handled carefully in the field and packing house and is not well adapted to bulk harvesting.

Normally it sells well above Florida fruit offered at the same time, but is in competition with high quality Washington Navel oranges from central California districts.

The chief problem is production. Many groves produce less than 300 field boxes per acre, although higher yields are obtained in some groves. Proper grove management appears to increase yields, and the highest yields are generally obtained from groves planted on the heavier soils.

High day temperatures above 100° F. during May and early June appear to be unfavorable climatic factors which reduce the yield. At present, satisfactory commercial production is not obtained in the Yuma area.

FIGURE 2.—Washington Navel oranges in the Salt River Valley just before harvest in November.

Valencia

This variety normally attains an 8:1 solids-acid ratio (minimum legal requirement) about mid-February and harvesting usually begins about March 1. However, the fruit reaches its best quality in April or May. Fortunately, this period coincides with the termination of the Southern California Navel harvest when their fruit tends to become low in quality and prior to the development of the highest quality of their summer ripening Valencia. Accordingly, a favorable market may develop when supplies of fruit are not excessive.

In the Salt River Valley area the chief problem is the protection of the fruit from freezing. New plantings should be confined to only the warmest areas. Yields range from 300-700 field boxes per acre in well cared for commercial groves. In Yuma, yields tend to be lower than in the Salt River Valley.

Arizona fruit is typically oval in shape, and has a medium thick orange-colored peel. It is juicy with a pleasing flavor which is highly satisfactory to the consumer. It ships exceedingly well and is readily adapted to bulk harvest practices.

Miscellaneous Sweet Orange Varieties

A number of other varieties of oranges, several of which originated in Arizona, are presently grown. These varieties include Diller, Parson Brown, Butler, and Hamlin. All of these varieties produce satisfactorily, and several have the advantage of superior cold resistance of leaves and twigs. However, they are usually harvested between December 15 and February 15 when the citrus market is depressed by heavy shipments from other districts. Accordingly, these varieties frequently sell at low prices.

Production is higher than the Valencia but the fruit is smaller. The fruit is not sufficiently superior to similar varieties being marketed from Florida to command a premium.

Grapefruit Varieties

Marsh Seedless

In former years Marsh grapefruit constituted the greatest volume of citrus grown in Arizona. Unsatisfactory prices for the fruit, which were partly caused by the low returns from canned juice, caused growers to top-work some trees, accelerated subdivision of groves and almost completely stopped planting of new groves. The gradual decrease in production which occurred has reduced the supply until it is more in balance with the demand so that prices are gradually improving.

Grapefruit is usually sufficiently mature to harvest by early November but maximum quality is not obtained until beween February and June. Arizona fruit has a thicker peel, contains less juice and more acid than Florida and Texas fruit.

Although it has a clear attractive yellow color, this is not sufficient to offset the greater weight per size, the superior juiciness and lower acid content of fruit from other districts. It regularly sells for a lower price in competition with Texas and Florida fruit.

Redblush

Numerous strains of seedless grapefruit which have a pink flesh and a red blush on the peel are now available All have the characteristic thick peel, high acid, and low juiciness of the Marsh seedless fruit. The attractive pink color has provided substantially higher prices than Marsh grapefruit. While little marketing data are available at present, the Redblush fruit has also been discounted in the markets when sold in competition with similar Texas fruit.

Texas has replanted a large acreage of Redblush fruit. These trees are rapidly coming into production, so that the recent favorable returns may be seriously reduced.

Lemon Varieties

Lemons may be classified into three variety types: Lisbon, Eureka and Villafranca. Many strains of each of these have been developed and are recognized commercially. Although variations in shape and storage qualities of the fruit occur, all the fruits are sufficiently similar to be marketed together. The selection of a variety, therefore, is chiefly dependent upon tree characteristics.

Tests at the Yuma Mesa Citrus Experiment Station show that the Lisbon variety is more vigorous than the other two and has produced about 23 percent more fruit on large mature trees. The Lisbon type strains are very thorny and because of their extreme vigor present pruning problems.

Tree characteristics favor the Eureka and Villafranca types as they are nearly thornless and grow more slowly than the Lisbon. Budwood from several strains currently grown in California is available but their fruiting behavior in Arizona is not known.

Normally, only a single crop of lemons is set during March and April. These ripen between October and December. Lemon shipments are closely controlled because all fruit is produced in California and Arizona. Therefore, selling prices of fresh fruit have generally been favorable. Arizona fruit tends to have a slightly rougher peel but contains a higher juice content than coastal California fruit. These characteristics have not been important marketing factors so far.

The increasing consumption of frozen lemonade concentrate has supplied an outlet for fruit withheld from the fresh fruit market. However, the value of this by-product fruit has dropped to a very low level and it appears that this will continue because higher prices allow the importation of lemon juice from foreign countries.

Production tends to be high when the trees have not been seriously injured by cold. Frost damage to the trees is the chief hazard in lemon production. Trees growing in Arizona are occasionally frozen back severely, but rapid recovery regularly occurs. Large trees survived and grew rapidly even after they were frozen back to the main scaffolds by a temperature of 14 degrees F. with a duration of eleven hours below 26 degrees F. in January, 1950.

Tangerine Type Fruits

Clementine (Algerian) Tangerine

This variety ripens between November 15 and December 15, and the present small crop is sold for the Christmas trade chiefly in California and Utah. Although the market for this fruit is limited, the amount of fruit is so small that financial returns to the grower have been generally very high.

The fruit is yellow-orange in color. It has a sweet pleasing flavor which has found a very favorable consumer response.

The chief problems are low yields with a tendency toward alternate bearing, and granulation, which is the drying and hardening of the juice sacs, early in the season. Granulation appears to be more serious in fruit from young, vigorous trees than in fruit from older trees. It also is more serious in fruit from trees that are growing on rough lemon root than on sour orange root.

Much evidence exists that yields can be improved by providing for cross pollination of the flowers. Pollen from flowers of Dancy tangerine, Kinnow mandarin and Temple orange trees has induced improved fruit yields in certain years. The Butler and Hamlin orange also appear to be pollinators. Cross pollinated fruit contains more seeds than unpollinated fruit.

Bees have proven useful in disseminating pollen. It appears to be desirable to plant in such a manner that at least one pollinator tree is adjacent to each Clementine tree. This requires every third tree in every third row or one ninth of the trees to be pollinators. Many modifications of this system are under trial by growers at present. It may be that more pollinator trees are required.

Dancy Tangerine

This small, deep orange colored fruit ripens during February, March and April. Because of the lateness of maturity, the small size of the fruit and the possible losses by freezing, this variety is not extensively planted. When picked at the proper maturity it has excellent quality. To minimize freeze losses, it should be planted only in the warmer areas. It is an excellent pollinator for Clementine.

Kara Mandarin

This is a hybrid obtained by crossing the Satsuma and King mandarins. At Yuma, it can be harvested in December but attains its best flavor in February and March. The fruit is medium large, with a deep orange color. The pulp has a deep rich yellow-orange color and a unique flavor. When grown on sour orange root, the tree has made good growth but tends toward alternate bearing at Yuma.

Kinnow Mandarin

This hybrid variety was obtained by crossing King Mandarin with Willow Leaf Mandarin. The fruit is medium to large in size, yellow orange in color, with a rich, spicy, pleasant flavor. It ripens in December in the Yuma area, but does not reach full flavor and quality until February and March in the Salt River Valley. The fruit holds without deterioration on the tree until April and ships well.

It has two main disadvantages: (1) a strong tendency toward alternate bearing caused by the failure of blossoms to develop in "off seasons"; (2) the presence of a large number of seeds in the fruit. Trees of this variety grow extremely vigorously particularly when topworked on grapefruit. Quality and flavor of fruit are much improved by growing it on sour orange root instead of rough lemon. It can be used as a pollen source for Clementine tangerine.. Because of its alternate production of blossoms more trees are required for this purpose. The acreage devoted to this variety is presently being rapidly expanded.

Minneola Tangelo

This hybrid variety was obtained by crossing the Bowen gapefruit with Dancy tangerine. The fruit is large and oval with a raised base, with a very deep attractive scarlet-orange color, and a rich, pleasing flavor. At Yuma, it may be harvested in December. In the Salt River Valley ripening is much later. Small experimental plantings appear to be warranted.

Establishing a Young Grove

Selection of Grove Site

Four factors must be considered in the selection of a grove site: Winter temperatures; quantity and quality of the water; soil characteristics; land contour.

Winter Temperatures

Severe freezes may occur in all districts, but their frequency differs widely between and within districts. Usually, in the Yuma Mesa area the warmer zones are near the edge of the mesa or on top of the ridge.

In the Salt River Valley small areas near the mountains northwest of Glendale are generally warm. Other warm zones are isolated small areas on the steeper slopes near Camelback Mountain and in the South Mountain district and the northeast portion of the Mesa district.

Observations during the development of the Phoenix North Central district and the Mesa district suggest that areas planted solidly to citrus may become colder after the trees are fifteen to twenty years old. The large leaf area of the older trees causes a more rapid loss of radiant heat at night and prevents direct heating of the soil by the sun during the day. The large trees also may interfere with normal air drainage through the area. Thus, a warm area in the desert may become progressively colder as more groves are planted and the trees become larger.

Water Quantity and Quality

A mature citrus grove in the Salt River Valley requires at least 48 acre inches of water per acre for irrigation each year, and 60 inches is desirable. In general, water which contains over 1,000 ppm. (parts per million) of total soluble salts, 300 ppm. of chlorides or 0.5 ppm. of boron should be avoided. Such water has caused slight injury to grapefruit trees.

If more than 60 acre inches per acre of water are available and soil drainafe is good, the soil can be leached at each irrigation, thus allowing the use of more saline water than would otherwise be possible.

Soil Requirements

Citrus trees grow well in a wide range of soil types if appropriate rootstocks are used. Excellent growth is obtained in deep sandy soils, sandy loam and clay loam types.

Excessively rocky soils and soils which have a heavy accumulation of calcium carbonate (caliche) within 24 inches of the surface should be avoided. Gravelly and sandy soils hold less moisture and therefore require more frequent irrigation and a larger total amount of water during the year than loam type soils.

Field Contours

Before citrus trees are planted, the land should be graded to a uniform slight slope so that irrigation water can be applied with maximum efficiency. Highly satisfactory plantings recently have been made where fields are terraced so each irrigation unit is absolutely level.

Under this system water is applied in permanent basins and no water runs off the field. The depth of grading and type of program used will depend upon the type and depth of the soil.

Many new citrus areas are within Soil Conservation Districts. Field men from the Soil Conservation Service should be contacted to examine the soil, map the existing contours and recommend the proper grading operations.

Selection of Rootstock

The sour orange *(Citrus aurantium)* is currently predominently used as a rootstock in the Salt River Valley area and the Rough lemon *(Citrus limon)* has been almost exclusively used in the Yuma area in recent years. The use of different rootstocks reflects adaptation to the different soils in the two areas.

Tests at the Citrus Experiment Station at Yuma have shown that grapefruit, Valencia orange and Eureka lemon budded on Rough lemon root have grown more rapidly and yielded about twice as much fruit as similar trees grown on sour orange root (Table 2). *(See at top of the next page)*. In the loam and clay loam soils of the Salt River Valley lesser differences in growth rates and yields have occurred.

Several problems have arisen with the Rough lemon root. It has been more susceptible to Brown rot gummosis than the sour orange and the roots and crowns of many Rough lemon rootstock trees have been damaged by this disease.

Observations on the presence of iron chlorosis in trees in highly calcareous soils show that Rough lemon roots do not absorb iron as efficiently as the roots of sour orange. The Rough lemon is susceptible to the xyloporosis virus and trees grown from buds infected with this disease have become nonproductive.

Fruit produced on trees growing on Rough lemon rootstock contain less acid and solids, lower quality and flavor, and develop granulation more readily than fruit growing on sour orange rootstock.

The chief objection to the sour orange arises from its susceptibility to tristeza (Quick decline) disease. This virus disease, which kills sweet orange trees growing on sour orange rootstock, has been prevalent in coastal California citrus districts since about 1942 but has not spread to the desert areas.

TABLE 2.—YIELDS* OF FRUIT FROM TREES GROWING ON ROUGH LEMON AND SOUR ORANGE ROOTSTOCKS AT THE YUMA MESA CITRUS EXPERIMENT STATION

Rootstock	Variety			
	Redblush Grapefruit	Valencia Orange	Clementine (Algerian) Tangerine	Eureka Lemon
Rough Lemon	480	254	326	539
Sour Orange	260	133	113	268

**Average yield in pounds of fruit per tree for 4 years, 1955 to 1958, when the trees were 12 to 16 years of age.*

Cleopatra mandarin may be the most satisfactory substiute for sour orange. Tree growth, fruit production and quality and resistance to soil fungi are about equal to sour orange, but it appears to be more subject to iron chlorosis. Trees on this root in experimental plantings are still too young to determine their ultimate value.

Further rootstock tests indicate that Rangpur lime, Troyer citrange, Citrumelo and Willow-Leaf mandarin are also possible satisfactory substitutes for sour orange.

Trees on Rangpur lime have produced as rapid growth and high yields as trees on Rough lemon in sandy soils and this rootstock appears to have advantages over Rough lemon in heavy soils.

Selection of Budwood

The selection of superior budwood is the most important single requirement in obtaining a vigorous, high producing tree. Budwood should be obtained from disease free, vigorous, high yielding trees which produce typical good quality fruit.

Virus diseases such as scaly bark (psorosis) are present in the buds of diseased trees. Nursery trees grown from buds obtained from such diseased trees will have the same virus diseases as the parent tree. Among these virus diseases transmitted through buds are tristeza, psorosis, exocortis and xyloporosis and possibly stubborn (see pages 29 and 30 for descriptions of these diseases.)

While some of these diseases apparently cause little harmful effects unless the bud is placed in a susceptible rootstock, it appears advisable to obtain completely disease free budwood whenever possible.

There is no bud certification program in Arizona at present. However, budwood which is free of virus diseases, so far as known at present, has been imported from California and distributed to Arizona nurserymen. This budwood is also available in limited quantities to all growers at the Citrus Experiment Stations at Yuma and Tempe.

The following strains of varieties originally developed at the California Citrus Experiment Station at Riverside have been introduced: Nucellar Red Grapefruit, Nucellar Marsh Grapefruit, Frost Nucellar Washington Navel, Frost Nucellar Valencia, Campbell Nucellar Valencia, Olinda Nucellar Valencia, Campbell Valencia, Frost Nucellar Lisbon lemon and Frost Nucellar Eureka lemon.

Varieties from the United States Department of Agriculture Sub-tropical Horticulture Field Station at Indio are: Nucellar Kinnow mandarin, Nucellar Dancy tangerine, Nucellar Orlando tangelo, Nucellar Willow-Leaf mandarin.

The term nucellar means that the budwood has been obtained from a nucellar seedling of the variety indicated. Nucellar seedlings have been so designated because the seedling develops from the nucellus tissue of the ovule alongside the normal fertilized embryo. Nucellar embryos arise without fertilization, therefore are genetically identical to the parent tree, and apparently are free of virus diseases.

Buds from recently germinated nucellar seedlings produce extremely vigorous, large, thorny trees. Fruit production is delayed and the first fruit produced usually is very large and of coarse texture. After the seedling is 7 to 11 years old, more normal high quality fruit is produced and it eventually yields more fruit than old established varieties.

The above strains have been so recently introduced that they h yet produced fruit in Arizona. their performance here is unk

However, since most existin es of Arizona orange, grapef tangerine budwood have be now known to carry virus dis appears to be less hazardous budwood from at least some unproven strains than to obta wood from the older establis rieties.

Spacing of Trees

During past years a standa ing of 22 x 22 ft. (ninety t acre) has been used generall varieties. Experience with t of planting has now shown th er production per acre can be ed for the first 10 to 15 years trees are planted per acre.

The spacing required will v the variety, soil type and loc the grove with respect to free age and length of the growi son. Rapid growing species grapefruit and lemons should ed further apart than Valenci es.

The slow growing Washing vel requires the closest plant tance. Where rapid growth o fertile soils, wider spacing sh used than in soil types where growth rates occur. Trees can spaced farther apart in area are normally warmer during t ter, than in the colder areas.

Several types of programs being used:

(1) Standard square spaci 22 x 22 feet for oranges and feet for lemons as has been the past.

(2) Close spacing in the ro the objective of forming a which will eventually be pru chanically. Spacings for this range from 11-15 feet in the r rows 22 to 26 feet apart d upon the factors mentioned a

(3) Intermediate spacing at about 16 feet in the row rows 20-22 feet apart. This is being used with Washingto oranges.

The latter two programs more trees per acre which w in greater income during th

5 to 20 years. Pruning or removal of lternate trees will be required as ver crowding occurs.

Culture of Young Trees

A young tree should be planted so hat the top of the ball of earth obained in the nursery is near the soil urface and the bud union from 4 to ; inches above it. It should be thorughly irrigated soon after planting. f the tree has settled it should be aised. In any event, the bud union nust be well above the final soil level.

A 1 x 1 inch redwood stake should e driven into the soil close to the ree. The trunk of the tree should be protected with a heavy newspaper nat which can enclose the tree and take or only the tree as shown in Figure 3. This mat holds the tree firmly to the stake, protects the trunk from sunburn and cold injury and shields the trunk from weed oil herbicidal spray materials if non-tillage culture is used.

The root system of a newly planted tree has been severely reduced when the tree was balled in the nursery. To obtain good growth on the transplanted tree this ball of soil must be kept moist. This requires irrigation at intervals of 8 to 18 days (depending on soil and weather) during the first summer until the roots grow into the surrounding soil.

FIGURE 3.—Young tree with trunk properly protected with newspaper mat and supported with redwood stake. Heavy tar paper mulch keeps soil moist around young tree allowing longer intervals between irrigations.

The irrigation guidance Table on page 21 could be used as a guide. In the sandy soils of the Yuma mesa newly planted trees should be irrigated about twice as frequently as indicated in the schedule.

Large annual weeds, Bermuda and Johnson grass seriously reduce tree growth. Shallow cultivations before the weeds are large are required. Deep disking near the tree cuts the young roots and reduces tree growth.

Excellent growth has occurred on newly planted trees under non-tillage culture with oil spray weed control and mulches of cotton gin trash or hay applied soon after planting (Figure 4). Tests at the Citrus Experiment Station near Tempe show such a program reduced evaporation of water from the soil sufficiently to allow about a 50 per cent longer interval between irrigations than was required by non-mulched trees.

This program appears to be highly desirable particularly if hedge row planting is followed and the land is properly graded.

Replants in Mature Grove

Diseased and weak trees in old groves seriously reduce per acre yields. Many growers hesitate to remove these trees because of the difficulties entailed in caring for replants. Tests have illustrated several points in addition to those mentioned in the previous section, which will improve tree growth and reduce the cost of caring for replant trees.

Old tree roots, Bermuda and Johnson grass, which must be controlled, should be dug out before a citrus tree is replanted.

After the tree has been planted a basin about four feet in diameter should be made around it and filled with water at each irrigation. A strip of 55 pound black tar roofing paper 30 x 36 inches in size should be placed around the tree, cutting a slit and a very small hole for the tree in the center. After placing the paper flat on the ground around the tree, it should be covered with a thin layer of soil as shown in Fig. 3.

FIGURE 4.—Frost Nucellar Navel trees budded on Cleopatra rootstock 18 months after planting. Trees were grown under non-tillage culture with weeds controlled with oil sprays and irrigation by flooding between permanent borders on each side of the tree row.

This paper prevents weed growth and reduces moisture losses due to evaporation so that extra irrigations are not required. Johnson and bermuda grass in the surrounding area can be readily controlled with weed oil sprays applied while the weeds are still small.

Fumigation of the soil where old trees have been removed has been reported to produce superior growth of replant trees in certain groves. Experiments at the Yuma and Salt River Valley Citrus Experiment Stations have not produced conclusive evidence of the value of the treatment. It appears that the degree of response to the fumigation treatment may depend on the numbers of nematodes and disease organisms in the soil.

Topworking Mature Trees

Because grapefruit has not been as profitable as oranges in the Salt River Valley, many trees are being topworked. Possibly because of the extreme summer heat, trees have not been successfully topworked by cutting off the tree near the ground and budding the young shoots as is done in the coastal region of California.

The following procedure has been successfully used in Arizona.

In late February or early March the small limbs are cut back to four- to twelve-inch long stubs, excepting one large upright limb on the southwest side of the tree. The lower small branches on this remaining large "nurse" limb are removed and about three-fourths of its inner circumference is girdled with the pruning saw.

The girdle is made above the point where the limb is later to be removed. The trunk and lower part of the "nurse" limb are then whitewashed.

Young twigs develop from dormant buds on the main trunk and scaffold studs. Buds are placed in these twigs when they are 3/8-inch in diameter, which is usually in late May or June (Figure 5-A).

Six or eight of the strongest, well-placed new shoots are budded by using the T-cut shield budding method. The buds are wrapped immediately with waxed muslin budding cloth and are unwrapped after they have united with the stock, usually about two weeks later.

The shoot is then cut back to the edge of the bud shield to stimulate growth. If the bud has not united, the shoot can be rebudded during July and early August.

Budding can be done later, but the new growth made by these late buds is so tender that it is likely to be damaged if freezes occur in the winter. It is better to delay further budding until late October. These late buds are not unwrapped until spring.

When the new sprouts are about 20 inches long, they are tipped back to prevent breakage by wind and to stimulate lateral shoot growth.

If freezes and unfavorable conditions have not occurred, the new growth will be sturdy and three to four feet long at the end of the second year (Figure 5-B). Then the tree is able to survive the shock of the removal of the nurse limb, which should be done in March, two years after topworking started (Figure 5-C). A small crop of fruit will set the following year (Figure 5-D).

It is necessary to avoid over-irrigation during the topworking period. From three-quarters to seven-eighths of the leaves are removed from the tree when topworking is initiated and, therefore, the water requirement is reduced.

In general, the normal irrigation intervals can be approximately doubled.

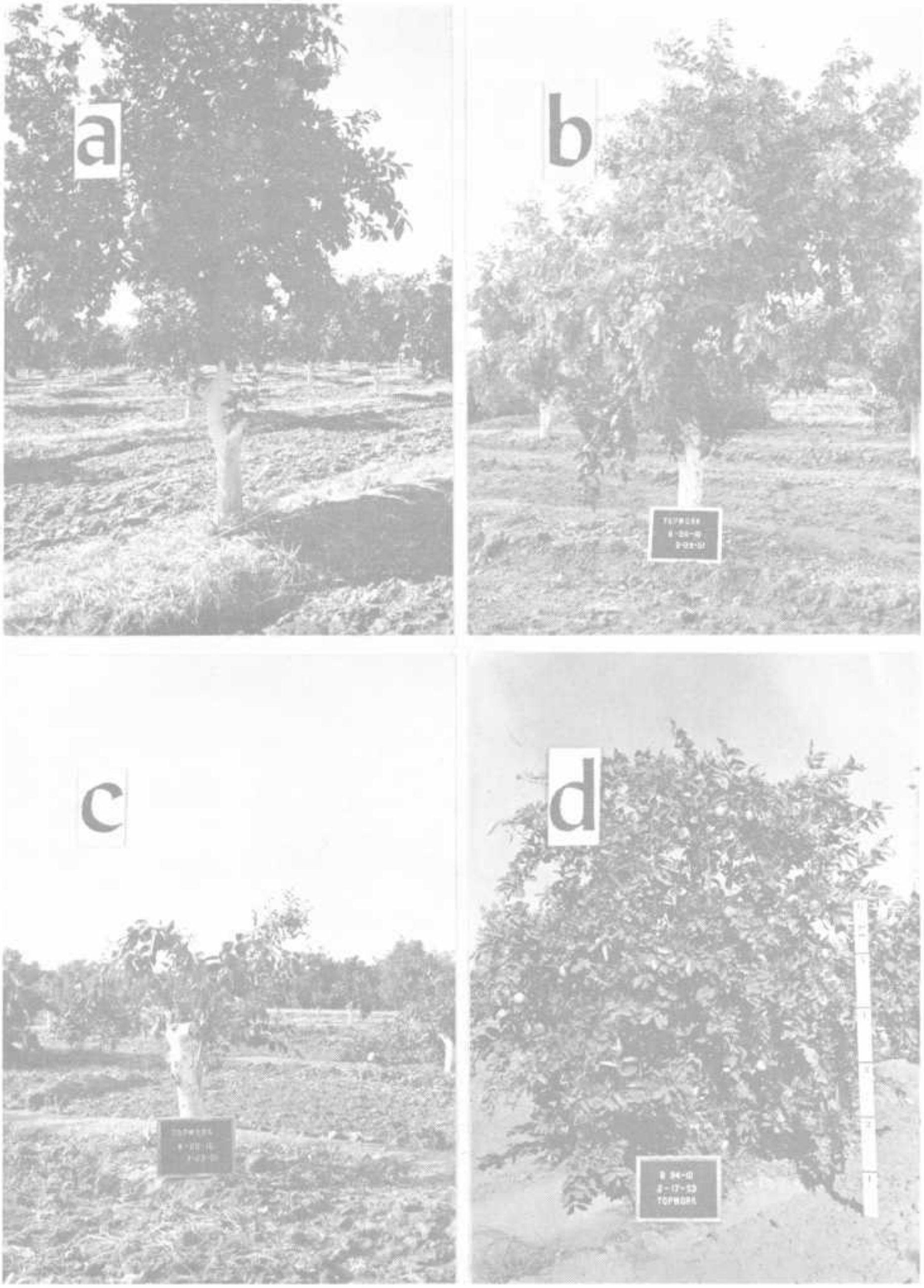


FIGURE 5.—(a.) Grapefruit tree pruned for topworking. Young shoots on trunk are large enough to bud. (b.) Tree two years after shoots have been budded. Grapefruit top ready to be removed. (c.) Same tree as B after grapefruit nurse limb has been removed. (d.) Tree two years after grapefruit nurse limb was removed. Tree has produced 1.2 boxes of Valencia oranges.

This is particularly important during the year following the removal of the nurse limb. The new growth should be observed and if the leaves become chlorotic (yellow with green veins), the irrigation interval should immediately be lengthened.

As citrus thrips may seriously damage new growth, these insects should be controlled during the spring and fall. (See page 27).

Most established groves contain diseased trees. An obviously diseased tree should never be topworked. Xyloporosis disease may be present but undetected in grapefruit (see page 30). If varieties which are susceptible to this disease are topworked they will become infected and an unsatisfactory tree may result.

Pruning

Experimental work with citrus pruning has recently been started and only limited data is available.

Field observations indicate that the removal of dead and weak wood is the only pruning required by grapefruit and oranges until the trees are possibly 20-25 years old. This should be done between February and May every four to six years by breaking off the smaller dead limbs (the operator wears gloves) and sawing off the large dead and very weak limbs.

Removal of deadwood, most of the inside sucker growth and the weaker ends of old limbs is frequently done with the Washington Navel orange with the expectation of improving yields and grades. Tests during four consecutive years which compared 40 trees pruned in the above manner with 40 unpruned trees showed that this program failed to improve either yield or grade. Apparently Washington Navel trees require only the occasional removal of deadwood and sucker growth as recommended for other orange varieties.

On large grapefruit trees, the center of the tree becomes shaded which causes the small inside limbs to die. Eventually the tree consists of an outer shell of leaves. As the trees grow close together production is reduced in the lower parts of the tree.

Pruning of such trees is necessary to induce new growth inside the tree and to provide light for the lower parts. Various programs for pruning such trees are under trial by growers and at the Experiment Stations at Yuma and Tempe.

These programs involve cutting the side branches back 2-4 feet and removal of parts of the top. Both hand pruning and mechanical hedging equipment have been used.

Oservations and data obtained to date indicate that all types of pruning reduce yield. Severe top removal (cutting back about 1/4 of the top and hedging all sides) has reduced yields up to 40 percent.

Hedging alone has produced up to 15 percent reduction in yield. The reduction varied with the severity of the pruning. This relatively small reduction apparently has been recovered after two years.

Although the development of new shoots from dormant buds on the scaffold limbs inside the tree was variable, the maximum amount of new growth tended to be produced on the most drastically pruned trees. To induce prolific inside growth severe pruning of the sides and top was required.

Sufficient evidence has not been obtained to be certain of the best pruning program to follow. It appears that when grapefruit trees are touching and shading has reduced the crop on the lower part of the tree, or when the tree has become so high that harvesting cannot readily be accomplished, pruning should be done. Under such conditions severe pruning is required, and the crop will be reduced for several years.

Lemons present a different problem. Young trees develop long vigorous shoots which only produce fruit near the tip. Many growers cut back these vigorous limbs in an attempt to produce stronger branches and induce fruit production lower on the tree.

However, satisfactory trees have been grown without pruning the top. On these unpruned trees the long limbs bend with the fruit and new growth then occurs lower on these limbs.

It is generally considered desirable to remove suckers from the trunk and lower scaffold branches each year. As the trees become crowded, hedging and severe top pruning may be required to reestablish fruiting in the lower parts of the tree, as is the case with grapefruit.

After limbs have been damaged by freezing, pruning should be delayed until the new spring growth has developed into shoots several inches long. At this time it is possible to definitely identify the frozen areas and remove them. If pruning is done too early, live wood may be removed or the pruning may not be sufficient so that a second pruning will be required later.

Growth of Fruit in Relation to Harvest

The growth of citrus fruit in the Salt River Valley has been followed by measuring the circumference of the same fruit at 3 to 15 day intervals from June until harvest. Valencia orange growth has been followed for 10 years.

Grapefruit, Washington Navel orange and lemon growth was measured during 5 years. The average growth patterns obtained from these measurements may be considered normal (Figure 6, page 12).

Wide deviations from these average growth patterns have occurred during the periods studied. These variations, which occurred on trees subjected to similar irrigation and fertilization each year, were caused by changes in the number of fruit on the tree and climatic conditions.

During the most rapid growth period between June 15 and November 15 the number of fruit on the tree exerted the major effect on the rate of growth of Valencia oranges. An increase from 2.5 to 5 boxes of fruit per tree decreased the daily rate of growth from .81 to .62 cubic centimeters per day.

Climatic differences modified this effect. As maximum temperatures increased above 100° F. the rate of growth progressively decreased and growth sometimes stopped at temperatures above 112° F. Rainfall during the summer with its accompanying lower temperatures and higher humidity caused growth rates to increase.

A marked change in growth rates has occurred about mid-November. This is related to the onset of cold weather. Very little or no growth occurred when minimum temperatures dropped to 32° and the fruit shrank at temperatures of 26° to 28° F. and below. Total growth between mid-November and March 1 has been correlated with the sum of the degree days below 32° F.

Varieties differ in growth characteristics. Grapefruit grew most rapidly during the summer and at a reduced rate in the fall. After growth had been restricted by winter cold weather, rapid growth again occurred during warm weather in February and March. Growth stopped in April but the fruit often did not begin to drop until June or July.

With Valencia oranges summer and fall growth was uniform. Spring growth was resumed at a lower rate which continued throughout an entire second growing season. The fruit may not drop until it is more than 2 years old.

Navel oranges grew rapidly in the summer and early fall. The rate then gradually decreased as the fruit matured in December and almost stopped in January when the fruit began to soften and drop.

Lemon growth was uniform throughout the summer and fall. Growth stopped if low temperatures occurred in November, but was resumed at a normal rate when the temperatures became warmer. Rapid growth continued during favorable temperature periods in January and February.

This information provides a guide for harvesting fruit if current weather conditions are considered. With grapefruit, if large sizes have been harvested in November and the winter temperatures have been low with many nights below 32° F. little growth will occur so a second picking should be delayed until early March.

If winter temperatures are above normal, and particularly if rainfall is also high, growth continues normally so that a second harvest can be made in February. No changes in size occur after mid-April.

If harvesting is to be delayed until July, repeated experiments have shown that fruit drop can be reduced over 50 percent and markedly superior firmness can be retained by spraying the trees with 10 ppm. 2-4-D (39% acid) in April when the trees are sprayed for thrips.

With the Valencia orange approximately a 10 percent increase in size may be expected between March 15 and June 1, the normal harvest period.

Lemons increased an average of 63 percent in size during the harvest period between September 15 and December 15. Since this large amount of growth occurs, ring picking is advisable. This large increase in size must be considered in making crop estimates in September.

Cultivation and Cover Crops

General experiences with growing citrus trees in Arizona indicate that the citrus tree will grow successfully under a wide range of cultural practices. Fundamental features of soil management and practices associated with successful culture are discussed in the following section.

Principles of Cultivation

Three fundamental features must be considered in the tillage program: (1) Maintenance of soil structure so that water infiltration rates are rapid, (2) Prevention of excessive competition by cover crops for water and nutrients needed by the tree, (3) Moderation of climatic conditions.

It apparently is not possible to satisfy all of these features with any one cultural practice. For example, observations and the yield records as shown in Figure 7 reveal that permanent bermuda sod, mowed frequently, gradually restricted yields and tree growth, and increased frost damage, although good soil structure was maintained.

Non-tillage by killing weeds with oil sprays provided high production and tree growth and the least injury from freezes, but the irrigation water puddled the bare surface soil so that the water entered very slowly. Disking weeds four times each year also maintained high yields and minimized frost injury, but formed a plow sole 6 to 10 inches below the surface and thus retarded the movement of water into the soil.

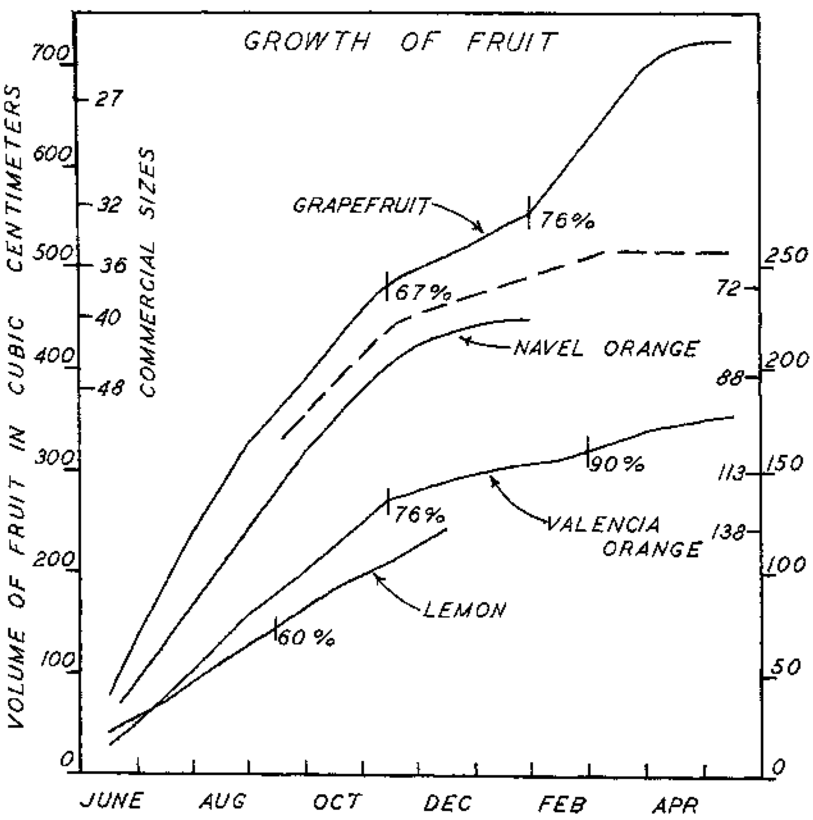


FIGURE 6.—Average growth of Marsh grapefruit, Washington Navel and Valencia oranges and lemons in the Salt River Valley. Note: size scale on left refers to grapefruit only; size scale for oranges and lemons is on the right. Percentages refer to per cent of final growth at the dates indicated.
(Data from University of Arizona Citrus Experiment Station).

Maintenance of Soil Structure

In Arizona citrus groves, surface irrigation, disking with heavy equipment, and hauling fruit in heavy trucks all compact the soil. In a compacted soil, water penetrates slowly, aeration may be restricted, and root development is not normal.

Soil compaction has occurred in nearly all old groves growing in sandy loam or heavier soil types. To reduce the amount of compaction, it is best to allow cover crops or weeds to grow 2 to 4 feet high between each disk cultivation.

The extensive root systems of these weeds decay after the tops are incorporated with the soil and tend to keep the soil open. The cover crop, also, lessens the compactive action of the heavy tractor and disk.

Occasionally it may be necessary to loosen the upper 10 to 12 inches of soil with a chisel type renovator. Such chiseling should be done between July and October when the soil is very dry and hard so that the soil is broken into large clods. Any tillage operation which is not absolutely necessary should be avoided.

Soil compaction is not a serious problem in the sandy soils of the Yuma Mesa district.

Prevention of Competition

The citrus tree appears to grow best without competition from cover crops. However, if the soil is kept free of weeds by frequent disking or renovating, the structure of the soil is gradually destroyed.

Oil spray is a satisfactory method for weed control. Also, limited evidence in Arizona indicates that irrigation of bare, loam-type soil tends to change the surface soil structure and reduces water infiltration rates.

Moderation of Climatic Conditions

Two unfavorable climatic conditions exist in Southern Arizona.

In the summer the extreme heat and low humidity are unfavorable for shoot growth and near surface root development. Cover crops which shade the soil reduce soil temperatures and improve conditions for root development. Also, the transpiration of water by cover crops increases the humidity in the air immediately surrounding the tree, thus providing a condition more favorable to tree growth.

In the winter, trees and fruit are frequently damaged by freezes. Serious freezes are moderated by providing conditions which allow the maximum heat transfer from the soil to the tree. To obtain the best heat radiation the soil should be bare (free from weeds), and firm (as it is after an irrigation).

Practical Tillage Programs

Tillage programs reflect the development of new types of farm machinery and are rarely tested extensively before being put into practical use. Programs which have been used successfully or new methods which warrant special consideration follow.

Cover Crop Program

Cover cropus are generally grown in Arizona citrus groves. To lessen cold damage, cover crops should always be thoroughly disked under during October, and the grove irrigated in early November so that the soil is bare and firm during the frost hazard period between November 10 and February 20.

This cultural practice is fundamental to any citrus tillage program. After this condition is satisfied, several tillage methods can be followed which are satisfactory. Two plans are presented.

Plan I

In all citrus districts, many weeds are present, and it is extremely difficult to establish legume cover crops which convert nitrogen from the air into nitrate nitrogen in the soil.

Sour clover *(Melilotus indica)* may be planted broadcast after the October disking. Little growth will take place until February. Rapid growth begins in March and continues until blossoming in April. The plants are usually disked in May.

Summer weeds such as Johnson grass, Bermuda grass, careless weed, and sunflowers compete so seriously with summer legumes such as sesbania, cowpeas or guar that it has been found to be impractical to try to grow summer legumes under these conditions. Therefore, the summer program following sour clover in the spring is to allow the weeds to grow until they are 2 to 4 feet high and disk them under. Diskings for this purpose are usually required in July and August.

Plan II

In many instances, winter weeds such as mallow, wild oats and mustard grow profusely and prevent growth of the sour clover. When this occurs, it is best to disk in late February or early March before new shoot growth on the trees is extensive.

Hubam *(Melilotus annua)* or biennial white sweet clover *(Melilotus alba)* can be planted following this cultivation. This time of the year is the most favorable for the successful establishment of a legume cover crop, because it is late for winter weed seed germination and early for the sprouting of summer weed seeds.

These clovers are grown until July or early August, and then disked under. Weed growth after the clover is disked is usually controlled by the regular annual cultivation in October.

The recent development of the rotary stalk chopper has provided a substitute for disking during the spring and summer. If flood irrigation is used with wide sloping center borders weeds can be economically kept under control by using this implement.

Rototillers also provide a satisfactory substitute for disks in sandy soils where the soil structure cannot be easily damaged. They are presently used in the Yuma area and have the advantages of leaving the soil relatively level, and the depth can be closely controlled.

Non-tillage Program

Non-tillage of the soil with weeds controlled by spraying with herbicidal oils has been tested for 15 years at the Citrus Experiment Station near Tempe. Yield, grade and size of fruit and growth of grapefruit trees under this program have been similar to results obtained from trees under the disk-cover crop system (Figure 7). Slightly less injury during freezes has occurred under the non-tillage system. The chief practical objection is the cost. This was $40 to $50 per acre for oil herbicides during the initial two years and has ranged from $22 to $28 per acre per year thereafter. Non-tillage has reduced the rate wa-

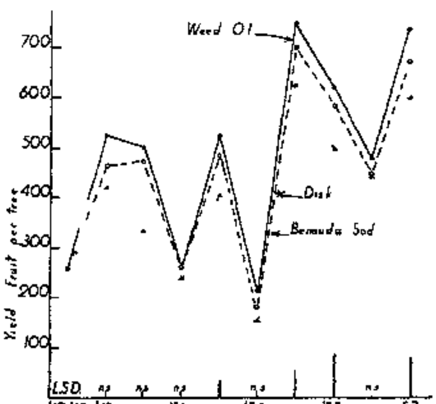


FIGURE 7.—Effect of cultural practices on yield of Marsh grapefruit in the Salt River Valley. Trees grown under non-tillage with oil spray weed control have produced similarly to those disked 4 times per year. Permanent bermuda grass mowed 6-8 times per year has resulted in significantly reduced yields in 3 of the final 4 years of the experiment.

(Data from University of Arizona Citrus Experiment Station).

ter enters the soil so irrigation procedures may require modification.

Non-tillage has had certain operational advantages. Irrigation has been more efficient because the grove has always been ready for irrigation and the progress of the water could be easily observed so that only the required amount was applied. Since weeds were not present to use water, less water was required.

The danger from freeze damage has been lessened because the soil is always in the optimum condition for heat transfer. When orchard heaters were used, the annual cost of placement was eliminated. Picking and pruning operations were facilitated and gophers did not enter the grove.

The non-tillage program is recommended for newly planted groves. With young trees only a single furrow or border on each side of the tree is required to supply water to the tree for the initial 3 or 4 years. Since only about one-third the area need be sprayed, oil spray weed control will be cheaper than disk cultivation combined with hoeing around the small trees. If mulches of gin trash or hay are used in the summer up to 50 percent less water is required. Superior growth of trees has occurred in some tests.

Non-tillage, also, may have advantages in groves where large trees interfere with the operation of equipment and where little weed growth occurs, in small groves where disking is inconvenient, and in groves where the contour is such that furrow irrigation does not efficiently apply water to the trees.

Fertilization

Principles of Nutrition

The small feeder roots of citrus trees are surrounded by a thin film of water from which they absorb a large number of dissolved materials. The major elements needed in relatively large quantities are nitrogen, phosphorus and potassium.

In addition, micro-elements such as iron, zinc and manganese are required in very small quantities. All must be present for the plant to live, but after the needs of the tree are supplied, larger amounts of any particular one will not produce increased growth or yields and may even be harmful.

The absorbed elements move through tube-like structures in the woody part of the tree (the xylem) to the leaves, where they enter into the formation special materials. The leaf absorbs carbon dioxide from the air and converts this, in combination with water, into sugar which in turn is used to form the major portion of all he special compounds present in the tree. These manufacturing processes the leaf are affected by many factors such as light, heat and the amount of water supplied to the leaf by the roots.

The factors influencing the manufacturing processes have a direct relationship to tree growth and fruit character. When all the essential elements are present in the soil solution, soil moisture is plentiful, and light and temperature conditions are favorable, lush vegetative growth occurs.

Under these conditions much of the materials manufactured by the leaves are used to make new growth, and lesser amounts of sugar are transported to the fruit. When any unfavorable condition for growth occurs such as low temperatures, a moderate deficiency in nitrogen, or inadequate soil moisture, fruit and tree growth is retarded and carbohydrates accumulate in the fruit, leaves, twigs and roots. When favorable conditions for growth again are present, abundant growth takes place and profuse blossoming may occur.

Lemon growers in Sicily utilize this principle to produce "off season" summer ripening *(Verdelli)* fruit. They allow the trees to become dry in the late summer and follow this growth check with nitrogen fertilization and heavy irrigations in the fall. This practice induces blossoming and setting of lemons which ripen the following summer.

In the desert area, neglected grapefruit trees have grown rapidly and set abnormally heavy crops of fruit when normal irrigation, fertilization, and cultivation have been resumed.

The direct effects of cultural practices between July and November upon the carbohydrates in the fruit are set forth in Table 3. Limiting either water or nitrogen during this period produces larger amounts of total soluble solids and vitamin C in the fruit than was obtained through frequent irrigations and heavy nitrogen fertilization. Coupled with this growth check have been restricted tree growth, reduced fruit size, and more uniform fruit setting.

The practical application of a growth check program presents certain difficulties. Nitrogen cannot be easily controlled in fertile, heavy soils. Moisture stresses can be easily obtained.

Tests extending over 10 years have shown that trees subjected to late summer and fall moisture stresses have produced more fruit of smaller size than uniformly irrigated trees. It presently appears that a moderate growth check between two irrigations in the late summer and fall can be used to advantage in orange groves where the trees are large and capable of producing heavy crops.

TABLE 3.—EFFECT OF NITROGEN DEFICIENCY OR MOISTURE STRESS UPON SOLUBLE SOLIDS, ACID AND VITAMIN C IN THE FRUIT

Valencia Orange (a) Soil Moisture Controlled				Marsh Grapefruit (b) Nitrogen Fertilizer Controlled			
Irrigation	Soluble Solids %	Acid %	Vit. C (c)	Nitrogen	Soluble Solids %	Acid %	Vit. C (c)
Wet all year	11.2	1.00	51	High all year	10.7	1.75	43
Dry Aug., Oct.	12.0	1.10	55	Low all year	11.7	1.56	49
L.S.D. (d)	.27	.05	1.5	L.S.D.	.63	.07	3.8

(a) Data from Citrus Experiment Station at Tempe—Valencia Irrigation Experiment—Field Day Report, 1954—mimeographed—R. H. Hilgeman.
(b) Data from Citrus Experiment Station in Salt River Valley. High nitrogen from alfalfa hay mulch; Low nitrogen from sawdust mulch. Soil moisture and temperature similar in each plot. Unpublished data—January 1955—R. H. Hilgeman and L. H. Howland.
(c) Milligrams of Vitamin C per 100 milliliters juice.
(d) Differences between comparisons required for significance.

TABLE 4.—FERTILIZER EXPERIMENTS WITH CITRUS

AREA	YUMA				SALT RIVER VALLEY			
EXPERIMENT	A		B		C		D	
Soil	Silted Superstition Sand		Desert Superstition Sand		Laveen Clay Loam		Mohave Gravelly Sandy Loam	
Variety	Grapefruit		Lemon		Valencia		Grapefruit	
Rootstock	Sour orange		Rough lemon		Sour orange		Sour orange	
Years of Expt.	1936-43		1954-58		1934-1942		1949-58	
Age of Trees	8-15		3-7		5-12		18-28	
	Fertilizer applied each year per tree	Yield[a] fruit per tree	Fertilizer applied each year per tree	Yield[b] fruit per tree	Fertilizer applied each year per tree	Yield[c] fruit per tree	Fertilizer applied each year per tree	Yield[d] fruit per tree
	None	38	5# Am. Sul.	65	None	353	3# Am. Nit.	548
	180# Manure	109	12# Am. Sul.	109	100# Manure	342	9# 11-48 Am. Phos.	550
	6# Cal. Nit.	270	20# Am. Sul.	101	200# Manure	318	200# Manure	528
	12# Cal. Nit.	342	12# Am. Sul. 5# Tr. Phos.	249	6# Am. Sul.	324		
	5# Am. Sul.	296	12# Am. Sul. 200# Manure	243	8# 11-48 Am. Phos.	364		
	10# Am. Sul.	353	12# Am. Sul. 5# Tr. Phos. 200# Manure	261				
	5# Am. Sul. 5# Pot. Sul.	296	20# Am. Sul. 5# Tr. Phos. 200# Manure	249				
	5# Am. Sul. 5# Tr. Phos.	295						

(a) 7 year test: average yield during 5, 6 and 7 years of experiment in fruit / tree.
(b) Test in progress: yield in 1958, the 4th year of the experiment, in fruit / tree.
(c) 8 year test: average yield during 5, 6, 7 and 8 years of experiment in fruit / tree.
(d) Test in progress: average yield during 7, 8, 9 and 10 years of experiment in fruit / tree.

Methods of Determining Fertilizer Requirements

Three methods have been used to determine the fertilizer needs of the tree: (1) Field Fertilizer Experiments, (2) Leaf Analysis, (3) Soil Analysis.

Field Fertilizer Experiments

Basic information on the fertilizer needs of the tree must be obtained from fertilizer experiments in which the different elements are applied in varying amounts and the fruiting response recorded. Such experimental results must be considered as specific for the variety, age of tree and soil type involved and cannot be interpreted to hold under conditions which are markedly different.

In the interpretation of yields from any experiment it is necessary to consider the normal differences which exist between trees. Adjacent trees treated identically often have widely different yields. Statistical studies of yield data show that in almost all experiments with citrus trees the average yields between two treatments must differ by more than 15 to 20 percent before the differences can be said to be caused by the treatments.

During the past 30 years numerous fertilizer experiments have been conducted to detemine nutritional requirements. Yield summaries from four such experiments are shown in Table 4.

Experiment A shows clearly that on the Yuma Mesa sandy soils containing Colorado river silt one pound of nitrogen was definitely required. The need for two pounds was not conclusive but a trend toward more production with larger amounts is evident. Postassium and phosphate did not increase yields, and manure apparently was a poor source of nitrogen.

Experiment B, which is being conducted at present on the Yuma Mesa on Superstition sand with no silt accumulation has markedly different results. Increasing the nitrogen application on young lemon trees from one pound per tree to 2½ pounds improved yields, but a further increase to 4 pounds per tree resulted in no increase in yield, indicating that some other factor was limiting the yield.

That the limiting factor was probably phosphate is demonstrated by the relatively large increase in yield which occurred when phosphate was supplied either by the addition of treble superphosphate or by the addition of manure. Apparently, 2½ pounds of nitrogen per tree is sufficient for phosphate fertilized trees up to four years of age.

In the Salt River Valley two experiments illustrate different responses. Experiment C tested the response of young Valencia trees growing in a fertile clay loam soil. The results clearly show no benefit from any type of fertilizer. Observations on such trees as they grow older indicate that this high original fertility is gradually depleted so that eventually nitrogen fertilization is required.

Experiment D which is presently continuing at the Citrus Experiment Station near Tempe, evaluates the long time effects of fertilization of grapefruit with ammonium nitrate, ammonium phosphate and manure. Yields have been similar from these treatments for the first 9 years of the test. After the seventh year, manure fertilization has increased the nitrogen, phosphorus and potassium in the leaves in comparison with the other treatments. These trees have tended to have more iron chlorosis.

Other experiments have shown that yields were not changed significantly by very large applications of potassium, phosphorus and magnesium. Such treatments affected uptake of other elements as follows: potassium fertilization increased potassium and decreased magnesium uptake; phosphorous fertilization failed to increase phosphorus but increased calcium and decreased copper; magnesium fertilization increased that element but had no effect on others. Acid in the fruit was increased by potassium and decreased by phosphorus but no appreciable effect upon U.S. Grades occurred.

The precise amount of nitrogen required annually has not been established. Most nitrogen compounds are soluble. Nitrate nitrogen leaches more readily than ammonium nitrogen. Irrigation water leaches them below the root zone, but the rate of leaching differs between soil types.

Cover crops may use or manufacture nitrogen as they grow, and return this to the soil when disked under. Fallen citrus leaves, blossoms, twigs and fruit all add nitrogen to the soil.

Thus, the nitrogen supply to the surface roots is constantly partially replenished. These highly variable factors all influence the amount of nitrogen which must be added each year to maintain vigorous growth.

In the sandy soils of the Yuma area, nitrogen is rapidly leached below the root zone so several applications of nitrogen are required during the year to maintain adequate amounts within the root area.

The fertilization of trees by spraying the nitrogenous compound, urea, on the leaves before and after blossoming to increase fruit set has been found to be ineffective for this purpose unless a nitrogen deficiency existed. When a nitrogen deficiency existed, the nitrogen in the leaves was increased, but greater increases were obtained from applications of one pound of nitrogen to the soil.

Nitrogen deficiency frequently occurs in young grapefruit and lemon leaves during the winter. Because of low soil temperatures insufficient nitrogen is apparently taken up by the roots to prevent this condition. Foliar feeding of urea may alleviate this condition.

Leaf Analysis

It has been shown that field experiments are required to demonstrate fertilizer requirements, but the results tend to be specific for the trees and soil involved in the test. By analyzing leaves from trees in fertilizer tests, information has been obtained about the amount of the various elements present.

These values have then been correlated with tree responses so that the fertilizer needs of the tree may be determined without a field test. Such analyses have proven useful when properly interpreted with particular reference to nitrogen and phosphate analyses.

Difficulties in interpreting the analyses have been encountered because: the composition of the leaves changes as they become older; one element influences the uptake of another element (examples: high nitrogen is associated with high calcium and low phosphorus and vice versa; high potassium is associated with low magnesium and vice versa).

At present the best levels for each element have not been established. Leaf analyses of Arizona leaves show there are ample quantities of potassium present. In the Salt River Valley trees, ample quantities of phosphorus are present. At Yuma, the critical level for phosphorus in lemon leaves which respond to phosphorus fertilization has not been established.

Nitrogen fertilization is usually required in all areas to maintain good tree growth and fruiting. Fertilization of grapefruit is required when spring growth leaves that are analyzed in October and November have less than 1.9 percent nitrogen in the dry matter of the leaves. Similarly, fertilization of orange trees is required when less than 2.2 percent nitrogen is present.

TABLE 5.—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF ARIZONA CITRUS LEAVES AND MINIMUM ALUES REQUIRED*

	Low %	High %	Min. Value %
Grapefruit			
Nitrogen	1.40	2.25	1.90a
Phosphorus	.11	.35	.11a
Potassium	.90	4.00	.90a
Valencia Orange			
Nitrogen	1.80	2.70	2.30b
Phosphorus	.11	.16	.11b
Potassium	.80	1.65	.90b

* *Percentage of dry weight in 6-8 month old leaves.*

a. *Minimum values which have been associated with good production in Arizona.*

b. *Minimum values which have been found associated with good production in Florida and California. Sufficient tests have not been made in Arizona to establish values.*

Soil Analyses

Analyses of soils from fertilizer tests have thus far failed to reveal a close relationship between the amounts of available fertilizing elements present in the soil and tree response. This apparently is caused by several factors.

Citrus tree root systems are deep and wide-spreading so that nutrients are absorbed from a large mass of soil. Nutrients are apparently absorbed throughout the year and some are known to be stored in the tree. Soil analyses reveal that available nitrogen tends to vary throughout the year.

Thus, nitrate determinations at any one time are of little value for interpreting the nitogen requirements. Since the trees in the Salt River Valley do not respond to phosphorus and potassium fertilization, there has been no opportunity to establish minimum values for these elements.

Time to Apply Fertilizer

Mature fruiting citrus trees in Arizona produce between 75 and 95 per cent of their total leaves during February, March and April. During this period as many as 40,000 blossoms may be formed on a mature tree. The development of these leaves and blossoms requires large amounts of nutrients, particularly nitrogen.

Experiments at the Citrus Experiment Station on the Yuma Mesa have shown that trees deficient in nitrogen in the spring (leaf nitrogen 1.45 per cent on June 1) set only 62 per cent as many fruits as those which were high in nitrogen (leaf nitrogen 2.1 per cent on June 1). Thus, it is evident that to obtain maximum yields the leaves should contain a large amount of nitrogen during the spring growth period.

Experiments in the Salt River Valley on the timing of fertilizer applications to obtain high nitrogen spring leaves have revealed that nitrate nitrogen and urea applied in February or early March, and ammonium nitrogen applied in December produced the highest nitrogen content in spring leaves. Ammonium nitrate, which is now commonly used, presumably would combine the rapid uptake of nitrate with the slower response from ammonia to provide available nitrogen over the longest period.

Manure applied in August produced the highest levels from this source, but a single application to a nitrogen deficient tree did not produce the high nitrogen levels obtained from mineral fertilization.

The changes in the nitrogen content of grapefruit leaves recorded from a part of this experiment are illustrated in Fig. 8. It will be noted that in the spring, when the young leaves were enlarging, their nitrogen content increased rapidly. Part of this nitrogen was apparently supplied from the old leaves which showed a decrease during this period.

Fertilization with 6 pounds of calcium nitrate increased the nitrogen content of old leaves within six days and produced a high nitrogen content in spring leaves during April and May. The gradual changes thereafter [illegible] gest that the effects of this fertilization were largely depleted by June 15.

In contrast, the slower absorption from manure was indicated by the failure of old leaves to increase in nitrogen and by the intermediate nitrogen content of the spring leaves in April and May. However, absorption continued throughout the year so that a high level of nitrogen existed in January. The unfertilized trees were low in nitrogen throughout the year.

It may be concluded from these and other tests that mineral nitrogen should be applied in the winter or early spring (Dec. 15-Mar. 15) depending upon the form of nitrogen used. Manure should be applied in the late summer and fall (Aug. 15-Nov. 1).

This test and other experiments show that when nitrogen is used regularly in the Salt River Valley soils a high nitrogen level is maintained throughout the year. Under these conditions exact timing becomes of less importance.

Minor Element Nutrition

Zinc

Mild zinc deficiency symptoms are frequently observed and occasionally severe mottle conditions have developed in Arizona groves. The severity of the symptoms varies from year to year. Leaves may develop severe mottle leaf patterns and completely recover without treatment or major changes in culture.

Most tests with sprays have failed to produce clearly defined responses. However, several recent tests on trees with severe symptoms have resulted in marked improvement. Trees were sprayed with a solution containing 5 lbs. of zinc and 2 lbs. of lime to 100 gallons of water in either January or March.

Additions of urea, manganese sulfate, citric acid and glycerin to the above mixture failed to improve the response. Regular annual spraying of trees which had very mild zinc symptoms with the above materials has failed to improve yields.

New compounds and other elements are being tested as they become available. Before applying minor element sprays or fertilizer mixes consult your County Agricultural Agent or The University of Arizona Agricultural Experiment Station.

Iron

Iron deficiency, or lime-induced chlorosis is prevalent in many groves, particularly those growing in calcareous clay loam soils. The leaves on affected trees turn yellow-green, then yellow, and eventually, almost white. The veins in the leaves remain green. Twig dieback then follows, and soon larger limbs are affected until only the scaffold branches remain.

Usually from eight to fifteen years are required for extensive dieback to develop. This condition is caused by the failure of the tree to take up iron from the soil. The fundamental factors associated with the failure of the roots to absorb iron are unknown.

Iron chlorosis is very frequently associated with over-irrigation in which the sub-soil is continuously wet. Changing the irrigation program so that the sub-soils are allowed to become dry during the late summer has resulted in marked improvement in several instances.

Water should not be allowed to stand around trees for extended periods (twenty-four to seventy-two hours). To correct conditions in certain groves, it is necessary to construct borders around affected trees to reduce the water supply.

If changing irrigation programs is not effective, the application of iron compounds to the soil is required.

Severe iron chlorosis has been completely alleviated by the use of chelated iron compounds Sequestrene 138 Fe and Sequestrene 330 Fe. The amount of Sequestrene 138 Fe required ranges from ½ ounce on recently planted nursery trees to 8 ounces on very large mature trees.

Approximately three times as much Sequestrene 330 Fe is required to produce the same effect. Applications of Sequestrene 138 Fe produced marked responses within 7 to 14 days after treatment and have been effective for a little more than two years. The Sequestrene 330 Fe produced a slower response but was effective for a longer period.

Best results are obtained by applying the material to the entire root system. This is done by constructing a large basin around the tree and applying the materials to the entire soil area under and around the trees. After incorporating the material into the surface inch of soil the basin should be flooded with water.

Generally satisfactory results, also, have been obtained by applying the material in two shallow trenches—one inside and the other outside the drip of the tree. Maximum benefits have been obtained when trees were treated during April and May.

Iron sulfate applied in trenches in the spring at rates of 3 to 35 lbs. per tree depending upon size have also produced marked responses. However, the rate of recovery has been slower and the improvement tended to be more variable than occurred with Sequestrene 138 Fe.

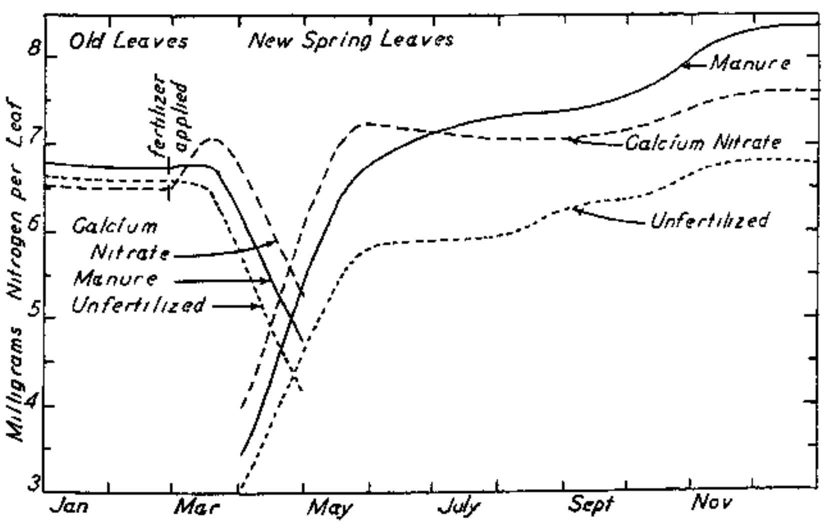


FIGURE 8.—Seasonal changes in the total nitrogen in leaves from grapefruit trees fertilized in February with 6 pounds of calcium nitrate, 200 pounds of manure and from unfertilized trees. In November, leaves from unfertilized trees were yellow-green in color and contained 1.62 percent nitrogen in the dry matter. In contrast, leaves from the manured trees were green in color and contained 1.92 percent nitrogen in the dry matter. (Data obtained in 1940 from nitrogen-deficient, twenty-eight-year-old trees growing in Cajon gravelly loam soil in the Salt River Valley).

TABLE 6.—A GENERAL GUIDE FOR CITRUS FERTILIZATION OF LARGE, MATURE TREES WITH COMMERCIAL NITROGEN

	Location and Soil Type					
	Yuma		Salt River Valley			
	Fine Sand		Sandy Loam		Clay Loam	
	Lbs. N per tree	Time Applied	Lbs. N per tree	Time Applied	Lbs. N per tree	Time Applied
Grapefruit	2	Dec. & Feb.	1	Feb. or Dec. and Feb.	½-1	Feb.
Valencia Orange	2-3	Dec., Feb. Apr., July	1½	Feb. or Dec. and Feb.	¾-1	Feb.
Washington Navel	2-3	Dec., Feb. Apr., July	2	Dec., Feb. or Dec., Feb. Apr.	1-1½	Feb., Apr.
Lemon	2-4	Dec., Feb. Apr., July	3	Dec., Feb. Apr. and July	1½-2	Dec., Feb., Apr.

If irrigation water contains nitrogen, correct for amount applied.
10 ppm. nitrate in water—6.2 lbs. nitrogen per acre-foot of water.
Approximate amount of commercial fertilizer needed to provide 1 lb. of nitrogen: Ammonia gas 1.2 lbs.; Ammonium Sulfate 5 lbs.; Ammonium Nitrate 3.3 lbs.; Calcium Nitrate 6 lbs.; Urea 2.4 lbs.

Practical Fertilization Programs

Present information shows that citrus trees in Arizona do not require potassium or magnesium fertilization. The Salt River Valley soils and the silted Yuma Mesa soils do not require phosphorus. The non-silted Yuma Mesa sandy soils require phosphorus which can be supplied from either phosphate compounds or manure.

The exact amount has not been established. Two pounds of available phosphoric acid or 200 pounds of manure per tree per year apparently is ample for young trees. Since phosphate is not leached from the soil, it is probable that these amounts can be reduced after several years of application.

Nitrogen fertilization has increased fruit production and is generally required. All forms of commercial nitrogen have produced about equal responses so that the cheapest form is the best one to use. The trees can use only a limited amount of nitrogen so applying large amounts do not produce additional gains and may be harmful.

In determining the amount of nitrogen to apply, the condition of the tree provides the best guide. If the leaves during October to December are deep dark green in color, the nitrogen level of the tree is high and little or no nitrogen is required.

If the leaves are pale yellow-green in color, heavy nitrogen fertilization is neede . The amount of nitrogen needed to obtain a high nitrogen level is determined chiefly by the soil type. Sandy, gravelly soils have little natural fertility and nitrogen leaches rapidly so that several applications are required.

In contrast, clay loam types are frequently high in natural fertility and extensive leaching does not occur, so that single yearly light applications are sufficient (Table 6).

Grapefruit trees require a lesser amount of nitrogen to maintain high production of good quality fruit than do orange trees. This is particularly the case in the Yuma Mesa sandy soils where the development of a moderate nitrogen deficiency in the late summer has been frequently associated with improved quality of grapefruit.

Lemon trees appear to require more frequent applications and larger quantities of nitrogen than orange trees to maintain vigorous tree growth and high production. Nitrogen in orange trees should be maintained at a high level all year. This requires more frequent fertilization than is used on grapefruit trees.

Manure supplies nitrogen as well as other nutrients. In the Salt River Valley production has been maintained by annual applications of 10 tons per acre without additional nitrogen. However, such a program may contribute to the development of iron chlorosis. On the other hand, trees have been maintained in a healthy fruiting condition indefinitely by the use of weed cover crops with mineral nitrogen without manure.

Manure improves the soil structure and may supply some elements not known to be required at present. A program which includes an application of 5 to 10 tons of manure per acre once every three or four years will be ample to supply such possible requirements.

On the unsilted Yuma Mesa soils, manure supplies phosphorus and if used at rates of 5 to 10 tons per acre per year apparently can be substituted for commercial phosphates. However, it appears necessary to supplement manure with mineral nitrogen to obtain maximum tree growth and fruiting.

Irrigation

Soil Moisture And Fruit Growth

Soil contains a mixture of mineral particles ranging in size from gravel to clay. The small mineral particles of sand and silt hold a film of water on their surface, and the clay portions also retain water within the particle. The forces holding the film of water become very great as the film becomes thinner.

The roots of the citrus tree have the capacity to remove water from the soil particles by exerting counter forces up to about 265 pounds per square inch. Since the soil particles retain considerable amounts of water at this pressure, there is always water left in the soil which the roots are not able to obtain. The amount of water retained by the soil at this point is referred to as the wilting percentage of the soil.

Because many small particles have a greater area than a few large particles, silty clay soils contain more moisture at the wilting percentage than sandy soils. Consequently, for the same reason, silty clay soils hold more water when they have just been wet. Since they hold more moisture, irrigations can be at less frequent intervals than are required for sandy soils.

The plant can obtain water easily when the soil is saturated with water which is lightly held upon the soil particle. As the water in the soil is depleted, more force is required to remove the water from the soil particles.

Water is lost from the leaves of citrus trees through very small pores called stomata. Light causes these pores to open; darkness and lack of moisture cause them to close. When soil moisture is ample, and soil, air temperatures and light are favorable, the stomata open early in the morning and there is rapid loss of water (transpiration).

In the morning, water transpires from the leaf more rapidly than it is supplied by the roots. As this condition intensifies, water is removed from the fruit and it shrinks. Later in the day as these moisture stresses become more severe, the stomata close and the leaf may even wilt slightly. During the night, the water supply is replenished, the fruit refills with water, and growth of the fruit takes place.

As the soil becomes drier, the stomata close earlier in the day, so that less water is used by the plant. At night the water removed from the fruit is replenished but the amount of fruit growth is retarded, and tree growth is also restricted.

Figure 9 illustrates how two methods of irrigation affected the loss of water from the soil and the growth of the fruit. The wet plots were irrigated August 29, September 15, October 5, and November 1.

Only two light showers occurred in this interval, and the water removed from the soil amounted to 8.7 inches. This maintained, the soil moisture in the upper four feet of soil above 11 percent (wilting point 7.2 percent)

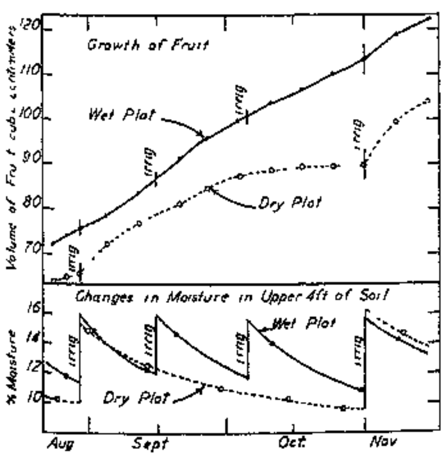


FIGURE 9.—Effect of irrigation upon the growth of Valencia orange fruit and the depletion of water from the soil. (Data from University of Arizona Citrus Experiment Station 1950).

and all of the soil, excepting the surface 4 inches, was well above the wilting point.

The greatest force holding the water to the soil at a depth of 9 inches was only 11 pounds per square inch. Under this irrigation program, the fruit grew rapidly and rather uniformly so that 57 percent of the fruit was 2.6 inches or larger in diameter when harvested in April.

The dry plot was irrigated on August 29 and November 1. In this interval, 5.3 inches of water were removed from the soil. During the first two weeks after the August 29 irrigation, water was rapidly used. At this time, fruit growth was greater than in the wet plot because the soil had been very dry prior to this irrigation.

After September 15, the soil moisture was removed more slowly as increasingly larger quantities of the soil in the root zone approached the wilting point. As this moisture loss became less, the growth of the fruit was gradually retarded and finally almost stopped.

After the November 1 irrigation, rapid fruit growth again took place, but the amount of growth was not sufficient to equal the loss during the dry period. As a consequence, smaller fruit gradually developed, and only 38 percent of the crop was above 2.6 inches in diameter in April.

This illustration shows clearly that when ample water is present in the soil the tree uses more water and the fruit grows more rapidly than when an alternate wet and dry pattern of irrigation is followed.

If the soil does not contain adequate moisture, the tree is capable of adapting to this condition. It will use less water and the fruit will grow more slowly.

This adaptation to a reduced supply of water occurs before the leaves wilt, so that a moisture shortage cannot be easily observed.

Use of Water From Different Depths

Water applied to a citrus grove is used by the trees, evaporates from the soil surface and percolates below the root system. By obtaining a record of the changes in the moisture content of the soil it is possible to calculate the total water removed.

The exact amount used by the tree, however, cannot be accurately determined because the evaporation and

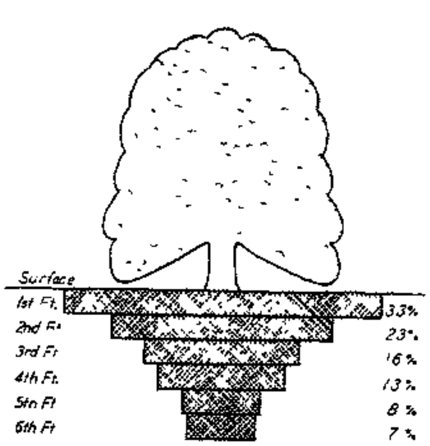


FIGURE 10.—Percentage of total water lost between irrigations from successively greater depths below 18 year old Valencia orange trees growing on sour orange rootstock in Mohave gravelly sandy loam in the Salt River Valley. Total water lost includes losses by evaporation from the soil surface, usage by the tree and by percolation to lower depths. (Data from University of Arizona Citrus Experiment Station).

percolation losses cannot be separated from the total. This total loss of water from the soil is referred to as evapotranspiration.

Data was obtained for three years from seventeen to nineteen-year-old Valencia orange trees budded on sour orange rootstock that were growing in Mohave sandy loam soil. Ten irrigations were applied annually which prevented the development of a serious water deficit in the trees.

Water was lost from the upper 6 feet in the proportions indicated in Figure 10. That is, 33 percent of the total water used throughout the year was lost from the first foot. 23 percent from the second, etc.

These losses do not reflect root distribution. The percentage of roots at different depths were as follows: 1st foot, 28; 2nd foot, 47; 3rd foot, 15; 4th foot, 4; 5th to 8th foot, 6.

The failure of the soil moisture changes to reflect root distribution is caused by evaporation and downward drainage of water. Several studies with large mature trees indicate that evaporation from the soil surface amounts to 13 to 18 percent of the water applied, and downward drainage up to 25 percent.

This information shows that it is not necessary to irrigate to the same depth at each irrigation because more than twice as much water is used from the upper 2 feet than from the 3rd to 6th foot. Thus, a heavy irrigation which penetrates to a depth of 6 feet could be followed by a light irrigation which penetrates to only 2 feet.

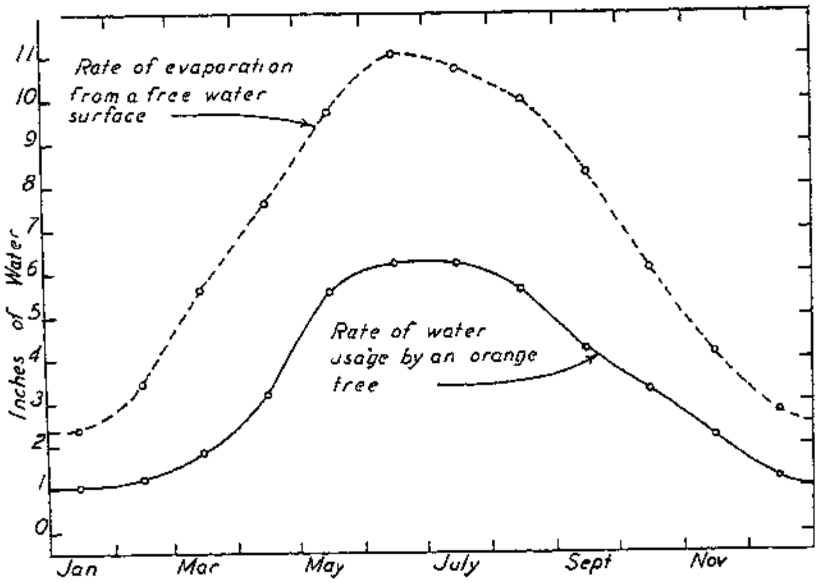


FIGURE 11.—Average rates of water evaporation from a free surface and depletion from the soil under Valencia orange trees for each month during a calendar year in the Salt River Valley. The loss of water from the soil is about 1 acre-inch in January and about 6 acre-inches in July.

Seasonal Use of Water

The rate at which water evaporates from an open container is determined by the temperature, relative humidity and wind movement.

Figure 11 shows that in the Salt River Valley about 2.3 inches of water evaporates from a United States Weather Bureau Standard Evaporation Unit during January. This gradually increases as the weather becomes warmer until June, when about 11 inches of water evaporate.

The amount of evapotranspiration loss from the soil beneath seventeen to nineteen-year-old Valencia orange trees growing on sour orange rootstock has been obtained for each month during a three-year period (Figure 11). These data reveal that the same factors which influence the rate of water loss from a free surface also influence the loss of water from the soil.

Thus, the evapotranspiration loss parallels closely the rate of loss from evaporation from a free surface. The lesser amount lost is because: (1) The stomata in the leaves of the tree close at night, thus preventing loss; (2) the evaporation of water from the soil surface is less than from a free surface.

This information provides a guide to the time of irrigation since it is evident that the tree requires about six times more water in June and July than January.

Response to Different Soil Moisture Levels

Large Valencia orange trees at the Citrus Experiment Station near Tempe are being grown under four irrigation schedules. Water is applied when the soil moisture has been reduced to three successively lower levels.

The wet schedule (A) maintained available water in the entire root zone (excepting the upper 4 inches for a few days before each irrigation).

The moderate schedule (B) allowed the upper foot of soil to reach the wilting range.

The dry schedule (C) allowed the upper two feet of soil to reach the wilting range which produced a slight wilting of leaves in the summer.

In schedule D trees were grown under schedule A between March and July and schedule C the remaining part of the year (Table 7).

A summary of the major effects which occurred as the soil was allowed to become dryer between irrigations follow: Tree trunk growth was reduced; the number of fruit per tree and the size of the fruit was reduced by extreme drying, but these features were not influenced by a moderate reduction of soil moisture as occurred in treatment B; soluble solids, ascorbic acid (vitamin C) and peel thickness were increased; the percentage of juice tended to be reduced.

Maintaining high soil moisture has induced iron chlorosis which has required treatment with chelated iron compounds to maintain tree health. The practice of maintaining high soil moisture throughout the root zone which is required to promote maximum tree growth is inconsistent with optimum iron nutrition in the soil type involved.

Irrigating to provide optimum soil moisture during the spring and early summer followed by stress periods in August and October as in schedule D has prevented the development of iron chlorosis, and induced the maximum yield of fruit. However, the fall dry period has restricted fruit growth and increased peel thickness.

TABLE 7.—EFFECT OF SOIL MOISTURE ON TREE GROWTH, FRUIT YIELD, SIZE AND QUALITY (a)

	Wet	Med.	Dry	Wet Spring Dry Fall	LSD (b)
Number Irrigations / year	15	10	5	9	
Acre Inches Water Applied	65	50	35	49	
Soil Moisture; % (c)	10.7	9.6	7.6	(d)	
Trunk Growth; Sq. cm. / year	19	16	12	15	2.6
Yield; fruit / tree	677	680	561	743	109
Size 113 and larger; % (e)	62	60	55	44	11
Soluble Solids; %	11.8	12.2	12.8	13.2	.66
Peel Thickness; m.m.	4.6	4.5	4.9	5.0	.34
Ascorbic Acid; mg/100 ml.	49	50	53	52	3.4
Juice by weight; %	54	53	52	51	—

(a) Data are averages of 7 years.
(b) Difference between any two values which is required to be significant.
(c) Percent soil moisture in upper 2 feet of soil just before irrigation, wilting range equals 6.5 to 8.5%.
(d) Irrigated on Wet schedule March to July and Dry schedule August to February.
(e) Percent of fruit of commercial carton size 113 and larger, or greater than 2.6" diameter.

TABLE 8.—A GENERAL GUIDANCE SCHEDULE FOR THE IRRIGATION OF ORANGE GROVES GROWING IN SANDY LOAM SOILS IN THE SALT RIVER VALLEY

Irrigation Dates*		
January 2	June 5	August 14
March 15	June 22	September 3
April 25	July 9	September 28[a]
May 16	July 26	November 1

a. The September 28 irrigation may be delayed until the leaves begin to wilt in mid-morning to prevent the development of iron chlorosis.

** Four and one-half acre inches of water are required at each irrigation to replace loss of 3½ inches used by the tree and 1 inch to wet cultivated layer. 4½-acre inches of water per acre are supplied as follows:*

100 Arizona Miners inches	*for 1 hr. 48 min.*
2 cu. ft. per second	*for 2 hr. 16 min.*
500 gal. per min.	*for 4 hr. 5 min.*

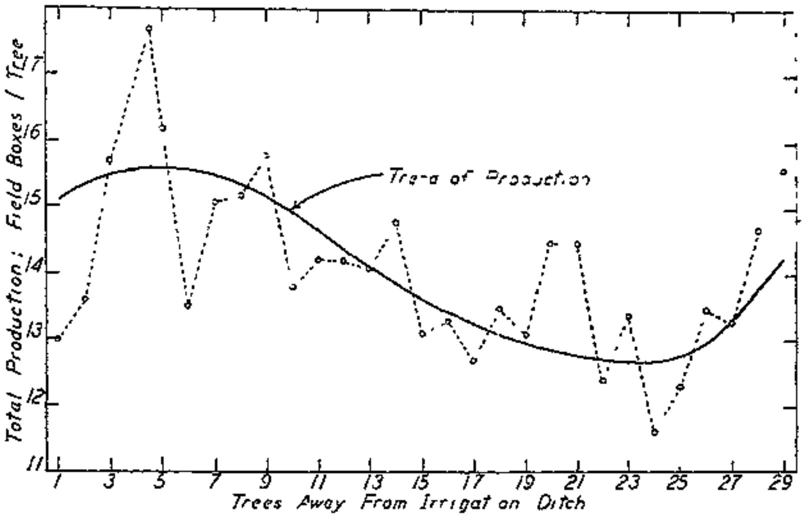


FIGURE 12.—Effect of distance from the source of water upon the production of Valencia oranges irrigated by flooding between borders. The yields are the average total production from each tree in four separated rows during the first twelve years after planting. Note the lower yields produced by the 10th to 27th trees away from the irrigation inlet. (Data from grower cooperative experiment in Salt River Valley 1934-42).

Practical Irrigation Programs

Since climatic conditions differ each year and soils in citrus areas vary in their capacity to hold water, it is not possible to present a precise schedule for irrigation. However, average sandy loam soils should be irrigated after about 3½ inches of water have been removed. Because about one inch is required to wet the surface cultivated area, a 4½-inch irrigation is required to refill the soil.

Calculations based upon the water usage data presented in Figure 11 show that a program of irrigation with an average of 4½ inches of water requires irrigations on the dates indicated in Table 8.

Heavy silt or clay soil holds more water, so that a longer interval can be used but more water must be applied at each irrigation. If the soil is sandy, it will hold less water so shorter intervals between irrigations with less water are required.

If a program of wetting only the dry soil is followed, one or two irrigations with less than 4½ inches must be followed by one with more than 4½ inches.

Periods of above-average warm weather or above average winds will shorten the intervals. Rains, cloudy days and below-normal temperatures will increase the intervals.

Experience during the past 10 years has shown that tensiometers (instruments to measure the forces holding the water to the soil particles) can be used as a guide for irrigation. Satisfactory fruit growth, high yields and a large amount of tree growth have been obtained at the Citrus Experiment Station in the Salt River Valley when trees have been irrigated when the soil moisture tension reaches 400-500 centimeters of water at a depth of 24 inches on the northeast side of the tree.

Tests in a deep loam soil in the Mesa district have shown that irrigations applied when tensions at 30 inches are between 500 and 600 provided satisfactory fruit growth. It appears at present that the proper tension level at which to irrigate differs with the soil type and root distribution. To determine exact values, tensiometer readings should be correlated with fruit growth for at least one season.

Tensiometers also quickly reflect the depth of penetration of irrigation water. Several commercial models are available.

In groves where iron chlorosis (yellow leaves with green veins) tends to develop, the soil should be allowed to dry rather thoroughly at least once each year in the late summer or in October.

A very heavy irrigation should be given at least once each year, preferably in January, to leach salts into the sub-soils. The soil should be examined occasionally with an auger or tube to determine if the water has penetrated into the sub-soil.

If the water supply is limited, irrigations should be made according to the suggested schedule between March and June. Longer intervals should then be used during the late summer and fall. Enough water should be held in reserve for a thorough irrigation in November.

Methods of Applying Water to a Grove

The practical problem of inexpensively and efficiently applying a uniform amount of water to each tree in a grove has not been solved. In most groves, the trees near the pipe line receive more water than those near the end of the grove away from the pipe line.

The effect of such irrigation upon the yield of fruit from a grove growing in Mohave clay loam which has been considered well irrigated by the flood system is shown in Figure 12. Note the decrease in fruit production as the distance from the pipe line increases to the second tree from the lower end of the row. The upper trees and lower two trees received more water than the intervening trees.

This failure to efficiently distribute water, resulted in a loss in this instance of at least 110 field boxes per acre. Once this situation is established, many years of efficient irrigation will be required to improve yields.

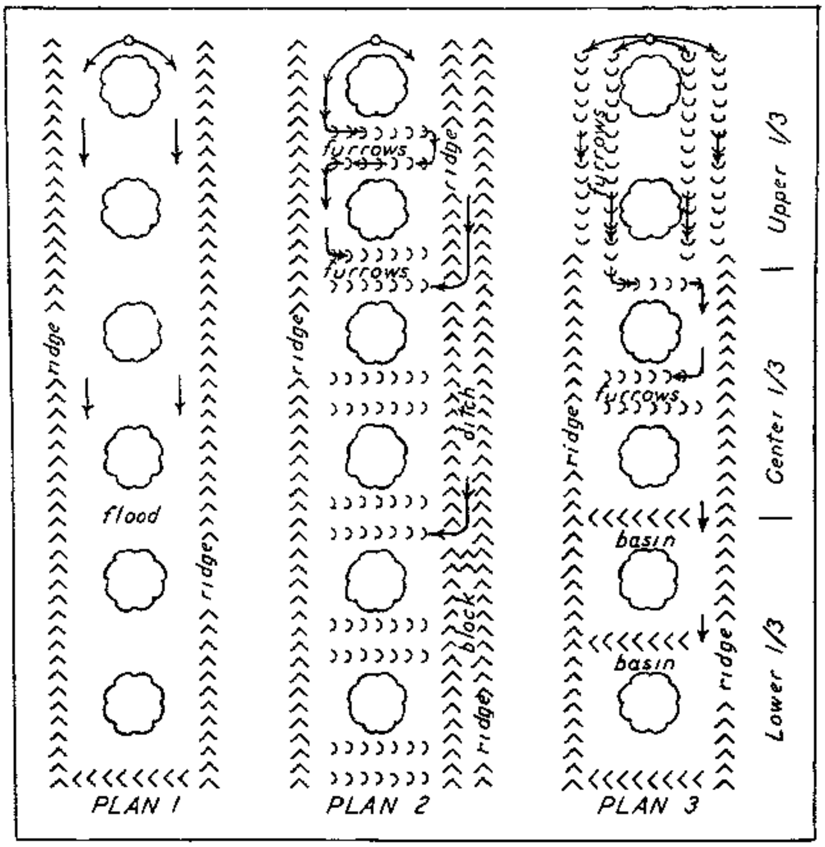


FIGURE 13.—Methods of applying irrigation water. Plan 1. Flood between ridges; soil graded to uniform slope. Plan 2. Center ditch; block and ridge with cross furrows; lower one-third irrigated first; center one-third second; upper one-third last. Plan 3. Furrow upper one-third; cross furrow block and ridge center one-third; basin lower one-third. Different types allow water to run at different rates to provide more uniform penetration of water.

Flood & Furrow Systems

Three plans which will improve the uniformity of water application and reduce the amount of waste water are presented in the following sections and illustrated in Figure 13.

Plan 1

This is a method of irrigation by running water between two large ridges. This method requires that the field be graded to a uniform slight slope of about ½-1 inch per 100 feet or in some cases to a perfect level before the trees are planted. A high ridge is formed between each row, which is closed at the end, so that a large basin is formed. The basin is filled with the desired amount of water and no waste water runs off the land.

Because of reduced irrigation costs and very efficient usage of water provided by this system, any grower making a new planting should thoroughly check the feasibility of using this system. This method is used extensively in the Yuma region and has proven satisfactory. In heavy clay loam soils, however, difficulty from Brown rot gummosis may develop, and special precautions must be taken to keep water away from the trunks of the trees.

Plan 2

Most mature groves in the Salt River region are situated on land which was not properly leveled prior to planting. A common method of irrigation is the cross furrow and block-ridge system. Water is allowed to enter at the upper end and run off at the lower which results in an unequal distribution of water.

This situation can be improved by making two ridges between each row. After furrowing the two ridges are made close together to form a ditch between each row. Water is first turned into the ditch and cut into the cross furrows of the lower one-third of the row. When it has reached the end of the row, another cut is made to irrigate the center third and again irrigate the lower third.

After this operation is completed, the water is applied to the upper one-third and allowed to irrigate the entire row. Variations in soil types call for modifications of this program.

Plan 3

Here the upper one-third of the row is irrigated in straight furrows, the center one-third with the cross furrow and block-ridge system and the lower one-third with basins made with the block-ridge machine.

Because the water runs more rapidly through the straight furrows than in the cross furrows and very slowly in the basin area, a more uniform penetration of water across the entire row is obtained.

Marked differences frequently exist in the rate water enters the soil at different times after cultivation. During the first irrigation, after the furrows are formed, water usually penetrates more rapidly than during the second one.

Frequently, weed growth clogs the furrows when the third irrigation is applied, so that the water runs slowly and again penetrates more rapidly. These differences can be corrected by using a larger amount of water in each row during the first and third irrigations than is used in the second.

Protection Against Freezing

Almost all Arizona Citrus is growing in the warmer locations of the State. Nevertheless, past experience has shown that trees and fruit in almost all areas are subject to freezing injury.

Protecting citrus trees against frost involves the transfer or conservation of heat. Heat is transferred by three methods: radiation, convection, and conduction.

Radiant heat moves in a straight path from one object to another by electromagnetic waves. The sun warms all objects on the earth with radiant heat during the day and radiant heat is lost from the earth into space during the night.

Dry air transmits radiant heat without intercepting an appreciable quantity whereas clouds and moist air intercept part of the energy and reflect it. Thus, heat is not lost from the earth as rapidly on a cloudy night as on a clear dry night.

During freezes in Arizona the chief damage occurs from the localized loss of radiant heat from groves. Since orchard heaters produce radiant heat they should be placed so that as many trees as possible are in a direct line with the heaters.

Radiant heat warms unequally. Bare soil absorbs more heat than soil covered with vegetation. This uneven heating causes winds or convection currents.

Convection transfers heat energy in gases or liquids from one particle of matter to another. Temperature inversion or the "ceiling" on a cold night develops as a result of convection heat transfer. During the day the radiant heat from the sun warms the earth, which in turn warms the air in contact with it. This warmer, lighter air rises and is replaced by colder air. This produces currents so that a layer of warm air gradually extends upward to elevations of 500 to 1800 feet.

After sunset the earth loses radiant heat and becomes colder than the air. Air in contact with the cold soil, trees and other objects then becomes colder. This heavy colder air remains close to the ground so that an inversion of temperature occurs.

Data acquired between 1938 and 1954 in citrus groves during nights below 26° F. show that temperatures at 50 feet above the ground range from 4° to 17° F. warmer than at 5 feet. Normally, differences of 7° to 9° F. may be expected.

Cold air flows slowly to lower elevations and is replaced by warmer upper air. Local wind movement mixes upper warmer air with colder lower air. These two general air movements cause the great differences in air temperatures which frequently occur within the different citrus districts.

Freezes occur when cold masses of polar air enter the state from the north or northwest and often are concurrent with freezes in Southern California. They may occur in early November and late March, but the main danger period lies between December 1 and February 20.

During periods of freezing temperatures the following characteristics usually prevail—clear skies; day temperatures always above freezing (45° F. to 55° F.); freezing on three or four consecutive nights, with the second night the coldest; dew forming at low temperatures (20° to 30° F.); ceiling temperatures at 50 feet elevation average about 7° F. warmer than at 5 feet between midnight and sunrise.

Temperature Relationships and Plant Responses During Freezes

Fundamental temperature relationships in the Salt River Valley which commonly occur during freezes are illustrated in Figure 14. An updrift of air to the mountains occurred just after sunset and before sunrise with downdrift movement during most of the night. The sharp drop in temperature at the 5-foot level after sunset was not accompanied by a similar drop in upper air temperature so that a ceiling developed (7:00 p.m.).

During dew formation, heat was released so that temperatures remained constant (7:00-11:00 p.m.). During periods of calm, sharp drops in temperature occurred (11:00 p.m.-1:00 a.m.) and (1:30 a.m.-3:00 a.m.), whereas steep increases took place when light breezes mixed the warm upper air with the cooler lower air (1:00 a.m.-1:30 a.m.).

Fruit protected inside the tree was markedly warmer than the outside exposed fruit and did not approach the danger point although the air temperature at 5 feet reached 22.8 degrees. Exposed fruit on the outer side of the tree supercooled to a temperature of 24.8 degrees before it froze at 5:00 a.m.

Upon freezing, the release of heat as the ice crystals formed quickly warmed the fruit. Such super-cooling may happen frequently. When it does not occur, the fruit begins to freeze at 26.5 degrees or 27.0 degrees. A gradual release of heat maintains this temperature until the fruit is completely frozen.

These differences between air and fruit temperatures show clearly the need for using temperatures of fruit in various positions on the tree as a guide for the use of any frost-protection methods. They also partly explain the differences in fruit damage observed after many freezes.

Frost Protection For Young Trees

It is necessary to protect trees under three years of age from cold injury. A simple, effective method is to place a layer of maize stalks or other

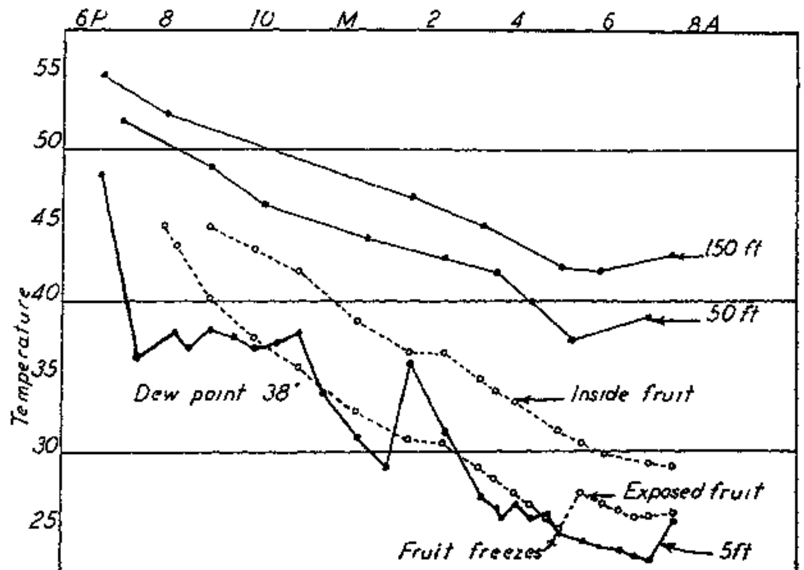


FIGURE 14.—Typical temperature relationships during a cold night show that temperatures at five feet are always colder than the temperatures are at 50 and 150 feet elevation. Fruit temperatures depend upon exposure and are warmer than the air early in the evening. Exposed fruit is sometimes below air temperatures and may undercool to 24-25 degrees F. before freezing.

(Data obtained from fruit thermometers, thermometers on captive balloons and in United States Weather Bureau official thermometer shelters at the former Glynn Stannard grove at 44th Street and Arizona Canal, northeast of Phoenix, on night of Feb. 17-18, 1938).

FIGURE 15. — Young tree protected against cold injury with sorghum stalks and soil hilled around base of tree.

insulating materials around the tree as shown in Figure 15.

From 15 to 20 stalks are placed around the tree and tied securely. Some leaves and branches should not be covered as leaves need light and air to live.

After the stalks are in place, earth should be banked around the lower one-third to one-half of the trunk to help hold the stalks in place and provide additional protection should a severe freeze kill the entire head of the tree. Trees should be protected in early November and the stalks removed in mid-March.

Frost Protection For Mature Trees

Large trees and fruit can be protected by (1) favorable culture practices (2) irrigation, (3) wind machines, (4) orchard heaters or (5) combinations of these methods.

The size, variety and value of the crop must be considered in relation to the costs of protection. Past experience indicates that culture and irrigation are the most economically feasible methods of protection for Washington Navel and Sweet seedling orange varieties, the Clementine (Algerian) tangerine and grapefruit. This is because most of the crop of these orange and tangerine varieties is harvested prior to the normal onset of severe freezes and grapefruit withstands lower temperatures without injury.

If yields are large, it will be profitable to protect Valencia orange, lemons, and late ripening tangerines with heaters and wind machines because of their high value and susceptibility to damage.

The leaves and twigs of citrus varieties differ in cold resistance, usually in the following increasing order of hardiness—Mexican lime; Bears lime, Eureka and Lisbon lemons; Marsh grapefruit; Valencia orange and Washington Navel oranges; Hamlin, Diller and Butler oranges; Clementine (Algerian) and Dancy tangerines; Kinnow mandarin.

Protection by Cultural Program

During a freeze, heat is lost from the exposed leaves, twigs and fruit and the tree becomes colder. This heat loss is partially replaced by radiation of heat to the exposed parts of the trees from the warmer unexposed parts of the tree and from the soil. Since the soil is much warmer than the air it constitutes the major heat reserve supply.

Optimum conditions for the conduction of heat out of the soil to replace heat lost from the tree occur when the soil is firm, bare and moist. Conversely this provides the best conditions for absorption of heat from the sun during the day to replenish the heat lost at night.

If the soil is insulated with a layer of loose disked dry soil or covered with mulches this heat interchange is retarded and the trees are colder. Cover crops interfere with such heat interchange and also provide additional surface to radiate heat. Trees in such groves may be 3 to 6 degrees colder than in groves where the soil is bare, firm and moist.

Bare, firm, moist soil is essential for successful frost protection regardless of the supplemental heat supply. To provide this condition weeds should be disked deeply in late October or early November and a heavy irrigation applied to thoroughly firm the soil.

Protection by Irrigation Water

Water loses heat as it becomes colder. Thus, irrigating during a freeze provides heat. It has been estimated that the radiation loss of heat from a grove during a freeze amounts to 900,000 Btu* per acre per hour. One acre inch of water covering one acre will release about 866,000 Btu as it chills from 70° F. to 32° F.

It is evident that applying water will temper the effect of the freeze but not supply complete protection. The release of heat from the water is rapid when it is warm and becomes slower as the water cools.

When the water freezes, the latent heat of freezing causes the release of 144 Btu per lb. of water so the formation of 1/8 inch of ice releases approximately 420,000 Btu per acre which also will partially offset heat loss.

Field tests have shown that irrigation water raised air temperatures from 2.5° to 4° F. when the initial water temperature was 65° and the air temperature was 26° F. The warmer running water at the upper ends of the rows produced larger increases than the colder water at the lower end of the rows. Standing cold water produced little increase.

Protection by Orchard Heaters

Orchard heaters provide the most dependable uniform source of heat. Several types of heaters are available. The Jumbo stack and the California Return Stack types produce the least smoke and the largest amount of radiant heat.

For complete protection, if the grove is isolated, one heater per tree should be placed in the outside 2 rows and the remaining part at the rate of 45 heaters per acre or one for each two standard spaced trees.

Records were obtained on many nights in a two-acre portion of a grove heated with 45 Jumbo heaters per acre. Air temperatures were raised from 3° to 5° F. during freezes.

Fruit receiving radiant heat was warmed above air temperatures. During severe freezes with minimum temperatures of 19° to 21° F. and 10 to 12 hour periods below 25° F. temperatures dropped below the safe level and damage occurred.

Orchard heaters burn oil at the rate of about one gallon per hour. At present oil prices it is extremely expensive to supply heat from this

*Btu—British Thermal Unit is the amount of heat required to raise the temperature of one pound of water 1 degree F.

rce. Orchard heaters are now prin-ally used to supplement wind ma-nes and are not lit until critical iditions develop. The heat produc-appears to be more efficiently used connection with wind machines, n when heaters are used alone.

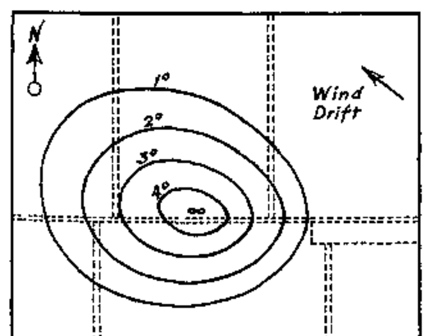
Protection by Wind Machines

Vind machines provide protection blowing the warmer upper air ove the grove down over the trees. us the amount of temperature in-ase obtained depends upon the ex-t of temperature inversion and the wer of the machine.

arge machines of high horsepower required to effectively mix the hter warmer upper air with the vier, colder lower air. The differ-ce in temperature between the air 5 feet and 50 feet has been shown be closely correlated with the tem-rature increases induced by the ma-ine.

The pattern of the protected area influenced by the direction and vel-ity of the wind drift. The average ttern of temperature increases ob-ved on ten nights around a dual 0 horsepower rotating wind machine uipped with 13.5 feet propellors shown in Figure 16. With a drift of out two miles per hour the tem-rature increase zone was about ice as great downdrift as updrift.

This machine provided protection r 8 to 12 acres when temperatures re 21°-23° F. with durations of 5 to hours below 26° F. It did not pro-de adequate protection at tempera-tures of 19°-20° F. Under such conditions supplemental heat from orchard heaters or irrigation water is required to maintain safe temperatures.



IGURE 16.—Pattern of average increases in temperature produced by a dual 150 H.P. rotating wind machine. Data is average of 10 nights in 1954-55; wind drift about 1¼ to 2 m/hr. from S. E.; inversion 5 to 50 ft., average 7.6° F.; control temperature during wind machine operation, average 24.4° F.; control absolute minimum temperature, average 22.2° F. (Data obtained at University of Arizona Citrus Experiment Station).

Operation of Frost Protection Programs

When the trees are growing in November and March, leaves and young shoots can be damaged by a few degrees of chilling below 29° F. However, during the fall many nights with temperatures between 29° to 32° F. usually precede a serious freeze. Gradual exposure to successively lower temperatures stops growth and "hardens" these tissues.

After healthy, mature large trees have gone through a period of extensive hardening, leaves and twigs have withstood minimum temperatures of 19 to 21° F. with 11 hours below 26° F. without injury. Thus, in midwinter protection is required primarily for fruit.

The orange fruit freezes at about 26.5° F. unless supercooling occurs. Because most of the fruit on a tree is usually several degrees warmer than the current air temperature, freezing of fruit normally does not occur until air temperatures have been below 26° F. for 2 to 4 hours.

In midwinter during the dormant period, if the soil is bare, firm and moist, protection is required for oranges on nights when the temperature is expected to be below 26° F. for more than two hours. Lemons are small so they freeze with fewer hours of chilling than oranges and should be protected when temperatures are about 2 degrees higher. Because of their large size, grapefruit require more hours of chilling before freezing, thus, the temperature can be about 2 degrees lower before protection is required.

In the fall and spring protection is required for tender leaves, twigs and blossoms when the temperature is expected to be below 29° F.

Because the operation of a wind machine is relatively inexpensive it should be used on all nights when temperatures are expected to drop below the values indicated for the different fruit varieties, blossoms and leaves indicated above. The temperatures at which the machine should be started are dependent on the extent of the cold period expected during the night.

If a minimum temperature of 20° F. with 8 hours or more below 26° F. is expected, the machine should be started soon after sundown. If temperatures of 22° to 24° F. are expected the machine should be started when the temperature reaches 28° to 32° F. depending upon the duration expected.

If the dew point is above these temperatures, the machine should be started at temperatures slightly above the dew point to reduce dew formation on the fruit.

Orchard heaters are normally used to supplement the wind machine. Limited firing should begin as the temperatures drop to the lower limits of the safe zone, with additional heaters being lit as necessary to maintain this temperature. Many growers do not light heaters until the small exposed fruit begins to freeze.

The presence of "slush ice" in the fruit when cut with a sharp knife indicates that the fruit is near the danger point. If further chilling does not occur such fruit repeatedly has failed to show commercial frost injury in the form of hesperidin crystals on the segment membranes or dry juice sacs later in the season.

Physiological Disorders

June Drop

June drop refers to the dropping of young fruit above ½ inch in diameter during late May, June and early July. The extent of this drop is the most important factor in the production of oranges in Arizona.

Fruit drop occurs as a result of the formation of a layer of cells, known as abscission layer, at the point of attachment of the fruit to the stem. The development of abscission layers is contolled by changes in the amount of natural growth hormones or auxins in the fruit and stem.

Climatic and nutritional factors discussed below may exert their principle effect through changing the concentration of auxins.

Excessive "June drop" apparently is induced by severe internal moisture deficits which develop in the tree during periods of high temperature and low humidity. Yields from 1944 to 1959 at the Citrus Experiment Station and from certain Salt River Valley groves show that the least drop has occurred on Washington Navel and Valencia orange trees in years when maximum temperatures were below 100° F. between bloom and June 7. Excessive drop occurred in years when maximum temperatures attained 108° to 112° F. during this interval.

The severity of the drop is apparently modified by carbohydrate conditions in the tree. Less drop has been recorded from trees which have had a higher carbohydrate content induced by stresses from low soil moisture or a nitrogen deficiency during the preceeding year. Also, markedly less drop has occurred in all groves in the Salt River Valley in several years following severe freezes in January.

Pollination of flowers apparently affects "June Drop." Seedy varieties such as the Dancy tangerine and Kinnow mandarin which have been pollinated have been largely unaffected by unfavorable climatic conditions. Local varieties of seedy oranges such as the Butler and Diller also have been less affected by "June Drop" than the Washington Navel which largely produces parthenocarpic fruit without pollination.

"June Drop," also, appears to be influenced by the presence of mature fruit on the tree. Harvesting grapefruit prior to bloom has resulted in increased yields.

Numerous tests with nutritional sprays containing nitrogen, zinc, manganese, copper, lime, glycerine, sugar and others have failed to reduce drop consistently. Hormone-like compounds such as 2-4-D and 2-4-5-T likewise have failed. High soil moisture and many different nitrogen fertilizion programs during the drop period have all been ineffective.

Split Fruit

Split fruit occasionally occurs on orange trees, particularly the Washington Navel. Splitting appears to be caused by abnormal changes in the growth rate of the fruit induced by weather conditions. Measurements of a Valencia fruit which eventually split showed that growth stopped on 5 days during very hot weather in June. Subsequent growth after irrigation and rains was above normal prior to splitting in October.

It appears that the cells of the peel were injured during the non-growth period by the high temperatures. When favorable growth conditions occurred, cell enlargement and new cell division in this injured area apparently failed to keep pace with cell enlargement in the internal portions so that splitting occurred.

Peel injury apparently was not related directly to high heat (sunburn) but to a water stress within the small fruit. Losses apparently are greater during years when the fruit is smaller than normal in June at the time of the high temperatures. Losses do not appear to be directly affected by the irrigation program followed.

Mesophyll Collapse

Mesophyll Collapse commonly referred to as "electric wind burn" occurs only during late September, October and November. The injury has been associated with dry winds of medium high velocity which may have occurred over a short period. However, in recent years damage has also occurred when the humidity has been relatively high or winds generally light.

Leaves produced on vigorous midsummer shoots are the most susceptible to injury. The underside of the leaf (mesophyll tissue) appears to be damaged first and the leaf may dry rapidly and then drop.

In some instances leaves, which appear to be only slightly injured, drop when they are still green; in other cases the leaf becomes entirely dry and develops a greyish color before dropping. Occasionally leaves may be slightly injured and fail to drop.

Many times the new partly developed leaves on the fall flush of growth at the tip of the shoot are undamaged. In such cases new growth arises from the defoliated branch and no permanent damage occurs. Under severe conditions, however, all leaves on the twig drop, gum exudes from the bark and the twig dies back to the older wood whence it originated. In a few instances where very severe damage occurs the older spring leaves are affected and fruit may drop.

There is no known control for the disorder. Observations on different experimental treatments at the Citrus Experiment Station in the Salt River Valley indicate that the amount of summer growth and the general vegetative condition of the tree affects the susceptibility to injury.

Trees grown with ample water and heavy nitrogen fertilization have been more severely damaged than unfertilized trees or less frequently irrigated trees. Trees which are under a moderate to severe moisture stress at the time the winds occur have been more severely damaged than unstressed trees.

Spraying trees with 2,4-D, nutritional sprays and insecticides to control mites has not reduced the injury. Species differ in susceptibility usually in the following increasing order of resistance: grapefruit, orange, tangerine and lemon.

Granulation

Granulation of fruit develops occasionally, but cannot be considered a serious problem except on Clementine (Algerian) tangerines particularly in the Yuma district. This is a physiological disorder in which the cell walls of the numerous small cells which make up each juice sac thicken and the cell contents become gelatinized.

When this condition develops, carbon dioxide is trapped in the cells causing a white crystal-like effect; thus, the disorder is also referred to as "crystallization."

With Valencia oranges and grapefruit this disease is initiated at the stem end of the fruit and usually occurs on the largest fruit where it is associated with over-maturity. It also may develop following injury from freezing. Losses can be reduced by picking before extensive granulation develops.

With the Clementine tangerine, granulation may develop in early November before the fruit is fully colored and edible. Studies at the Yuma Mesa Citrus Experiment Station have shown that granulation is much more serious in fruit on trees budded on Rough lemon root than in fruit on trees growing on sour orange root.

Irrigation is Factor

Irrigation has been shown to affect granulation; frequent irrigations (one week intervals in the summer) have caused more fruit to develop granulation than infrequent irrigations (three week intervals in the summer). Granulation has usually been more serious when a light crop of fruit is set.

Complete granulation of fruit has been induced in the Clementine tangerine and the Washington Navel orange by a 1/8-inch girdle made in the spring which remained open until September.

Citrus Insect Control

The writers wish to acknowledge the help of Dr. Paul D. Gerhardt, Associate Entomologist, University of Arizona, who assisted in supplying information presented in this section.

Citrus Thrips

Citrus Thrips *(Scirtothrips citri)* is the chief insect causing damage to citrus in Arizona which requires control measures. The insects appear on the new spring twig growth in early March. They rapidly increase in numbers, reaching a peak population at the time blossoms open in April (Figure 17.)

After blossoming the population rapidly drops to a very low level in June. The insects then begin to increase slowly in July and August and rapidly in September so that a second peak of population arrives in early October.

Distorted leaves with silvery streaks are characteristic symptoms of citrus thrips damage; however, the most severe injury occurs on the fruit. A scar ring around the button and scarring of other portions of the fruit is characteristic of severe infestations. This damage occurs when the fruit is very small—between ¼ to ¾ of an inch in diameter.

Thrips begin to attack about the time the flower petals are ready to fall and the young fruit is exposed. Severe injury by this pest may cause loss in crop income by a reduction in the grade of the fruit.

The flower thrips found in citrus blossoms, is sometimes confused with the citrus thrips. Apparently, flower thrips do not damage fruit or foliage.

Control of citrus thrips is necessary in most years particularly with the Washington Navel orange, the Clementine tangerine and the Kinnow mandarin. Insecticides normally are applied in the spring after nearly all of the blossom petals have dropped.

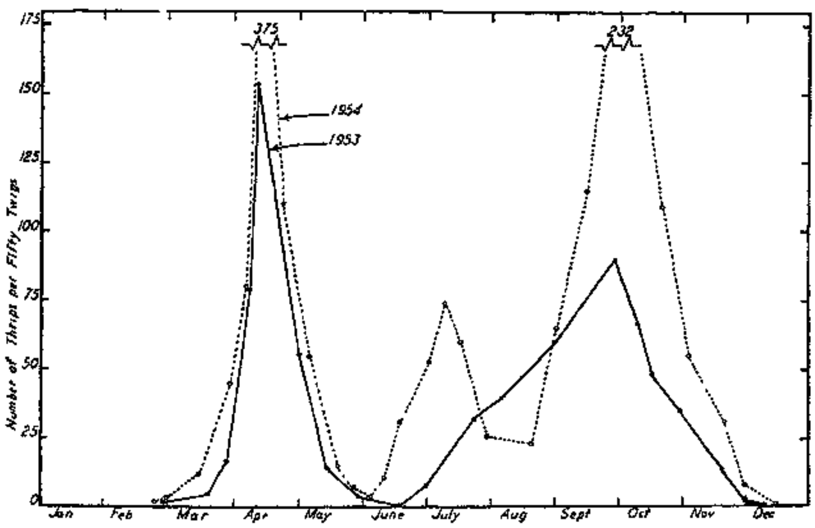


FIGURE 17.—Seasonal changes in citrus thrips population on Washington Navel orange trees in 1953 and 1954 at the University of Arizona Citrus Experiment Station in the Salt River Valley. (Data obtained by Lemac Hopkins; Citrus Field Day Report; Octo. 23, 1954; mimeographed).

TABLE 9.—SPRAY MATERIALS PER ACRE FOR CITRUS THRIPS CONTROL

Material	Spray Rig	Airplane
Dieldren	1/2 lb. or 1/3 gal. 15% E.C. 200-300 gal. water	½ lb. 15 gal. water
Sabadilla	1½ gal. 10 lb. sugar 200-300 gal. water	not used
DDT	6-8 lb. 50% wettable 200-300 gal. water	5% dust 50 lb.
Dieldren plus Wettable Sulfur	1/3 gal. 15% E.C. plus 10 lbs. 200-300 gal. water	2% Dieldren with 40 or 50% Sulfur 30 lbs. dust

Recent work suggests that this control program may be improved by an application of sulfur about 30 days prior to full bloom in addition to the regular spray programs. When high thrips populations build up during the summer and fall serious leaf injury has occurred on the most susceptible varieties mentioned above so control methods are advisable. This is especially necessary with nursery trees, young trees in the field and recently topworked trees.

Tarter emetic sugar sprays and DDT insecticides have been used in the past but the thrips in some areas have apparently developed a tolerance to these materials. Currently, dieldren, and sabadilla (Thrip tox) are in use and very good control has been obtained.

Also, a combination of dieldren and wettable sulfur has been used with good results. This later mix, however, must not be applied when temperatures are above 95° F. because of possible leaf burn from the sulfur. The amount of each material required is set forth in Table 9.

Thrips control programs are under constant study and new materials and methods are being developed. Consult your County Agricultural Agent each year for recommended procedures.

Cottony Cushion Scale

Cottony Cushion Scale *(Icerya purchasi)* infestations became a serious problem on grapefruit between 1950 and 1956. The Vedalia ladybird beetle feeds on the scale and had previously completely controlled it. During the above period high scale populations built up during the early summer before the Vedalia population increased sufficiently to consume them.

Much honey dew was produced by the scale and dropped on the fruit. Sooty mold fungus grew on the honeydew resulting in dirty fruit that required washing. Spraying for control of the scale was required in some groves. Parathion and malathion were both effective.

Since 1956 Vedalia beetles have very efficiently controlled the scale as soon as it appeared.

Brown Wasps

Brown Wasps *(Polistes exclamans)* appeared in the Salt River Valley about 1951 and soon became a problem in that they interfered with picking. Since 1958 they have failed to appear. This insect can be knocked down and killed by spraying the nests with Thanite.

To prepare this spray, mix ½ cup of 100 per cent Thanite concentrate with 2½ gallons of spray base oil. It can be applied from a 3-gallon-compressed-air knapsack sprayer. Approach the tree cautiously and spray the nests which have wasps in them.

Citrus Disease Control

The authors wish to acknowledge and to express their appreciation to Dr. Ross M. Allen, Associate Plant Pathologist, University of Arizona, and to Dr. John B. Carpenter, Plant Pathologist, U.S.D.A.; A.R.S., who collaborated in supplying technical information, revising and presenting the information set forth in this section.

FUNGUS DISEASES

Because of the dry climatic conditions which prevail most of the time in Arizona, only a few fungus diseases cause trouble, and losses from these are slight.

Brown Rot Gummosis

Brown rot gummosis is caused ordinarily by either of two fungi which are prevalent in the soil in most citrus groves. During the cooler weather of winter and spring and in clay loam soils *Phytophthora citrophthora* usually is the causal agent, whereas during the warmer months and in sandy soil types, infection is generally coused by *Phytophthora parasitica.*

The fungus enters the root or trunk when the soil is wet so the danger of infection is increased during periods of above normal rainfall and by over-irrigation particularly in poorly drained soils. The fungus penetrates the bark and spreads through the inner bark, cambium and a thin outer wood layer, frequently girdling the infected part.

The bark first appears water soaked, then turns reddish-brown and finally black. A reddish area develops at the edge of the infection and profuse gumming may occur.

To treat the infection the soil is dug away from the base of the tree so that the lower trunk and upper roots are exposed. The bark and gum in the infected area are cut away and about 3/8 inch of healthy bark removed from around the entire edge of the infected zone to provide healthy tissue for the healing process. The entire area is painted with bordeaux paste. The tree should be observed frequently during the next few months to be sure that the infection has been checked.

Citrus varieties vary in their susceptibility to infection. Rootstocks may be rated in the following increasing order of resistance: Rough lemon, sweet orange, mandarin, sour orange, trifoliate orange hybrids and trifoliate orange.

Sour orange has good field resistance to the fungi, so few infections occur when this rootstock is used. To obtain the maximum value from sour orange rootstock, nursery trees should be budded 6-8 inches above the ground level and the young trees transplanted to maintain this level. Soil should not be allowed to accumulate above the bud union.

Damage to the more susceptible Rough lemon rootstock can be reduced by keeping irrigation water away from the tree trunk. Losses can be reduced in groves where infection is prevalent by removing soil so that the lower trunk, crown and upper main roots are exposed to the air.

Black Rot

Black rot of oranges is caused by the fungus *"Alternaria citri."* Damage is almost entirely confined to the Washington Navel orange. Spores of the fungus enter the navel portion and apparently start to grow in late June. This may cause the fruit to drop during July, or the infected fruit may remain on the tree until it begins to ripen.

As the fruit ripens, the fungus grows into the segments from the central black core of infection in the navel. The fruit colors prematurely and may drop. Normally, less than 2 per cent of the crop is affected so that control measures have not been developed.

Rio Grande Gummosis

Rio Grande gummosis occurs in Arizona in grapefruit trees or the grapefruit portion of topworked trees. It should not be confused with brown rot gummosis which starts at the ground level or at the bud union and spreads upward and laterally, through the bark.

Rio Grande gummosis starts with gum pockets under the bark of the trunk or scaffold branches and may spread upward or downward in the tree. These gum pockets enlarge, break through the wood and rupture the bark longitudinally. Profuse quantities of gum may exude from the wound.

Several lesions may flow simultaneously. Frequently the wood around the pocket becomes pink or orange color. A weakened tree may drop part of its leaves, and develop iron and zinc deficiency symptoms.

In most cases the flow of gum ceases without any treatment after a period of 3 to 12 months. The cambium on the inner side of the damaged bark remains active so the wood quickly heals over the gum pocket.

In most cases the tree returns to normal health and productivity. However, the infection remains in the tree, wood decay may follow and gum outbreaks recur. Frequent recurrences eventually weaken the tree so that it becomes unproductive.

Treating the tree with chelated iron compounds (see page 17) has been observed to hasten recovery.

Trees with somewhat similar symptoms are found in other citrus areas where the disease is called Ferment gum and Florida gummosis. The cause of the disease in Arizona is not known although it appears to be infectious.

Dry Root Rot

Dry root rot, which occurs spasmodically in trees of all ages in Arizona, involves rapid decay of the roots. The first indication of the disease usually occurs when the leaves wilt suddenly. They then dry in place and the tree dies.

In some instances only part of the roots are affected causing death of a portion of the tree. In other instances the damage is less extensive and partial wilting with dropping of leaves occurs leaving the trees weakened and unproductive.

In the early stages, some parts or all of the main and lateral roots show moist decay with the bark soft and spongy. Usually decayed areas spread from lateral roots to the main root system. As the diseases progresses the bark dries and crumbles. The cause is unknown.

VIRUS DISEASES

Virus diseases cause a greater economic loss in Arizona than fungus diseases. The virus diseases described in this section are systemic and are present in the buds.

There is no known cure for them. They can be avoided by selecting budwood from healthy trees. As far as is presently known, the nucellar varieties (See page 8) are much less likely to carry virus diseases than old line strains.

Psorosis Disease

Psorosis Disease "Scaly Bark" is present in Arizona particularly in the Yuma area. Other forms of the disease such as blind pocket, concave gum and crinkly leaf, are caused by different strains of the vrius and seldom occur in Arizona.

Small pustules arise on the trunk and main scaffold branches usually after the trees are 15 to 20 years old. These eruptions enlarge with formation of numerous small scales of dry bark. Large areas may show scaling.

Gumming frequently occurs as the disease becomes more severe. The tree gradually declines, becomes unproductive and must be removed. In some regions scraping the trunk to the green portion and applying dinitro compounds has prolonged the life of diseased trees. The disease is transferred only through budwood.

Stubborn Disease

Stubborn Disease is considered to be caused by an unidentified virus or group of viruses. It causes the most serious economic loss in the widely infected old line Washington Navel orange where production has been reduced up to 40 per cent on the trees in many old groves.

It is widely prevalent in grapefruit, but tree growth and production are usually not seriously reduced. It occurs less frequently in the Valencia orange and is rarely found in sweet seedling varieties.

Affected trees may be classified into three growth type groups. (1) Growth is stunted early in the life of the tree. Spring growth is characterized by short twigs with multiple lateral bud development which causes the tree to be flat-topped and brushy. Slow dieback of brushy growth occurs. Yields and fruit quality are markedly reduced. Many Washington Navel but very few Valencia and grapefruit trees are in this group.

(2) Nearly normal growth for many years followed by development of symptoms described in group 1. Such conditions frequently begin to appear on the south and top part of the tree and spread slowly throughout the tree. Excessive leaf drop and die back of seemingly normal branches may occur. Washington Navel and almost all infected Valencia orange trees are in this group (Figure 18).

(3) Practically normal tree growth with only slight evidence of the disease in a few fruit. Most infected grapefruit trees are in this group.

The most reliable symptoms of the disease in Valencia and grapefruit appear in the fruit which develops an "acorn" shape as a result of reduced growth at the stylar end during the winter. Also, many fruit may be abnormally small and the inner white peel may develop a blue color. In Washington Navel, however, the fruit are usually large, coarse, lacking in flavor and few "acorn" types develop.

Other conditions commonly associated with stubborn disease are: horizontal ridges on the trunk formed by slow growth of semi-dormant multiple buds; occasional honeycomb pitting of the bark near the bud union with corresponding pegs in the wood; off season bloom between August and December; heavy defoliation in December; abnormal leaf growth with spring leaves upright and curled upward or drooping and curled under, and unusually rounded summer leaves with prominent white midribs; zinc mottle, iron chlorosis and irregular yellow leaf mottle patterns.

There is no known cure for Stubborn Disease. Trees in group 1 have never been observed to recover and must be removed. Orange trees in group 2 have responded to soil treatments with chelated iron, but it is doubtful if the treatment is of economic value.

Washington Navel trees of type 2 have been topworked to Lisbon lemon and reasonably good growth and fruiting have occurred. Trees of Marsh grapefruit in group 3 have been topworked with Valencia orange which has grown vigorously without evidence of the disease for 10 years.

The disease is apparently transferred primarily through budwood.

FIGURE 18. — Washington Navel orange tree seriously affected with Stubborn disease (Class 2). Tree is 28 years old. This tree produced about 60% of normal yield until 18 years old. During the following 10 years yields gradually declined to a few fruit.

Tristeza

Tristeza, also known as Quick Decline in California, seriously stunts or kills sweet orange trees growing on sour orange rootstock. The virus induces plugging of the food conducting vessels in the bark (phloem) near the bud union. This reduces movement of nutrients to the roots so they are weakened and unable to function properly.

When severe moisture stresses occur the leaves may wilt and die rapidly. In instances where the plugging is incomplete the tree is only stunted.

The virus is transferred from tree to tree by several species of aphids as well as in budwood. When tristeza is established in a citrus district, oranges can be grown only on tolerant rootstocks which are not affected by the disease. Such tolerant rootstocks include: Rough lemon, sweet orange, Cleopatra mandarin, Troyer citrange, trifoliate orange and many others.

In Arizona the disease is present in nearly all Meyer lemon trees but so far has not been found in orange varieties. An order has now been issued by the Arizona Commission of Agriculture and Horticulture prohibiting further propagation of the Meyer lemon and infected trees in groves and homesites are being removed.

Most progressive citrus growers have voluntarily removed these Meyer lemon trees for the benefit of the industry. Arizona has a unique geographical isolation from other citrus areas, so that by the removal of these trees it can become disease free.

Because of the presence of the disease in California coastal areas, it rep-

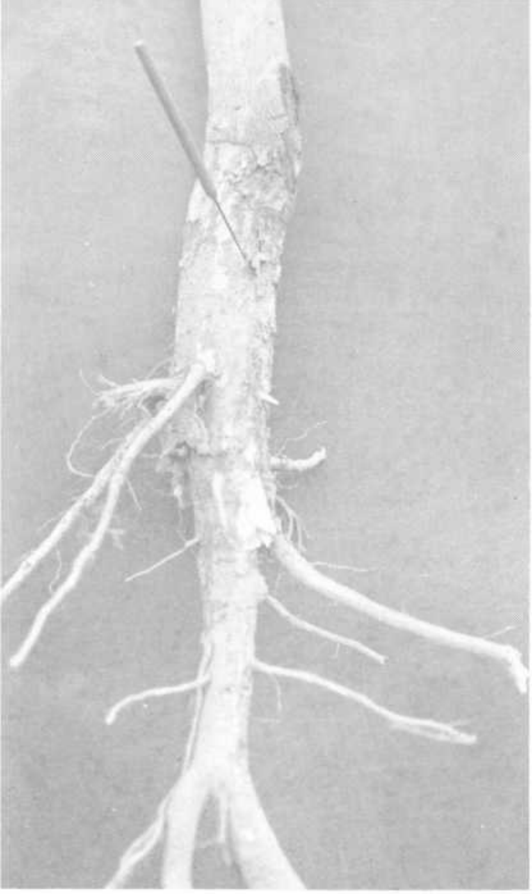


FIGURE 19. — Exocortis disease showing bark scales and decayed tap root on Rangpur lime rootstock budded with Redblush grapefruit. Virus infection was introduced from Redblush grapefruit scion.

resents a menace to Arizona trees. However, it has been present in these areas for about 19 years and has not yet spread to the Coachella Valley; therefore, the danger of spread to Arizona presently does not appear to be serious as long as all citrus plants are indexed for tristeza before being brought into the state and present quarantine regulations remain in force.

Xyloporosis

Xyloporosis is apparently widely prevalent in Arizona citrus trees, but because the sweet orange, grapefruit, acid lemons and sour orange are highly tolerant to its major effects it has not been detected. When susceptible varieties are infected, the virus causes deformed wood and bark growth chiefly near the bud union. Deep pits are formed in the wood and corresponding pegs develop in the bark. Reddish brown gum accumulates in the bark which undoubtedly restricts the movement of nutrients so the tree is stunted.

Susceptible varieties are damaged when used as either a stock or scion. Among the susceptible varieties are Rough lemon, Palestine sweet lime, many tangelo varieties (especially Orlando), most mandarin varieties, kumquat and calamondin. Although effects of this virus cannot be readily detected on tolerant varieties it appears possible that it may be related to the loss of vigor and decline of old trees.

The disease appears to be transferred only through budwood.

Exocortis

Exocortis only affects seriously the Rangpur lime, trifoliate orange and certain trifoliate orange hybrids which are used principally for rootstocks. When infected varieties are budded on these rootstocks the disease causes thin scales to develop on the bark of the rootstock portion of the trunk and upper roots (Figure 19). This bark damage interferes with normal root growth and the tree is stunted. Because the susceptible rootstocks have not been used commercially in Arizona no evidence of the disease is present. Nevertheless, recent tests indicate that exocortis is widespread in Arizona trees.

All oldline Redblush grapefruit, many Clementine tangerines, and lemons are infected. The disease has been found in Marsh grapefruit, Washington Navel, Valencia, and Hamlin oranges, Eureka, Villafranco and Lisbon lemons. It may have a possible relationship to the highly variable fruiting and rootstock responses associated with Clementine tangerine.

Nematodes

The technical information presented in this section was provided by Dr. Harold Reynolds, Nematologist, U.S. Dept. of Agri., Agri. Research Service.

Small feeder citrus roots are attacked by microscopic worms called nematodes. Surveys have shown that about 50 percent of Arizona groves have populations of the citrus nematode *Tylenchulus semipenetrans*, and many groves were found with populations of dagger and stylet nematodes.

Nematodes can be controlled by nematocides without injury to trees.

The citrus nematode enters and feeds on small roots. Soil particles cling rather tightly to infested roots because the worms secrete a gelatinous material around egg masses. If such incrusted roots are found the presence of nematodes may be suspected.

Emulsifiable dibromochloropropane applied in irrigation water at the rate of 2 gallons of actual material per acre has resulted in almost 100 percent reduction in population. When complete groves were treated and a good kill obtained only a slight build up has occurred during the following 4 year period.

The effect of nematodes upon citrus tree growth and production in Arizona has not been completely demonstrated. In some instances good cultural practices have apparently maintained satisfactory trees even though large populations were present. However, certain badly infested groves have eventually become less productive. Recent tests at Yuma and in the Salt River Valley have shown that treatment of old groves where nematode populations were high has significantly increased the yield of fruit and enlarged the size of the fruit.

In groves where nematodes are present, the fruit is small and shoot growth is weak, a control program should be initiated in part of the grove. When a response is noted the remaining part of the grove can be treated. Best results have been obtained when control measures are combined with pruning and heavy nitrogen fertilization.

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