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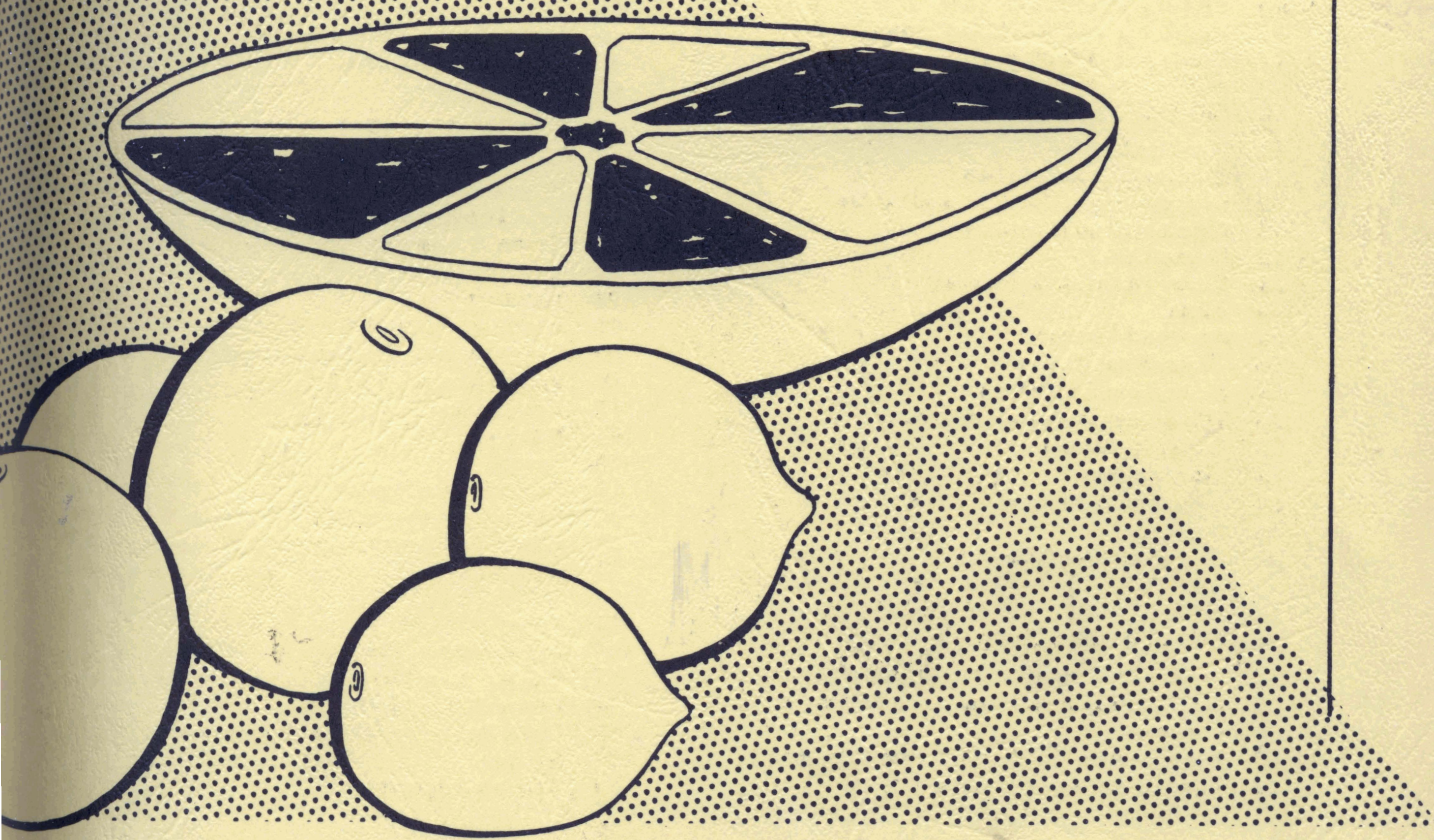
Guide for Citrus Production

in the Lower Rio Grande Valley



TEXAS A&M UNIVERSITY

TEXAS AGRICULTURAL EXPERIMENT STATION . . . TEXAS AGRICULTURAL EXTENSION SERVICE

College Station, Texas

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VALLEY CITRUS AND ITS POTENTIAL

*Norman Maxwell, Ralph Petersen, Robert Orton and Donald Haddock**

The earliest record of citrus planted in the Valley is a planting of seedling orange trees, made by Don Macedona Vela in the early 1880's, on the Laguna Seca Ranch, north of Edinburg. John Shary was one of the early pioneers in developing the citrus industry in the Valley and is generally known as the father of the Texas citrus industry.

One of the earliest successful commercial citrus plantings on sour orange rootstock was made by Charles Volz in 1908. Previous commercial plantings had been made by others on trifoliate orange rootstock but the trees did not survive because trifoliate orange is not adaptable to high alkaline soils and water containing high chlorides.

The Valley citrus industry came into recognition in 1920 when about 124,000 trees were reported for the area. The rate of tree plantings increased to a peak of near 14,000,000 trees in 1949. The 1949 and 1951 freezes reduced the number to 3,500,000. At the time of the 1962 freeze, which destroyed about 30 percent of the trees, there were close to 7,000,000 trees in the Valley.

Production figures for 1919 through 1962 are shown in Table 1.

The many changes in the Valley citrus industry have been gradual, but many were focused on disasters like the 1934 hurricane, 1949, 1951, and 1962 freezes. After every disaster the industry has come back better in some respect than it was before.

Early plantings were mainly white seedy grapefruit and seedy oranges. Varieties gradually changed to white seedless and pink grapefruit and a mixture of seedy and seedless oranges. After the discovery of budsports of red grapefruit in 1929 and 1931, new plantings of grapefruit were changed to red seedless grapefruit. Most orange plantings are now of the seedless varieties, but some seedy pineapple groves are planted, principally for processing.

Most of the major variety changes were tied closely to freezes and market preference. Until 1951 there were still many old groves with mixed varieties of seedy white and seedless white grapefruit, pink seedy and seedless grapefruit, and seedless oranges. After the 1951 freeze, when 80 percent of the existing industry was destroyed, most new plantings of grapefruit were red grapefruit and a few white marsh for specialty processing. New orange plantings were seedless early oranges, a few seedy pineapple oranges in mid-season, and the Valencia—a late season variety.

Other changes over the years include:

1. Closer tree spacing
2. Greater use of mechanical grove care equipment

Table 1. Texas citrus fruit production in boxes (1 3/5 bu. boxes).

	Oranges	Grapefruit	Total
1919-20	9,000	3,000	12,000
1920-21	5,000	5,000	10,000
1921-22	5,000	8,000	13,000
1922-23	10,000	35,000	45,000
1923-24	6,000	65,000	71,000
1924-25	17,000	301,000	318,000
1925-26	12,000	200,000	212,000
1926-27	41,000	361,000	402,000
1927-28	85,000	524,000	609,000
1928-29	125,000	753,000	878,000
1929-30	261,000	1,550,000	1,811,000
1930-31	250,000	1,200,000	1,450,000
1931-32	520,000	2,600,000	3,120,000
1932-33	325,000	1,440,000	1,765,000
1933-34	430,000	1,200,000	1,630,000
1934-35	650,000	2,740,000	3,390,000
1935-36	777,000	2,780,000	3,557,000
1936-37	2,000,000	9,630,000	11,630,000
1937-38	1,440,000	11,840,000	13,280,000
1938-39	2,815,000	15,670,000	18,485,000
1939-40	2,360,000	14,400,000	16,760,000
1940-41	2,650,000	13,650,000	16,300,000
1941-42	2,850,000	14,500,000	17,350,000
1942-43	2,550,000	17,510,000	20,060,000
1944-45	4,400,000	22,300,000	26,700,000
1945-46	4,480,000	24,000,000	28,480,000
1946-47	5,000,000	23,300,000	28,300,000
1947-48	5,200,000	23,200,000	28,400,000
1948-49	3,400,000	11,300,000	14,700,000
1949-50	1,760,000	6,400,000	8,160,000
1950-51	2,700,000	7,500,000	10,200,000
1951-52	300,000	200,000	500,000
1952-53	1,000,000	400,000	1,400,000
1953-54	900,000	1,200,000	2,100,000
1954-55	1,500,000	2,500,000	4,000,000
1955-56	1,600,000	2,200,000	3,800,000
1956-57	1,773,955	3,824,514	5,598,469
1957-58	2,000,000	3,500,000	5,500,000
1958-59	2,300,000	4,200,000	6,500,000
1959-60	2,800,000	5,500,000	8,300,000
1960-61	3,500,000	6,500,000	*10,000,000
1961-62	2,200,000	2,600,000	4,800,000

Source: USDA - AMS.
Compiled and distributed by the Valley Chamber of Commerce, Weslaco, Texas.
*USDA estimate.

*Respectively, associate horticulturist, Texas Agricultural Experiment Substation 15, Weslaco; farm management specialist, Texas Agricultural Extension Service, Weslaco; state climatologist, Weather Bureau Airport Station, Austin, Texas; and advisory agricultural meteorologist, Weather Bureau Agricultural Service Office, Weslaco, Texas.

3. Centralization of the citrus industry on soils most adaptable for citrus production.

COMPARISON TO OTHER AREAS

The potential for profitable citrus production in the Rio Grande Valley compares favorably to other U. S. Citrus producing areas, because of relatively low production costs and high quality fruit. The major disadvantage of citrus production in Texas is the hazard of a killing freeze. Unless an effective economical cold protection system can be developed, the risk of a killing freeze can offset any competitive advantage the Valley may have in production costs and fruit quality.

The yearly costs of operation in Texas are much lower than corresponding costs in other citrus producing areas. These costs include fertilizer, irrigation water, insecticide, machinery operation, labor, and taxes. Costs of establishing and developing an orchard in Texas are also much less than similar costs in competing areas.

Recurrent freezes in Texas have prevented citrus trees from maturing enough to produce heavily for sustained periods of time. The short time over which the establishment and development costs must be distributed has, in the past, meant that investment costs were high in Texas when compared to other areas where trees have produced over 40 years.

Yields from trees of the same age generally are lower in Texas than in California or Florida. However, these low yields are offset by the low production costs in Texas.

Costs of marketing Texas fruit probably are higher than similar costs in other areas because of the high variation in annual production. An additional factor could be the large number and small size of agencies marketing the fruit. Transportation costs from Texas to South Central and Mid-Western states are somewhat lower than such costs from other areas. The market area within which Texas has a transportation advantage should be large enough to absorb a substantial part of the fruit produced in Texas.

Market acceptance or consumer preference for Texas fruit is good compared to fruit from other areas. While the high quality of Texas fruit makes it especially suited to fresh sales, the trend in citrus consumption is to processed products. Facilities for processing citrus products are available in the Valley and should allow the Texas producer to sell his fruit for use in the most profitable form.

GENERAL DESCRIPTION OF CLIMATE

The Lower Rio Grande Valley (Cameron, Willacy, Hidalgo, and Starr Counties) has a subtropical, semiarid climate. Moist air from the Gulf of Mexico has a moderating effect on Lower Valley temperatures. The average daily minimum temperature of the coldest month, January, ranges from 52 degrees at Brownsville to 46 degrees at Rio Grande City, as shown in Table 2.

Freezes (32 degrees F or lower) do not occur every year in the Lower Valley. A fall freeze occurs about 7 years out of every 10, on an average, at Rio Grande City; 3 years out of every 5 at Mission; 1 year out of every 2 at Raymondville; and 2 out of every 5 at Harlingen. Spring freezes occur about 3 years out of every 4, on an average, at Harlingen and Raymondville; 4 years out of 5 at Mission; and 9 years out of 10 at Rio Grande City.

In general, average annual rainfall decreases as the distance from the Gulf of Mexico increases. Table 3 shows that it varies from about 26 inches in Willacy and Cameron Counties to around 19 to 23

Table 2. Minimum temperature (° F.) 1931-1962.

Station	Min. Temp.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Brownsville	Mean	52.2	55.1	59.3	65.6	71.1	75.0	76.1	75.9	73.2	67.2	58.5	53.8	65.3
	Extreme	19.0	22.0	32.0	41.0	53.0	64.0	68.0	66.0	55.0	44.0	34.0	29.0	19.0
Raymondville	Mean	49.4	52.3	57.1	63.7	69.0	72.5	73.4	73.0	70.8	63.9	55.1	50.8	62.6
	Extreme	14.0	19.0	28.0	37.0	48.0	59.0	65.0	61.0	51.0	40.0	28.0	26.0	14.0
Weslaco	Mean	50.7	53.9	58.3	65.7	69.9	73.3	74.1	73.8	71.2	64.8	56.7	52.2	63.7
	Extreme	16.0	19.0	31.0	38.0	47.0	61.0	67.0	62.0	48.0	40.0	30.0	24.0	16.0
Mission	Mean	48.4	51.7	56.5	63.6	69.3	73.1	74.1	73.8	71.0	63.9	54.9	49.8	62.5
	Extreme	18.0	19.0	31.0	39.0	48.0	59.0	67.0	63.0	51.0	40.0	29.0	25.0	18.0
Rio Grande City	Mean	46.2	49.7	54.7	62.0	68.8	73.0	74.3	73.8	70.5	62.8	52.6	47.6	61.3
	Extreme	10.0	15.0	28.0	32.0	44.0	56.0	59.0	60.0	52.0	39.0	27.0	23.0	10.0

Table 3. Mean precipitation (inches) 1931-1960.

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Brownsville	1.35	1.48	1.04	1.55	2.36	2.96	1.68	2.77	4.99	3.53	1.32	1.72	26.75
Raymondville	1.83	1.15	1.30	1.45	3.48	2.46	1.94	3.00	4.65	2.57	1.37	1.33	26.53
Weslaco	1.66	1.03	1.07	1.53	2.70	2.46	1.71	2.67	4.13	2.10	1.02	1.26	23.34
Mission	1.35	1.00	0.88	1.61	2.22	1.94	1.58	1.66	3.24	2.05	0.74	1.02	19.29
Rio Grande City	0.94	0.79	0.85	1.26	2.10	2.01	1.37	1.69	3.13	1.84	0.61	0.68	17.27

inches in Hidalgo, and to near 17 inches in Starr County. Most of the precipitation falls in the form of thundershowers, thus amounts are unevenly distributed both geographically and seasonally. Large variations may exist over relatively small areas. Long term weather records show that the most rain for any one month falls in September.

The general inadequacy and variability of rainfall necessitates the use of supplemental irrigation water for successful production of most agricultural crops in the Lower Rio Grande Valley.

The distribution of relative humidity is similar to rainfall. Highest values are observed along the coast; the lowest in the extreme western portion of Starr County. Mean annual relative humidity ranges from about 75 to 80 percent in Willacy and Cameron Counties to 65 to 70 percent in Starr County. Although monthly variations are small, lowest mean monthly relative humidities occur in March or April, and again in July and August. Highest monthly mean relative humidities occur in January and February, and again in May. Daily values are usually highest just before sunrise, and lowest during mid-afternoon. Mean relative humidity for selected hours at Brownsville and Laredo are shown in Table 4.

Table 4. Mean relative humidity for selected hours at Brownsville and Laredo, Texas.

Station	Mean relative humidity (%)				
	Year of record	Mid-night	6:00 a.m.	Noon	6:00 p.m.
Brownsville	1940-61	87	90	61	71
Laredo	1944-61	71	82	51	45

Source: Local Climatological Data, U. S. Weather Bureau, 1961.

SELECTING A SITE

*Morris Bailey, Norman Maxwell, David Carter and Donald Haddock**

Soil, water, and topography are major factors for consideration in selecting a site for citrus production.

SOIL FACTORS

Soils in the Lower Rio Grande Valley vary in texture from coarse sandy loams to fine textured clays. The best soils for citrus growing are deep and well drained. They should have a subsoil free from tight clay layers, and the free water table should not come higher than five feet from the surface.

The coarser textured soils in the Valley are the best citrus soils. These are classified as Brennan, Willacy, Delmita, and Hidalgo series. Clay lenses often occur at 4 to 6 feet in some of these soils and require tile drainage in order to grow citrus. Citrus production is also possible on Laredo, Raymondville, and other soil series of finer texture where drainage is good.

Before land is planted to citrus, a profile study of the area should be made to determine whether it has the characteristics to make a good orchard soil.

WATER QUALITY

Irrigation water quality depends upon the amount and kinds of dissolved salts the water contains. Chemical analyses will show what salts are present and the amount of each. From such analyses, the suitability of water for irrigation is determined, and irrigation waters are classified according to their total salt concentration in parts per million (ppm).

Citrus is salt sensitive. The recommended use of various classes *of irrigation water for citrus are* presented below.

CLASSIFICATION OF WATER	SALT CONCENTRATION, P.P.M.
C1—LOW - SALINITY WATER can be used for irrigation of citrus on most soils with little likelihood that a salinity problem will develop. Normal irrigation practices provide the small amount of leaching required to assure no salt accumulation.	**0 to 200**
C2—MEDIUM - SALINITY WATER can be used for citrus irrigation if a moderate amount of leaching occurs. Water in excess of that required to wet the rooting zone soil should be applied to provide for moderate leaching. The soil must have adequate natural or artificial drainage.	**200 to 500**
C3—MODERATELY HIGH - SALINITY WATER can be used occasionally for citrus irrigation if high amounts of leaching occurs. Several inches of water over that needed to wet the rooting zone soil should be applied at each irrigation. Adequate natural or artifical leaching is required. If possible, the next irrigation should be with better quality water, with some excess applied for leaching.	**500 to 1000**
C3B—HIGH-SALINITY WATER should not be used for citrus irrigation except to save trees that may die because of drouth. Use of this water may cause defoliation as well as other damage to trees. Following use of this low quality water, an irrigation with good quality water should be applied as soon as such water is available. Excess good quality water should be applied to provide for leaching.	**1000 to 1500**
C4—VERY HIGH - SALINITY WATER should not be used for citrus.	**Above 1500**

In addition to total salt concentration, other minerals must be considered when determining the suitability of irrigation water. These include boron, chloride, sodium, and residual carbonate plus bicarbonate concentrations. Only water with less than 1 ppm of boron are recommended for citrus irrigation. The best waters contain less than 0.3 ppm boron. Irrigation waters containing between 0.3 and 1.0 ppm boron may cause some boron toxicity to citrus. When necessary to use waters of the latter group, occasional irrigations with low boron waters (less than 0.3 ppm) should be applied in excess so that some leaching will occur.

Waters with a sodium-adsorption-ratio level below 8 are safe for citrus irrigation. Those with SAR levels of 8 to 15 are marginal, and continued use of waters with SAR levels above 20 will undoubtedly lead to serious sodium problems. Excessive residual carbonate plus bicarbonate in irrigation waters also will cause serious sodium problems with continual usage. Residual carbonate plus bicarbonate concentrations below 1.25 milliequivalents per liter are generally safe. Residual carbonate plus bicarbonate con-

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centrations between 1.25 and 2.50 milliequivalents per liter are marginal, and concentrations above 2.50 milliequivalents per liter are excessive.

Soil drainage, water supply sufficiency, and water application techniques also must be considered in relation to water quality. Where leaching is required, the source of water must supply enough water to accomplish the leaching, and drainage must be adequate for such leaching. Generally, sprinkler irrigation is not advisable for citrus except with the best quality waters for citrus can accumulate salts through leaves and through roots. Salt damage from a given water appears much earlier when citrus is sprinkler irrigated than when it is irrigated by other techniques.

Irrigation waters of the Lower Rio Grande Valley are of the medium to moderately high salinity classes. Many well waters also contain excessive boron concentrations and high SAR levels. Some well waters contain excessive residual carbonate plus bicarbonate concentrations. Most of the medium to moderately high salinity waters also contain high chloride concentrations that cause specific chloride toxicity to citrus.

Rainfall in the Lower Rio Grande Valley is adequate to provide a sizeable fraction of the water for citrus. Seasonal rains usually account for several irrigations each year. Often rains provide the occasional leaching with good quality water needed when using moderate to high salinity and boron waters for irrigation. Such leaching occurs only where soils are well drained, however.

Growers should use the highest quality of water available. They should be particularly cautious of well waters, since most of these waters are too high in both total salt and boron for citrus irrigation.

WATER AVAILABILITY

The water sources for the Lower Rio Grande Valley include natural precipitation, the Rio Grande River, and ground water. Generally, these sources supply adequate water for most land developed for irrigation in the Valley. Water shortages are common and sometimes severe, however.

The annual precipitation varies widely from year to year and may be several inches below average sometimes. When precipitation is below average, severe water shortages may result unless adequate irrigation water is available.

Shallow and deep wells supply irrigation water for 8,000 to 10,000 acres in the Valley. Additional acreages are irrigated from wells during drouth periods, but often, the water from these occasionally-used wells is of poor quality.

The principal source of irrigation water is the Rio Grande River. The Falcon Reservoir agreement allows for irrigation of about 750,000 acres in the United States below Falcon Dam, but the quantity of water needed to irrigate this acreage is not always available. Thus, water must be withheld from some eligible land in order that acreage planted to citrus can be adequately irrigated.

TOPOGRAPHY FACTORS

Cameron, Hidalgo, and Willacy are the principal citrus producing counties in Texas. They are in a generally flat and featureless plain with poor natural drainage. The elevation increases from sea level along the coast to 37 feet at Harlingen, 75 at Weslaco, 96 at Edinburg, and to 225 feet at McCook.

Even though the terrain features are poorly defined, they do affect the minimum temperature patterns under certain meteorological conditions. The elevation and slope of a site will influence the amount and rate of cold air drainage from adjacent fields into groves on calm, clear nights. Cold air, being heavier than warm air, sinks and moves downslope to a lower elevation when the nightime wind speed is generally less than three or four miles an hour. The cold air collects in bottoms or depressions, commonly called "cold pockets." In these cold pockets, citrus trees are subjected to temperatures a few degrees colder than those on top of small ridges during calm clear nights when radiation is maximum.

On the other hand, during periods of high northerly winds, citrus trees on top of small ridges and exposed northerly slopes may be subjected to temperatures a few degrees colder than those in bottoms or depressions and on southerly slopes.

IRRIGATION, SALINITY, AND DRAINAGE

*V. I. Myers, P. E. Ross and D. L. Carter**

IRRIGATION SYSTEMS FOR CITRUS GROVES

Surface irrigation is the predominant method used in Lower Rio Grande Valley citrus groves. If the system is properly designed and installed before the grove is planted, good irrigation efficiencies may be obtained with minimum labor. It is generally difficult to use surface irrigation efficiently in non-level groves, and it is almost impossible to do any major land forming after the grove is established. Some of the early citrus orchards were planted on slopes ranging from 1.5 to 3.0 percent.

A properly designed system will include land forming to proper grade, proper length and width of areas irrigated, adequate irrigation stream size, and an adequate delivery system. Assistance in design and installation of irrigation systems may be obtained by the landowners from the Soil Conservation Service through the Soil Conservation Districts.

Include as much area in one level plane as practical when leveling land for either citrus or row crops. Where topography permits, entire fields are leveled to one elevation. If the natural slopes are such that excessive top soil must be removed from the cut areas of the fields, bench leveling must be used. Whether the benched areas are straight or follow the contour of the land depends upon the degree and direction of slope. Less soil is removed when the benches follow the contour, but some grove owners prefer straight borders because of field appearance and harvesting ease. In some cases, the irrigation delivery system is more costly on contour benched land than it is for straight benches.

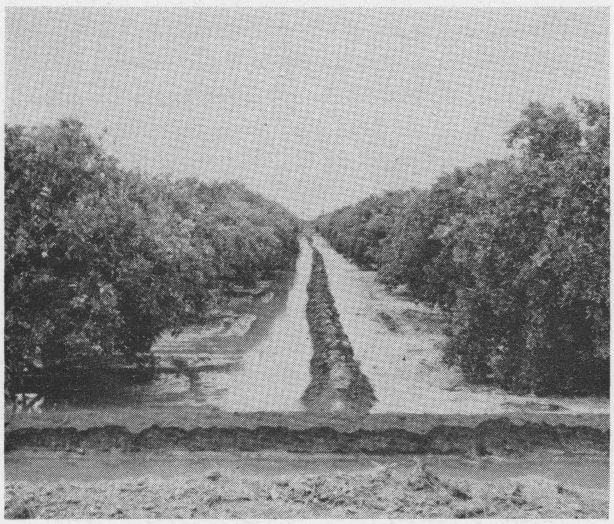

Fig. 1. Flooding is the most commonly used method of irrigating orchards, but it is the least efficient method.

Zero grade is best when it can be obtained without excessive removal of top soil from the cut areas. Permanent border ridges should be constructed to enclose level areas. The ridges should have an effective settled height of not less than 1 foot, and where tillage equipment must pass over the ridges, the side slopes should be flat enough for easy crossing. Side slopes of 6:1 can be negotiated easily by grove village equipment. The border ridges limit the width of the area irrigated with one irrigation stream and retain all water, whether irrigation or rainfall, which is applied to or falls in the area. The borders also prevent rainfall runoff from the tree area where they are used between each tree row.

The best Valley citrus soils are the sandy loams. They have good soil permeability. For this reason, irrigation runs generally should not be longer than 450 feet; in most of the sandier soils, better distribution of water can be obtained on runs of about 320 feet. The width for border irrigating should be the tree row width, which will range from 18 to 30 feet in most of the newly-planted groves. Some grove owners prefer to use a border for each two rows of trees, but where this is practiced, large irrigation streams are necessary to move the water over the land fast enough to cover the area in 30 to 45 minutes. Border widths in excess of 50 feet are not recommended.

On level borders, irrigation stream sizes of .04 to .08 cubic feet per second (c.f.s.) per foot of border width are adequate for uniform water distribution. Where clean cultivation is practiced and smooth border surfaces are maintained, the smaller stream will travel along the irrigation run at about 10 feet per minute. For soils on which citrus is planted, coverage of the soil with water in 30 to 45 minutes gives good distribution of water. If cover crops or mulches are present in groves, the irrigation stream must be

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larger to overcome the friction to flow of water caused by the cover.

The irrigation delivery system is an extremely important part of the overall system. Good physical control of the water helps achieve proper water distribution and to minimize labor requirements.

Underground concrete pipe with turnout valves for each tree row is an excellent delivery system. The initial cost of such a system is high but maintenance costs are comparatively low. Furthermore, no land is lost to the pipeline right-of-way, and a maximum area may be irrigated with little labor. Water may be applied uniformly to each tree row simply by regulating the amount of time each valve remains open.

The pipeline should be laid to a uniform grade and covered by at least 2.5 feet of soil. Surge pipes should be installed at the distal end of each pipe, at all turns of 90 degrees or less, and at the high point where 10 degree changes in grade are downward in the direction of flow. Where long lines are laid, it is well to have vents or surge pipes at least every 1,000 feet.

Pipeline size depends, of course, upon the volume of water to be handled. It is well to use sizes large enough to operate the system under minimum pressure heads consistent with the volume of water to be transported. Pressure heads in excess of 25 feet should be avoided in ordinary concrete pipe.

Turnout valves should be located in each bordered area to be irrigated. The valve should be of adequate size to handle the irrigation stream called for in the designed system. In sandy or easily eroded soils, the turnout valve should be installed 4 to 6 inches below the natural surface of the land. When this is done, the initial velocity of the water from the valve is reduced materially before it begins to spread over the border and lessens erosion near the turnout.

Pipeline delivery systems are highly desirable for citrus groves planted in contour borders. The enclosed system eliminates most difficulties in transporting irrigation water down steep slopes, and it reduces border ridge maintenance problems, since ridge cutting is not required to introduce water to lower borders.

Open ditch irrigation delivery systems are commonly used on fields where the gradient does not cause erosion. Frequently, these are temporary ditches built for each irrigation application, and they are destroyed during subsequent tillage operations. If open earth ditches are permanent or semi-permanent, a serious weed problem develops and tillage is inconvenient. Where open ditches are used, the water is generally delivered to the tree rows through cuts through the ditch bank. It is difficult to apply the same amount of water to each border using this method, because the opening in the ditch bank often increases in size as water passes through it. The labor involved in opening and closing the cuts is considerable, and the work involved is unpleasant. The initial expense of open ditch delivery systems is not great compared with other systems, but operation and maintenance costs are high.

Sprinkler irrigation systems are used effectively in groves established on sloping lands. It sometimes is tedious to fit the rate of the sprinkler output with the water intake rate of the soil, but doing so is necessary if best results are to be obtained. Outputs over one inch an hour generally exceed the intake rate of the soil and cause runoff, ponding, or both. The irrigator will often move the pipe when some ponding begins, without realizing that the upper slopes of the land may not have received enough water. If he does this too many times, the under-irrigated areas become drouthy, sometimes salty, and production is reduced.

Two types of sprinkler irrigation systems available in the Valley are pressure perforated pipe and rotary sprinklers. Rotary sprinklers generally cover more area per setting than do perforated pipe systems. But in larger trees, it is difficult to avoid blanked-out areas where tree foliage intercepts spray from rotating heads. Perforated pipe generally covers no more than one tree row width per setting and thus labor costs for moving are high. The perforated pipe may be operated on as little as 15 pounds per square inch (p.s.i.), however, whereas the rotary sprinklers require 45 p.s.i. or more.

Fig. 2. Closely mowed sod in conjunction with sprinkler irrigation is a popular system of orchard management.

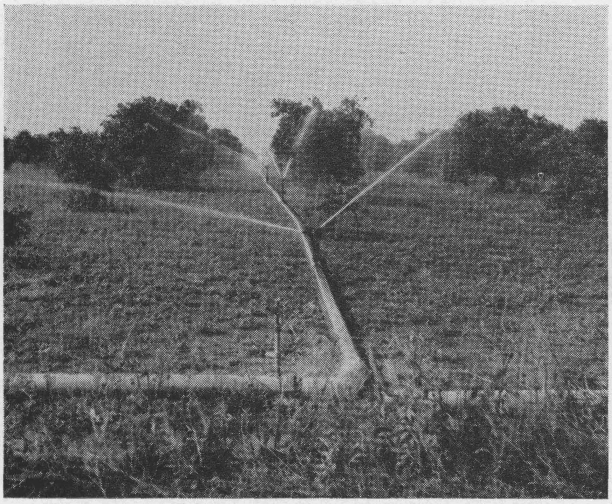

Fig. 3. Sprinkler irrigation is most efficient, especially on rolling land.

In choosing a sprinkler system, the owner should consider the cost and availability of labor versus the cost of power for operation and initial costs of the system.

Regardless of the type of irrigation system a grove owner may install, his results will only be as good as his system management. He must know when to irrigate and how much water to apply for best results. Above all, he must supervise the operation to make sure his instructions are carried out.

SALINITY PROBLEMS

Citrus is most sensitive to salinity. Both total salt concentration or osmotic effects and specific ion effects are pronounced in citrus.

Osmotic effects limit water absorption and combine with specific ion effects to cause leaf burning, necrosis, and in extreme cases, complete defoliation, twig die-back, and death of trees. Specific ions that severely damage citrus when present in high concentration are chloride (Cl^-), sodium (Na^+), and bicarbonate (HCO_3^-). Other ions have been reported to cause damage in some cases. Boron is also extremely toxic to citrus. It is often difficult to distinguish between the effects of total salts and those of specific ions. Usually, when total salt concentration is high enough to damage citrus, specific ion accumulations have also reached toxic levels.

The total salinity level of soil is determined by measuring the electrical conductivity of the saturation extract (ECe) in millimhos per centimeter and parts per million. Generally, citrus can be produced with little likelihood of salinity damage on soils with salinity levels below 1280 ppm throughout the rooting zone. Citrus can be grown on soils with salinity levels between 1280 and 2560 ppm with special management practices such as intermittent leaching and more frequent irrigations. Yields are usually lowered in spite of special management practices. Generally, tree survival is poor and production low on soils with salinity levels above 2560 ppm.

Soils of many areas in the Lower Rio Grande Valley are too saline for citrus production. Many of these soils have inadequate natural drainage and are difficult to drain artificially. Generally, since the coarser-textured, well-drained soils are least likely to be saline, they are the best for citrus production.

DRAINAGE PROBLEMS

Poor drainage, with the accompanying salinity problems, causes more damage to citrus than is ordinarily realized. Damage from high water tables and salinity usually are not recognized until trees begin to lose leaves or show other signs of extensive damage. Fruit yields frequently are reduced even though damage is not readily apparent.

Even the better citrus soils of the Valley are subject to high water tables and surface ponding in some areas. Drainage problems can exist in groves of irregular topography where ponding occurs or on leveled fields as a result of a rise in the water table. In many cases, the soils may allow free movement of water downward for several feet until an impervious layer is reached.

High water tables affect citrus production in many ways. Excessive soluble salts, which are toxic to citrus or which make less soil moisture available

Fig. 4. Surface drainage is important. Water on this level pan orchard came from a rain that occurred 3 days before the picture was made.

for plant use, accumulates in the soil. Soil structure cannot be maintained if the soil stays excessively wet. Poor aeration occurs in a poorly-drained soil, even for a distance of 1 or more feet above a water table. Citrus roots cannot survive in soil that remains saturated for prolonged periods. If water is not removed from the root zone within about 5 days, the root system can be severely damaged or destroyed.

Drainage and irrigation problems are so closely related that they must be treated as inseparable companions and handled accordingly. Surface drainage is provided when the irrigation system is properly installed. Subsurface drainage must be designed by a competent engineer and installed by a reliable contractor.

A drainage system must be designed to handle excess water. Suitable depth, spacing, and location of tiles are essential. Many old drainage systems in the Valley are not functioning properly. In some cases, tile lines have been improperly installed or have been spaced too far apart. In other cases, tile has been placed below an impermeable layer. In most instances, water and salts are not able to enter the tile fast enough because of the lack of filter or envelope material around the tile.

Where no drainage outlets are available to allow disposal of excess water, careful water management is the only alternative.

The following recommendations can minimize drainage problems.

1. Use proper land forming to achieve good water distribution.
2. Apply only the quantity of water needed to fill the soil profile each irrigation. An occasional excessive application may be necessary to leach accumulated salts from the soil.
3. Provide sub-surface drainage where necessary.

KINDS OF CITRUS AND THEIR VALUE

*E. O. Olson, Roger Young, Morris Bailey, Norman Maxwell, W. C. Cooper and Bruce Lime**

GRAPEFRUIT VARIETIES

The Valley's reputation as a citrus area is based primarily upon the high interior quality of its grapefruit. Valley grapefruit is sweeter than that raised in California, Arizona, and most parts of Florida.

In the 1920's, white and pink grapefruit varieties were planted extensively. About 1930, budsports of red grapefruit were found on Thompson (Pink Marsh) grapefruit trees in several locations in the Valley. Fruit from trees propagated from these budsports had a red blush on the rind and the pulp was a deeper red than Thompson or Foster grapefruit.

New grapefruit plantings have been mainly the red variety, but some white grapefruit is planted for specialized processing. White grapefruit reaches legal maturity in October and November and its sugar and acid is similar in taste to Red grapefruit.

Red grapefruit may reach legal maturity in October and is shipped until the following June. Acid decreases as the season progresses until it is low in late spring. The interior red color gradually fades from a rose red in October to a pink in the spring. Choice of trees probably should be based on freedom from virus diseases and not on the source of the budsport, since a test conducted by the Experiment Station at Weslaco showed no differences in fruit or trees propagated from these red budsports.

ORANGE VARIETIES

Oranges from the Lower Rio Grande Valley usually have thinner peel, less acid, and the peel is more yellow than fruit grown in areas with cooler nights. In terms of maturity, they generally are referred to as early, midseason, and late.

Early oranges that are most popular early-to-midseason varieties in Texas are Marrs and Hamlin.

Marrs, relatively unknown outside of Texas, passes legal maturity tests before other early oranges, primarily because of its low acidity. The Marrs originated as a navel-orange budsport discovered by O. F. Marrs of Donna, Texas. Early in the season, Marrs oranges must be picked after the dew has dried on the peel, or rind oil spot will develop during storage in the packing shed. Later in the season when the peel matures, rind oil spot is no longer a problem. The Marrs, which has high-solid and low-acid fruit, may be legally mature in September, but on the basis of flavor, peel maturity, and color-break of rind and juice, it actually matures in November. The Marrs sets fruit on young trees and consistently bears heavy crops. It is considered seedless, but its seediness varies, probably depending on the pollinator, since seedless and seedy fruit occur on the same tree. Marrs fruit attains larger sizes than Hamlin; it can be shipped through January with little deterioration of fruit.

Hamlin matures in late October or early November. It requires less care in harvesting and packing than early-season Marrs; it has slightly more acid and less sugar than the Marrs, and its juice has less color than the Marrs. Hamlin trees produce heavy yields of relatively seedless fruit. Hamlin oranges tend to be small sized and they dry out late in the season.

Hamlin and Marrs juice will not make top-quality concentrate consistently, because of their low acid and poor-color, but must be blended with Valencia juice.

Early oranges generally are easier to raise than late oranges and the fruit is harvested before greatest danger of freeze damage. However, early oranges frequently sell for low prices when markets are depressed by heavy shipments from other areas.

Some navel oranges have been raised in Texas for gift fruit and shipments for the Christmas trade. The navel orange has a reputation of low yields but receives higher returns per box compared to other varieties.

Navel oranges generally reach legal maturity in October and are usually shipped by Christmas.

Texas trees are mostly propagated from selections of the Washington navel.

Midseason oranges include several varieties. Pineapple orange in Texas refers to any seedy midseason orange, including Parson Brown, Ruby, Mediterranean sweet, the true Pineapple and other varieties, which reach legal maturity in November.

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Joppa and Jaffa varieties are both Shamouti seedlings and have been so intermingled that it is impossible to separate them in Texas. Both mature in November, and are relatively seedless. They tend to be alternate bearers and carry lighter crops than Marrs or Hamlin. In some seasons, they are susceptible to black-core disease, which causes fruit breakdown in transit and is especially objectionable for processing.

New plantings of varieties have decreased in recent years.

Late oranges are represented by the Valencia, the only late-season orange. It is probably the world's best variety and is grown in every commercial orange district in the world.

Valencia fruit is seedless and in Texas Valencia normally attains legal maturity in February. It is harvested until May. Prices have usually been favorable. Development of a Texas concentrate industry would require a high proportion of the high-acid, high-solid, good-color Valencia juice to blend with poor-color, low-acid juice from the popular early varieties such as the Marrs and Hamlin. Since Valencia has a late harvest, the fruit is exposed to freeze damage for longer periods than the early oranges. Valencia trees yield less than early or midseason oranges, but this is generally offset by the higher price received for the fruit.

TANGERINES AND TANGELOS

Tangerines and tangelos (tangerine x grapefruit hybrids) have been grown mainly in small plantings for Thanksgiving or gift-fruit sales. Trees of many tangerine and tangelo varieties have more cold hardiness than the Valencia orange. The fruits are easy to peel and have deep orange color and rich flavor. More plantings of tangerines and tangelos are recommended to supplement orange and grapefruit plantings.

Clementine (Algerian) tangerine matures in late October and November. The trees bear heavy crops of good-flavored, small-to-medium sized fruit that dries out rather quickly after reaching maturity. The blossoms are self sterile and require cross pollination. Clementine trees have exhibited a high degree of cold hardiness in Texas freezes in 1949, 1951, and 1962.

Dancy tangerine matures in December or January. The fruit is small to medium sized, is slightly more acid, does not dry out as quickly, and has a redder, more attractive rind than Clementine. Dancy trees were much less cold hardy than Clementine trees in 1951 and 1962 freezes.

Orlando tangelo (Duncan grapefruit x Dancy tangerine) matures in December, has a slick orange rind, pleasing flavor, few to many seeds depending on pollen source, is low in acid, and is the size and shape of a large tangerine. The peel is tight. Since the blossom is frequently self sterile, plantings of Orlando should be interplanted with other seedy varieties which act as pollinators.

Orlando trees have been planted extensively in Florida and have given good returns to growers. Orlandos were more cold hardy than most grapefruit or orange trees in Florida's freeze in 1962.

Minneola tangelo have been grown in small plantings for gift-fruit shipments. The fruit is shaped like a medium-large orange with stem end slightly raised. The rind is deep red-orange and the pulp is also a deep orange color with excellent flavor. The fruit matures from late January through February.

Temple "orange" is probably a tangor, a hybrid between tangerine and sweet orange. Small plantings occur throughout citrus districts. The fruit ripens in February and is attractive and richly flavored. It has a reputation for being cold-sensitive, primarily because it makes flushes of new growth during the winter.

LIMES, LEMONS, AND MISCELLANEOUS CITRUS

Mexican lime produces several crops per year of small acid fruits. There are spiney strains and spineless strains. Because they are extremely cold-sensitive, Mexican limes generally are raised only in small, noncommercial plantings. When grown as seedlings, they survive freezes even though frozen to the ground.

Eustis limequat (kumquat x lime) has fruit similar to Mexican lime but can withstand more cold than the lime. The Eustis limequat, however, cannot be propagated on sour orange rootstock; it can be grown on Cleopatra mandarin or calamondin (Austera tangerine x kumquat) rootstocks.

Lisbon and Eureka lemons are grown occasionally. However, both are cold sensitive and are risky commercial ventures.

Meyer lemon has been the commercial lemon of South Texas. It is somewhat less cold hardy than the grapefruit or sweet orange but is hardier than the Lisbon or Eureka lemon. Meyer lemon trees on their own roots, propagated from layers or cuttings, survive freezes even though frozen to the ground. Fruit ripens in late summer and is thinner skinned, juicier, bigger, but a poorer shipper than California-type lemons. While some Valley Meyer lemon trees carry tristeza virus, most Valley trees are descendants of three trees which for unexplained reasons were tristeza-free.

Ponderosa lemon, for lemons the size of footballs, is planted as a specialty fruit.

Kumquats and satsumas are cold hardy varieties for small, noncommercial plantings. Kumquats are usually propagated on Cleopatra mandarin or calamondin rootstock because trifoliate rootstock, which is used in other areas, is not adaptable to the Valley soils and water.

A continuing program of variety improvement is being conducted by the U. S. Department of Agriculture in cooperation with the Texas Agricultural Experiment Station. Virus-free budwood of almost every commercial variety has been found. New selections from breeding programs in California and Florida are under test, as are seedlings of varieties of commercial importance in other parts of the world. From these programs, varieties with improved tolerance to Texas hazards are expected. The present emphasis is on mandarin hybrids with increased cold hardiness.

ROOTSTOCKS — THEIR TOLERANCES AND COMMERCIAL VALUE

The success of a rootstock in the Valley is determined by many factors such as tolerance to salt, boron, alkalinity, disease and cold, fruit production and quality, and general adaptability to Valley soil types. However, the three main limiting factors usually are salt, disease, and cold tolerance. Many rootstocks have been tested with Valencia orange and red grapefruit tops while only a few stocks have been tested with Jaffa orange, Marrs orange, and Meyer lemon tops.

Tolerance to various diseases varies among rootstocks. Some are tolerant to tristeza and to most of the virus diseases known to infect the commercial strains of red grapefruit. These include Cleopatra and Ponkan mandarins; Kara and Kinnow tangors; San Jacinto, Webber, and Sampson tangelos; rough lemon; Rusk and Savage citranges; Sacaton citrumelo, Citrumelo 4475; and several sweet oranges. Commercial citrus varieties which are virus-free may be compatible with many more rootstocks.

Most sweet orange rootstocks, although tolerant to tristeza and several other viruses, are quite sensitive to foot rot.

There also is a wide range in salt, boron, and alkaline tolerances among rootstocks. Rootstocks with good salt tolerance are not necessarily tolerant to boron or alkalinity. Stocks showing good to moderate tolerance to salt, boron, and alkalinity include Cleopatra mandarin, Mexican lime, Rangpur mandarin lime, rough lemon, Savage citrange, and sour orange. No known rootstocks have good tolerance to all three soil factors: salt, boron, and alkalinity.

In mature groves, only Cleopatra mandarin exhibited good tolerance to cold during the 1962 freeze. Many stocks have shown moderate cold tolerance. These include several mandarins, tangors, tangelos, sweet and sour oranges, and grapefruit. Limes, lemons, most trifoliate orange hybrids and trifoliate orange have poor cold tolerance.

Two rootstocks, from all the stocks tested, have been found to be most adaptable for Valley conditions. These are sour orange and Cleopatra mandarin. Cleopatra mandarin, although more cold and salt tolerant than sour orange, is less alkaline tolerant. Trees on sour orange generally have larger fruit of slightly better quality than on Cleo, come into bearing earlier, and are easier to propagate. For these reasons, sour has been used more extensively than Cleo, although it is more susceptible to tristeza than the latter.

Sweet orange and grapefruit as stocks are not recommended because of their poorer cold and alkaline tolerance. Sweet orange is also susceptible to foot rot.

Trifoliate orange and most of its hybrids have poor salt and alkaline tolerance. Most are susceptible to several of the viruses carried by commercial citrus varieties.

The limes and lemons, while somewhat more tolerant to salt and boron, are very sensitive to cold and produce poorer fruit quality.

NURSERY TREES

*Bailey Sleeth and Morris Bailey**

DISEASES AND INSECTS

Nursery trees should be relatively free from insect pests.

The citrus nematode, *Tylenchulus semipenetrans,* is widely distributed in old groves in the lower Rio Grande Valley and may cause considerable root injury and loss in tree vigor. It is highly desirable to plant nematode-free trees on new land, or land that has been fumigated for parasitic citrus nematodes. To insure that nursery trees are free of nematodes, nursery stock should be grown on land that has not been previously planted to citrus or that has been treated properly with a nematocide.

Nursery trees having areas of exposed wood on the trunks, as a result of frost damage or mechanical injury, should be avoided. The original wound at the bud union line should be partially healed over. Profuse gumming or bleeding in the trunk should be viewed with suspicion as a possible indication of a diseased condition.

Virus diseases are not readily apparent in nursery trees. One virus disease, psorosis, has been a major cause of decline in productive trees 10 years and older in Valley groves. It can be prevented by planting trees free of psorosis virus. Other virus diseases such as exocortis and xyloporosis, present in certain old line citrus clones, can be avoided by planting trees that have been certified as virus-free by the Citrus Nursery Inspector of the Texas Department of Agriculture.

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TREE SIZE AND FORM

A sound, straight-trunked nursery tree 5/8 to 3/4 inches in diameter just above the bud-union is preferred for planting. A 1/2-inch tree is too small and generally will be retarded in growth and initial bearing. Trees larger than 1 inch lose much of their root system when dug and balled and may be slow in starting. Age is an important consideration in determining tree quality. The desired tree size should be attained within 9 to 12 months after budding.

Nursery trees are headed back in the nursery at an approximate height of 18 to 20 inches. Heading back is necessary in order to stimulate lateral growth which produces the framework branches.

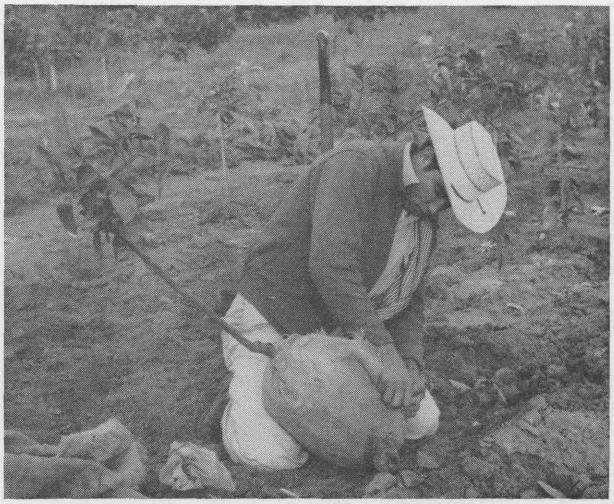

Fig. 5. Nursery stock in the Valley is sold as balled and burlaped trees.

GROVE ESTABLISHMENT

*Morris Bailey and Norman Maxwell**

TREE SPACING

Tree spacing is still an extremely important factor in the establishment of a citrus grove although concepts about spacing have changed much since the Valley citrus industry began. Before the 1949 freeze, most Valley groves were planted to a 25′ x 30′ spacing, allowing 58 trees per acre. After that freeze, the trend moved toward closer tree spacing, with the most common distances being 15′ x 25′ (116 trees per acre).

Close spacing definitely gives higher yields per acre during the first few years of production, and experiments in California have shown that closely-spaced groves will outyield wider-spaced groves over a long period. In one California experiment, after 20 years, a closely-spaced grove (12′ x 22′) outyielded a wider-spaced grove (24′ x 22′) by 62 percent. In this test yields per tree dropped as the trees became crowded, but yields per acre remained higher than in wider-spaced groves. With the costs of land, labor, equipment, and water increasing constantly, it is imperative that unit costs be reduced. Increases in yield per acre can do that.

Picking middles should be provided at regular intervals, however, in closely spaced groves.

PLANTING AND INITIAL CARE

In Texas, citrus trees are sold as balled trees. They will have the head cut back to correspond to the reduced root system. These trees may be planted immediately after digging or they can be held several days or longer by storing them in a sheltered place and keeping the balls wet.

When the trees are set in the field, care should be exercised that the root systems do not become too dry. It is a good idea to dig the holes ahead of time and as the trees are dropped off at each place, set them into the hole to prevent drying.

In planting the tree, the top of the ball should be about level or slightly above the soil around it, to allow settling after the initial irrigation. After filling most of the hole with soil and tamping it to prevent air pockets, the string around the top of the ball should be cut and the burlap folded back and covered with soil so that it will rot quickly.

Basins or strip borders should be built around the trees so they may be irrigated as soon as possible after setting.

Citrus trees may be planted successfully over a long period of time in the Valley—October through May. The early planting of October through December enables the trees to establish a root system and begin top growth that will make a large top during the coming season. Early planting is highly successful during mild winters, but in winters with one or more hard freezes, the succulent young trees often will be damaged by the cold.

An excellent time to plant is in late December and January, because the balled trees are dormant due to the digging. Also the weather is cool enough that top growth does not start until danger of freezes is past. All trees set in the fall and winter months should be banked with trash-free soil for protection against freezes.

Spring planting of trees, February through May, also is successful in the Valley. Trees planted in May often require more water the first season than those planted during the fall, winter, and early spring, because late planted trees generally cannot establish a strong root system before hot weather begins. Even so, these plantings will do well and will start producing fruit about the same time as the earlier planted trees.

FERTILIZING AND WATERING TREES

For mature trees, it makes little difference whether the year's allotment of fertilizer is one or several applications. Fertilizer applications on young trees definitely should be on a split basis, however, since they can be damaged by large amounts and can better utilize fertilizer when it is applied several times. Nitrogen is the only major element generally recommended for Valley citrus trees, although in some cases, a minor element deficiency may occur necessitating corrective measures. Nitrogen applied late in the fall may decrease cold hardiness.

General fertilizer recommendations are: 1/8 pound of nitrogen per tree each year for 1-year old trees;

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¼ pound of actual nitrogen per tree each year for 2-year old trees, and ½ pound of actual nitrogen per tree each year for 3-year old trees. If the trees are basin-irrigated (tank watered), the fertilizer can be mixed into the water and applied at the time of irrigation. If the trees are strip-irrigated, it may be more convenient to apply the fertilizer by hand. Extreme care should be exercised to avoid trunk burn and to assure even distribution of the material over the entire root zone area.

Young citrus trees should not be allowed to wilt as a result of moisture stress. During the hot, dry summer months, it is necessary to water basin-irrigated trees quite often (usually every 14 days). Strip-irrigated trees do not require quite so frequent watering since a larger area is watered during each irrigation. Strip-irrigated trees make faster growth than basin-irrigated trees, and, therefore, come into bearing earlier.

Fig. 6. During hot Valley summers, basin-irrigated citrus trees usually require waterings every 14 days.

PRUNING AND TRAINING TREES

Young citrus trees do not require much pruning or training to form a good bearing tree. When the trees arrive from the nursery, the scaffold limbs have already been formed. Generally, the major work in pruning is to break sprouts off the trunk and remove limbs that are dead or rubbing one another. Occasionally, a water sprout or shoot will grow faster than the rest of the tree. These either can be removed, if they are in a poor location, or cut back to correspond with the rest of the growth on the tree. Cutting back usually hardens and slows down growth so that it will make good fruiting wood.

Sometimes, in the second or third year, limbs will grow down and touch the ground. These should be cut back to avoid damage during tillage.

CARE OF BEARING TREES

*Morris Bailey, Norman Maxwell, Bailey Sleeth, Herbert Dean, Cleveland Gerard and Morris Bloodworth**

FERTILIZATION

Most Valley soils are quite fertile. The only major element generally required by Valley citrus trees is nitrogen, although in some groves, a minor element deficiency may exist in iron, zinc and manganese.

Iron is by far the most commonly noted unavailable minor element in Valley soils. When a minor element deficiency does occur, soil or foliar application of chelated materials should be made.

In the early spring, trees growing on sour orange rootstock may show symptoms of iron deficiency in the first growth flush. This condition will usually clear up without treatment as the soil temperature increases, however.

The rate of nitrogen to apply depends on tree size, age, and/or yield. Growers who base fertilizer application on yield should add one-fifth pound actual nitrogen per 70-pound field box of fruit produced. If fertilizer application is based on tree age, the recommended rates are as follows:

Tree Age	Total pounds actual N applied yearly[1]
4	¾
5	1
6	1 ⅛
7	1 ¼
8	1 ½
9	1 ¾
10 & over	2

[1]For sodded groves increase the fertilizer rates by 50%.

It makes little difference whether nitrogen is applied in one pre-bloom application or throughout the growing season. If two applications are made, the first should be made before the bloom period and the second either in May or August. If three applications are preferred, they should be made before bloom, during May, and finally in August.

Nitrogen should be broadcast evenly over the entire root zone area and as in the case of young trees, care should be exercised to avoid trunk burn. To prevent loss of material through volatilization and to dissolve the fertilizer into the root zone, the fertilization should be followed immediately by an irrigation. In semi-clean groves, it is also wise to disk the accumulated weeds and grasses before irrigating.

MECHANICAL CULTIVATION

Cultivation required in a citrus grove depends upon the type of soil management being used.

Groves in a semi-clean management system, used in most Valley groves, require disking and weed control from February through November.

The first disking is done in early February so that the grove can be prepared for irrigation and the ensuing spring growth. From then on, a light disking will keep weeds under control if timing coincides with irrigation. Disk cutting depth should be no deeper than two or three inches to avoid damage to tree roots.

Several types of offset equipment are available for control of weeds and vines under the trees, but there is a small area next to the trunk where weeds must be controlled by hand to avoid tree injury.

Where irrigation with sod culture is the soil management system, the weeds and grass can be kept under control with a cotton stalk shredder and offset equipment.

No matter what the system of soil management used, weeds and grasses should not be allowed to grow into trees where they can cause damage to fruit and young twigs. Besides, a heavy growth of weeds competes for moisture during the hot summer months.

Cultivation of citrus after September may affect the cold hardiness of the trees. Observations after the 1951 and 1962 freezes indicated that disking in late fall and winter in many groves caused the trees to be less dormant, resulting in more cold injury than sustained by trees in groves that did not have late cultivation.

DISEASES FROM FUNGUS AND VIRUS

Cotton root rot or Phymatotrichum root rot is a fungus that affects many species and varieties of plants. Under favorable conditions the fungus attacks

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citrus roots and frequently kills young trees. Young citrus tree loss is highest in intercroppings with cotton or alfalfa, two highly susceptible crops.

Sour orange is resistant to Phymatotrichum root rot and should be used as the rootstock for plantings in areas not entirely free of the fungus.

FLYSPECK (regreening) is another minor fungus disease that affects citrus fruit. The small black specks or spots, less than pinhead size, are closely woven hyphae, comparable to sclerotia. If numerous, the spots tend to give an unsightly appearance to mature fruit and lower its grade, making it mainly a problem to shippers of fancy grade fruit. For processing it is of little or no importance. In Texas, flyspeck is associated with dark green areas of mature grapefruit. The contrast between the dark green areas and the attractive light yellow of fruit is pronounced. Evidence indicates that the flyspeck fungus in areas of heavy infestation inhibits the green rind from changing to a light yellow as the fruit matures.

Lack of information on the biology of the fungus hinders the development of control measures; however, summer fungicidal sprays have increased the amount of clean fruit.

GREASY SPOT, sometimes called greasy melanose, occurs only on the leaves. The spots, at first yellowish brown, develop on one side of the older leaves. The spots darken, become slightly thickened and greasy in appearance. The greasy spots vary in shape and size, from small dots to areas 0.3 inches in diameter to solid diseased areas affecting most of the leaf surface. As the characteristic dark greasy spots develop, the leaves tend to become yellowish. Then plants defoliate prematurely in late summer and fall.

Greasy spot has been also associated with mite injury as well as a fungus. Summer sprays with neutral copper (0.5 pounds metallic copper in 100 gallons of water) or an oil emulsion spray have been effective. More preferable is a summer spray of zineb or maneb at the rate of 1.5 to 2.0 pounds per 100 gallons water for then the copper injury (star melanose) to the fruit can be avoided.

MELANOSE occurs on all varieties of citrus; however, grapefruit is somewhat more susceptible than oranges. The fungus attacks young fruit, leaves and twigs, but is of economic importance in Texas only because it lowers eye-appeal of fresh fruit. It is a wet season disease—a period of several days of high humidity is necessary for the fungus to sporulate and infect the young tender tissues. Mature or hardened tissues are resistant to infection.

Melanose spots on the fruit are at first light brown, circular, and sunken; later they become dark brown to almost black with a wax-like appearance. The surface of an affected area has a rough and sandpapery feel. Tear-streak patterns are sometimes caused by spore-laden water flowing over the fruit surface during light showers or heavy dews. Solid, heavily-infected areas of roughened scar tissue may cover a large part of the fruit. "Mudcake melanose" develops when the areas of scar tissue crack into more or less irregular patterns.

In severe cases, leaves may become twisted, lose their green color, and drop prematurely.

Melanose may be controlled effectively with neutral copper (0.75 pounds actual copper per 100 gallons of spray) when applied after petal fall and before the fruit averages 0.5 inches in diameter. The period of effective application is short—10 to 14 days following petal fall. A single high-pressure spray treatment usually gives excellent control. If humidity is low, during the first 2 to 3 weeks following petal fall, no spraying is necessary.

PHYTOPHTHORA COLLAR ROT (foot rot, brown rot gummosis) and seedling blight are caused by one or more species of Phytophthora. They attack the citrus tree both above and below ground and cause several types of injury to roots, trunk, branches, leaves, and fruit. Under favorable conditions, the fungi causing collar rot invade and kill the bark of the tree both above and below the bud union. The diseased tree is killed if the trunk is eventually girdled. Twig injury, leaf and blossom blight, and fruit decay may occur during or immediately after periods of rainy weather.

Citrus varieties differ in susceptibility to Phytophthora infection. Lemons, limes, and oranges are highly susceptible; somewhat less susceptible are grapefruit, rough lemon, and mandarins. Samson tangelo and sour oranges are resistant.

Phytophthora infection of the trunk base causes a profuse gumming on the surface of the bark lesion. The gum from infections below the soil line (collar or foot rot) is absorbed by the soil. Infections extending above the ground produce typical masses of exuded gum. The gum hardens in long vertical ridges on the surface of the bark or runs down into the soil. The fungus-invaded bark is killed, remains firm, darkens in color, and in time becomes shrunken and cracked, shredding in strips as it dries. The bark that remains alive above the fungus lesions often develops callus rolls that check further spread, especially in an upward direction. Sometimes the disease appears to be arrested, only to resume activity at a later date. Ultimately, the lesion may encircle the trunk and kill the tree, but the vertical spread is usually restricted to 1 to 2 feet above ground.

Phythophthora frequently affects young nursery stock in the Lower Rio Grande Valley during rainy periods. Lesions on the stems and blighting of leaves may kill large numbers of seedlings. Sour orange seedlings, which are quite resistant, succumb to infection in wet crowded nurseries.

Rootstocks highly resistant to Phytophthora infection should be used. Nursery seedlings should be budded fairly high, 5 to 6 inches, especially if the scion varieties are susceptible to Phytophthora. In planting trees in a grove, the bud union should be at least 5 inches above the ground line, or the tree should be planted to the same depth as grown in the nursery. Many infected trees may be saved by cutting out the trunk lesions to 0.2 inches beyond the discolored margins. The wound should be scraped clean and painted immediately with a good fungicidal tree wound paint. It will help keep down basal trunk infections and tree losses to adopt grove practices to prevent water from standing around the base of the tree for any length of time and the removal of tree banks as soon as danger of frost is past in the spring.

Good air and soil drainage will help prevent Phytophthora infection in citrus nurseries. Neutral copper (0.75 pounds metallic copper to 100 gallons of water) or zineb or maneb (2 pounds of 65-70 percent material to 100 gallons of water) applied as a spray at weekly intervals should control the disease in the nursery.

RIO GRANDE GUMMOSIS is a gum-exuding disease of grapefruit and shaddocks. It may be confused with other gum forming diseases as psorosis, exocortis, and Phytophthora root rot. Unprotected wounds are the main points of entry for the causal agent of Rio Grande Gummosis. Typical symptoms of the disease have been reproduced in Texas by inoculating grapefruit trees with *Diplodia natalensis*. The evidence indicates that *D. natalensis* is related to the occurrence of the disease in Texas, but that there may be other contributing causes.

In the early stages of the disease, gum exudes from a crack or blister in an area of darkened bark beneath which the cambium is discolored. Later, in affected trees, gum filled pockets may develop beneath the bark causing blister-like bumps at some distance from the point of infection. When the blisters break, copious gumming occurs. Areas of buff discolored wood with salmon-orange margins exist below the area of infected bark. The stained wood occurs in a band often an inch below the surface. The band of stained wood ranges from 0.2 to 0.5 inches in thickness, may be several inches wide, and spreads upward or downward two or more feet from the point of infection.

In the 1930's and 1940's, Rio Grande Gummosis prevailed in many Valley grapefruit groves; 50 to 60 percent of the trees were diseased. It is not a problem in uninjured trees growing on well drained soils. Control measures consists of protection of wounds against infection and good grove care practices.

SOOTY MOLD is caused by fungi feeding on the honey-dew excreted by certain insects. In recent years, sooty mold has been highly conspicuous in Valley groves as the result of heavy infestations of brown soft scale.

Sooty mold appears as a black velvety membranous coating over the leaves and fruit. The amount of sooty mold on the trees is roughly proportional to the number of parasitic honey-dew-excreting insects present. The black film is superficial and no parasitic relationship exists between the causal fungi and citrus tree.

The damage caused by sooty mold is indirect. Little or no effect on the tree may be noticed when the amount of sooty mold is small, but when it occurs in abundance, it may seriously retard growth, cause light blooming with reduced yield and increase susceptibility to drought. The black sooty covering interferes with photosynthesis and the formation of starches and sugars. Fruits covered with sooty mold ripen late and color unevenly. Often they are small in size and require washing at the packinghouse. Even in processing plants, sooty mold-covered fruits add to the mold or contamination hazard of juice products.

Sooty mold can be limited by a program to control the honey-dew-excreting insects such as white flies, aphids, mealybugs, and certain scales—especially the brown soft scale.

TWIG DIEBACK is common in Valley groves. Several different fungi, as well as many other factors, can cause dying back of young branches. The affected twigs may be killed back from one to several inches from the tips. Gum exudation occurs frequently at the margin of live and necrotic tissues. Damage by twig dieback usually is not severe. Cutting out infected twigs about 1 to 2 inches below the advancing margin of infection will help keep down injury.

Damage caused by virus diseases varies among scion-rootstock combinations from a slight slowing down in growth to loss in yield, stunting, decline, and eventual death. Three viruses—exocortis, xyloporosis, and tristeza—cause rootstock diseases while psorosis virus causes bark shelling on the trunk and branches of trees 8 to 10 years and older. These four viruses are bud-transmissable, and certain aphids can transmit the tristeza virus.

Citrus virus diseases in Texas can be controlled by planting virus-free trees. Tolerant rootstock-scion combinations should be used if virus-free trees are not obtainable. Nursery trees certified to be psorosis-free by the Nursery Inspector of the Texas Department of Agriculture are available at Valley citrus nurseries.

EXOCORTIS virus causes bark-shelling and stunting of trees on trifoliate orange, trifoliate hybrids, and Rangpur lime rootstocks. In the early stages of the disease, gum exudes from pustules at the base of the trunk which may extend from below the soil line up to the bud union. New bark forms beneath the pustules, while the outer bark sluffs off and causes bark-shelling. The rate of tree decline varies with tolerance to the exocortis virus; some affected trees may live for many years while others die within 2 or 3 years.

Sour orange and Cleopatra mandarin rootstocks are tolerant to exocortis. However, exocortis-infected scions on tolerant rootstocks, even though rootstock scaling does not occur, grow slower than exocortis-free trees on the same rootstock.

PSOROSIS has been the most serious disease affecting mature citrus trees in Texas. This disease has been spread chiefly by budding nursery stock with buds from infected trees. Rootgrafting is responsible for some spread of the disease after a grove is planted with both virus-free and virus-infected trees. Sweet orange, grapefruit, and tangerines are the more severely affected varieties.

Psorosis virus strains have common leaf symptoms, even though trunk and branch symptoms are different. The typical leaf patterns are (1) faint flecks or translucent areas between the veinlets and paralleling them and (2) chlorotic areas which resemble an oak leaf. The leaf patterns can best be seen on young leaves during the spring flush by transmitted light. They are generally symmetric, the pattern being similar on each side of the midrib. The flecking or chlorotic markings may be pronounced or obscure. They are not persistent and may disappear in a few days.

Leaf symptoms show whether nursery stock or young grove trees are infected with the psorosis virus. This method of detection has been used effectively in selecting psorosis-free bud-wood parent trees.

Bark scaling of trunks and larger branches is typical of psorosis symptoms in citrus trees 8 to 12 years old or older. The symptoms begin on the bark as scales of bark with or without gum formation. The scales of outer bark are dry, irregular flakes about 0.2 inches thick, with live, tan to buff-colored bark underneath. As the disease advances, the deeper layers of bark, and even wood becomes affected. Within a few years gum and resinlike deposits occur in the wood, and the affected area becomes brown or reddish brown, the discoloration developing in an irregular fashion. As the disease progresses, the rate of decline rapidly increases. Unless the tree is removed, it may linger on for many years as a non-productive tree.

TRISTEZA has caused tremendous losses in the citrus producing areas of South America, South Africa, Australia, California, Florida, and elsewhere. As yet, tristeza has caused no appreciable loss in Texas. Infected trees found in Texas have been traced to introduction or, as in the case of infected Meyer lemons, to propagation by the use of infected budwood. There is no evidence of aphid transmission of the virus in Texas.

Susceptible-rootstock combinations are sweet orange, tangerine, grapefruit, temple, and tangelo on sour orange. Tolerant combinations include sweet orange and tangerine on rough lemon and sweet orange on Rangpur lime or Cleopatra mandarin.

The symptoms of tristeza in a grove are not distinctive in that they are similar to those resulting from root injury, such as retardation of growth, thinning of foliage, and twig dieback.

The tristeza virus can be detected readily by leaf flecking or vein-clearing symptoms on Mexican lime seedlings if grafted with buds or tissue from citrus trees carrying the virus.

Where tristeza is a major problem, tolerant rootstocks must be used. In Texas where the disease has been found with no evidence of insect transmission, no control measure is necessary, except planting virus-free trees and preventing the introduction of either virulent strains of tristeza or the aphid vector or both. When a tristeza tolerant rootstock is found that approaches sour orange in its adaptability to Texas conditions, it would be well for growers to consider its use as a hedge against a future outbreak of tristeza.

XYLOPOROSIS virus affects many mandarin, mandarin hybrids, tangelo, and sweet lime scions and rootstocks. Orlando tangelo is especially susceptible. Sweet orange, sour orange, lemon, and grapefruit are tolerant to the virus.

The first external symptoms of xyloporosis appear in a susceptible rootstock, such as Orlando tangelo, 2 to 4 years after bud-infection as shallow elongate depressions 0.2 to 0.8 inches wide in the bark. The wood becomes channeled and pitted. The inner bark will have ridges, bumps, and peg-like structures that fit into the wood depressions. The pits often are lined with a dark brown resinous substance. Cracks develop in the bark, tissues become necrotic, scaling may develop, growth is retarded, yield declines, and the tree may die in a few years.

As for exocortis, effective control consists of planting new groves with xyloporosis-free trees.

PHYSIOLOGICAL DISORDERS

MESOPHYLL COLLAPSE is characterized by a sudden wilting and disorganization of the interior tissues of citrus leaves. One or more affected areas may develop on a leaf. The affected area is generally translucent, may turn yellow, dry out, and become light gray or brown. If severe enough, defoliation occurs.

Mesophyll collapse is induced by water stress caused by climatic and soil conditions that make it impossible for the tree to obtain sufficient water for all parts of the foliage. In the Valley, after several days of high, dry winds, extensive leaf damage often occurs followed by defoliation. Defoliation is greatest on the side of the tree exposed to the drying winds. Observations in Texas indicate that this condition is accentuated by heavy populations of the Texas citrus mite.

Foliage loss from mesophyll collapse can best be minimized by good grove cultural practices. Maintenance of adequate soil moisture and windbreaks are helpful. Any sort of cultivation that cuts or destroys citrus roots if followed by high dry winds will increase the damage.

RIND-OIL SPOT, *Oleocellosis,* has caused considerable loss to growers and shippers of Marrs orange when picked early in the season while the rind is still green. The spotting is caused by oil released from the oil glands. The spots vary in size, from less than 0.5 inches in diameter to large irregular areas involving a larger part of the surface of the orange. The spots are green in contrast to the yellow color of the normal rind after treatment with ethylene gas. High humidity is the underlying factor in susceptibility of Marrs orange to spotting.

Rind-oil spot can be prevented or greatly reduced by (1) picking fruit in afternoons of clear, sunny days; (2) deferring picking 2 or 3 days after a rain or an irrigation; (3) using fiberboard-lined field boxes or padded trailers; and (4) having pickers use cotton gloves. As a general rule, fruit susceptible to rind-oil spot injury should be picked only when the fruit surface is dry and handled carefully so as not to puncture or rupture the oil glands.

CHLOROSIS is a general term applied to a condition of citrus leaves in which, instead of the normal green, there is a yellow, light yellow, to almost white color. There are several causes of chlorosis with differences and similarities in symptoms. Iron or lime-induced chlorosis and mottle leaf or zinc deficiency are the two most common types of chlorosis in Valley groves.

IRON CHLOROSIS, a yellowing of the leaves of affected plants, usually occurs on trees growing in calcareous soils. Citrus growing on sour orange rootstock is relatively free of iron chlorosis, since it is more tolerant to lime-induced chlorosis than Cleopatra mandarin. Trees on Cleopatra mandarin rootstock growing in calcareous soils frequently develop chlorosis that may persist indefinitely.

A chelated iron compound, sequestrene 138, is effective in alkaline soils. In the nursery, it is applied at the rate of 2 to 3 ounces per 100 sq. ft. Suggested dosages, on a trial basis, for grove trees would be 1 ounce for 1 to 2 year-old trees to 0.5 to 0.7 pounds for mature trees.

MOTTLE-LEAF (zinc deficiency) is not distributed uniformly throughout a grove. The leaves show chlorotic areas, situated between the lateral veins on each side of the midrib. The part immediately next to the large veins and midrib remains green, while the chlorophyll is absent in the parts between. This results in irregular spotting or mottling.

Mottle-leaf is controlled effectively through the use of neutral zinc (1 pound actual zinc per 100 gallons of water) in the post-bloom spray. Usually, mottle-leaf affected trees recover during the summer without treatment. Unless the mottle-leaf condition is pronounced and tends to persist throughout the growing season, the application of zinc in the spray is probably only justifiable when it is combined with another spraying operation.

NEMATODES

Nematodes are microscopic worms, 0.01 to 0.04 inches long; many are parasitic on the roots of plants. The citrus nematode, *Tylenchulus semipenetrans,* has been found in more than 50 percent of the older citrus groves examined in the Valley. Other parasitic nematodes, dagger, *Xiphinema americanum*, and stylet, *Tylenchorhynchus* spp. have been found and may cause damage to the roots. The burrowing nematode, *Radopholus similis*, has not been found on citrus in South Texas. However, it is a serious pest in Florida causing spreading decline.

Good cultural practices, weed control, high fertility level and adequate moisture tend to offset damage from parasitic citrus nematodes. If an old grove is to be replanted within 2 or 3 years following removal, soil fumigation prior to replanting most likely will be beneficial. Some effective soil fumigants are ethylene dibromide, dichloropropane and dichloropropene mixture, and dibromochloropane when used as a preplant treatment. Use these fumigants at rates recommended by the manufacturer.

For best results, treat the entire planting area. However, fumigation of the individual tree planting sites uses less chemical and should be effective in increasing growth of the young trees. In tree site treatment, an area approximately 9 by 9 feet should be treated.

CITRUS MITES AND INSECTS

For specific control recommendations, consult L-559, Texas Guide for Controlling Pests and Diseases on Citrus, available at county extension agents' offices.

Mites

THE CITRUS RUST MITE, *Phyllocoptruta oleivora* (Ashmead), is about 1/200 of an inch long, wedge-shaped and light yellow. Under optimum weather conditions, 7 to 10 days are required for development of a generation from egg to egg. Rust mites usually are more prevalent on the east side of the tree and lower surface of the leaf. Rust mite damage has been associated with russeting of fruit which results in reduction in grade and size. They also cause injury to leaves and green twigs. Continuous periods of high relative humidity (75 to 95%) are favorable to increasing populations. Continuous periods of 20 to 40% relative humidity are not so favorable. Apply control measures at post-bloom followed by applications when needed.

THE TEXAS CITRUS MITE, *Eotetranychus banski* (McG.), has long been considered a pest of economic importance, although research information is lacking on the degree of damage. These pests prefer the upper surface of the leaf and are sometimes referred to as "spider mites." Eggs are disk-like and usually are laid on the sides of the mid-rib and branching veins. Adult mites are 1/70 of an inch long and vary in color from a lemon yellow to a dark green with dark blotches on each side down the back. After heavy feeding by this mite, the leaf will have a grayed appearance. During most months greater numbers will be found on the leaves on the south side of the tree. During normal years, their populations are small in February and March and a great increase follows in the April-July period although development has been observed during every month of the year. Hot and dry conditions favor development while rains will decrease populations.

FALSE SPIDER MITES, *Brevipalpus australis*, (Tucker) and *B. phoenicis* (Geijskes), are a potential problem if chemical control measures are not applied during the year. An association has been established with *B. australis* and the disease, leprosis. Leprosis was controlled in Florida by controlling this mite. These mites are small, flattened, reddish, and slow-moving. Their legs are whitish with two pair at the head end of the body and two pair slightly behind the middle. Population counts on leaves indicate an increase in June followed by greater numbers during the following months in untreated groves. Fruit and twigs are also attacked by this mite.

Armored Scales

Chaff scale, *Parlatoria pergandii* Comst., and California red scale, *Aonidiella aurantii* (Maskell) are the principal armored scales which have required chemical control in Texas. Long or Glover scale, *Lepidosaphes gloverii* (Pack.), purple scale, *Lepidosaphes beckii* (Newm.), and Florida red scale, *Chrysomphalus aonidum* (L.) have required chemical control in only a few locations. These scales move for 2 to 5 days after hatching, attacking all parts of the

Table 5. Characteristics for identification of the common armored scales on Texas citrus.

	Length or diameter of scale covering, inch	Scale covering		Scale color
		Shape	Color	
Chaff	1/15	Circular to elongate	Brownish to gray	Purple
Calif. red	1/13	Circular	Appears red	Yellow
Flor. red	1/13	Circular	Reddish brown	Yellow
Glover's	1/10-1/9	Long and narrow	Purplish brown	White to purple
Purple	1/12-1/9	Oyster shell	Purplish brown	White

tree. When the scale settles, it remains in the same place through the balance of its life. Scales extract the plant juices causing defoliation, dying of small twigs, fruit drop, and failure of fruit to color. Complete coverage of the tree is necessary if chemical control is to be successful. These armored scales may be classified by the characteristics given in Table 5.

Unarmored Scales

These scales do not have a separate armor covering their bodies, but retain their legs and can move to other locations to feed. Chemical control generally has not been necessary, except for brown soft scale, *Coccus hesperidum* L. Beneficial insects have been important in maintaining economic control. The secretion of honey dew by these scales provides a growth media for black sooty mold fungus. In many instances, the fungus is noticed before the scales are found.

BROWN SOFT SCALE has been the most important unarmored scale. Adults are brown to pale yellow, mottled, and oval in shape and ⅛ to 1/6 inch long. This scale attacks leaves and twigs and occasionally may be found on fruit. Its reproduction potential is very great. During average years, increases in populations may be found during May, and following that time, depending upon weather conditions and the degree of parasitization and predation by beneficial insects.

THE BARNACLE SCALE, *Ceroplastes cirripediformis* Comst., is found on rare occasions. The height of the adult is almost equal to its width. The six plates on the sides and one on the top distinguishes this dirty-white (mottled with brown) wax scale. This scale has been well controlled by beneficial insects.

A PULVINARIA SCALE has been found on rare occasions, such as following freezes. The scale is greenish, about 3/32 inch long, but with the cottony egg sac (with 4 ridges) fully extended measures about 5/16 inch long and is 3/32 inch wide.

Insects related to scales secrete honey dew and black sooty mold fungus is indicative of their presence. In a few instances, chemical control has been necessary.

COTTONY-CUSHION SCALE, *Icerya purchasi* Maskell, has been the most important of these insects. They congregate along the midrib of the leaves and on twigs. The young are reddish to brown with yellow, waxy threads extending from the body. Adult females are recognized by the reddish plate in front of the white, fluted egg sac and measures overall about ½ inch in length. The vedalia lady beetle is the best controlling agent and usually is found with the scale in this area.

THE CLOUDY-WINGED WHITEFLY, *Dialeurodes citrifolii* (Morg.) and the citrus whitefly, *D. citri* (Ashm.), occasionally invade citrus in this area. The eggs, laid on the undersurface of the leaf, are elongate and are attached to the leaf by a short stalk. After the crawler settles, the nymph becomes immobile and attains a length of about 1/25 inch. The adults are mealy-white and hold their wings roof-like over the body. Control is usually maintained by entomogenous fungi and beneficial insects.

THE CITRUS MEALYBUG, *Pseudococcus citri* (Risso), has been found in a few groves. Their bodies are distinctly segmented with lateral filaments covered with a white wax and may reach 1/4 inch in length. They collect around stems and where fruit touch one another in shaded areas. Large infestations will result in fruit drop.

Miscellaneous Insects

Numerous species of ants may be found in Valley groves. They may tend insects for honey dew and are a nuisance to workers in the grove. Ants that nest in the tree or those that enter the tree from the ground (such as the fire ant) may kill or disturb beneficial insects. Ant control is a good grove practice but chemicals for control should not be applied to the tree, except when individual nests must be treated.

THE SPIREA APHID, *Aphis spiraecola* Patch, and the cotton or melon aphid (*A. gossypii* Glover) are the most prevalent aphids found on citrus in this area. The black citrus aphid, *Toxoptera aurantii* (Fonsc.) may be found on occasions and the cowpea aphid, *A. medicaginis* Koch has been found on a few young citrus trees. Aphids attack the young succulent foliage on the undersurface and are unable to develop on mature leaves. Their feeding causes the leaves to curl and become distorted. Honey dew is secreted by aphids and acts as a media for black sooty mold fungus. In past years, only a few cases have been found where chemical control was economically feasible.

A FLATID PLANTHOPPER, *Metcalfa pruinosa* (Say), hatches during late March from eggs laid the previous summer. Nymphs, with sucking mouth parts, congregate around the fruit stems or undersurface of leaves. The adult stage is reached by mid or late May and this stage may be found as late as September. They have numerous host plants and prefer grapefruit to oranges. During some years, they are heavily parasitized and economic damage by this insect is questionable.

THE MEXICAN FRUIT FLY, *Anastrepha ludens* (Loew), is sometimes a problem with late fruit. Adults begin migrating from Mexico during late December or January after which quarantine regulations go into effect for certain interstate shipment of fruit. These flies cannot survive under Valley summer weather conditions. Larvae cause breakdown of the fruit either on the tree or after harvest.

THE ORANGE-DOG, *Papilio cresphontes* Cramer, is seldom found to be numerous on more than two or three trees in a grove. This caterpillar is grayish-brown with lighter patches and attains a length of 2½ inches. Two long horn-like reddish processes which emit a substance with a disagreeable smell are thrust out from behind the orange-dogs head when it is disturbed. Although the caterpillar feeds on the foliage, the adult is a harmless giant swallowtail butterfly. Hand-picking is the usual method for control.

PUSS CATERPILLAR LARVAE, *Megalopyge opercularis* (J. E. Sm.), are occasionally on citrus from mid-May to late-July and mid-September to mid-November. These caterpillars are tan or gray, have venomous setae among the soft hairs and may grow to 5/8 inch in length. They damage citrus trees by feeding on the leaves.

KATYDIDS usually do not attack more than a few trees in the grove. The most common of these hump-backed grasshoppers lays its eggs (clam-shaped) like a fringe around the edge of the leaf. Adults and nymphs feed on the leaves. Eggs are usually heavily parasitized.

A DESERT DAMPWOOD TERMITE, *Paraneotermes simplicicornis* (Banks), may be a problem where citrus is planted on recently-cleared brush land. Damage results from severing the large lateral roots and/or the tap root of young citrus. The termite will then feed upward in the trunk causing the trees to wither and die. Affected trees have been noted more during the winter months.

A STINK BUG, *Loxa Florida* Van Duzee, may feed on citrus fruit in September. As the area around the feeding puncture begins to decay, fruit changes to a yellow color and drops. This bug measures about 7/16 inch wide by ¾ inch long and is green with a reddish tinge around the edge of the body. The side of the body back of the head comes to a sharp point.

SNOUT BEETLES sometimes feed on citrus foliage during the spring and summer months. The larvae feed on the roots of plants. The adult of one specie is about 3/8 inch long by 1/8 inch wide, greenish-gray and has somewhat of a glow from greenish spots on the back. Most species are thought to have only one generation a year.

WOOD BORERS often attack weakened citrus trees, particularly after freezes. Dead wood is attractive to borers so they usually will not be found in healthy citrus trees. Tunnels in large branches are made by borers which remain in the tree for as long as 2 years while tunnels in the bark or just beneath are made by borers with a shorter life cycle.

CICADAS sometimes lay eggs in twigs during July and August. The bark of the twigs may gum and the twigs subsequently die.

WATER REQUIREMENTS OF CITRUS

Efficient irrigation practices are dependent upon a sensible application of the physics of soil moisture and an understanding of the use of water by plants. The use of water by plants is an energy controlled process which is modified by *climatic, plant* and *soil factors.*

Climatic Factors

Solar energy from the sun is the main source of energy which causes water to be vaporized from soil or leaf surfaces. The amount of solar energy which arrives at the evaporating or transpiring surface depends upon factors such as locality, time of year, time of day, and color of evaporating or transpiring surfaces.

The water requirement for citrus production is high in the Rio Grande Valley. Rainfall often supplies an important part of the water requirements of citrus. The average annual rainfall at Weslaco for example is about 23 inches a year. However, the annual precipitation varies considerably from year to year. The highest recorded annual precipitation was 40.4 inches in 1941. The lowest recorded was 7.8 inches in 1956. Irrigation schedules should be planned to take advantage of the normally high rainfall in May, June, and September.

Climatic factors also influence the irrigation practices in the fall and winter months. Citrus trees generally should not be irrigated after November and prior to February because of the danger of inducing growth during a time when there are possibilities of severe freezes. A freeze after flushing of citrus plants can cause severe damage to trees.

Fig. 7. Some orchards are kept clean cultivated most of the year. This is one method of conserving water for use by the trees.

Plant Factors

Some of the plant factors which influence water requirements are plant spacing and type of management used in the grove. Close spacing of groves can cause an increase in water requirements of citrus trees, but this increase probably would be relatively small.

A grower should consider his water supply when making decisions as to whether the grove will be clean-tilled or planted to cover crops or grass. The use of cover crops or grass in the grove will increase the moisture requirement. For example, research at Weslaco indicates that Coastal bermudagrass required 30 to 35 percent more water than clean-tilled or straw-mulched plots.

The use of water by plants is relatively high when the available moisture supply of the soil is high. Irrigation and rainfall replenishes the available water supply and therefore generally increases the water use by plants. The availability of water at increasing soil depth generally decreases because root development of plants including citrus decreases with soil depth. Size and vigor determine the root development as well as the amount of water available for plant use. Over-irrigation or heavy rainfall may reduce water use by causing root rot and an anaerobic condition which are unfavorable for plant growth and development.

Chemical and physical properties indirectly influence water requirement by affecting root development and plant growth. Fine-textured soils are not recommended generally for citrus production because they hold more water per foot of soil and may impede root development due to its density and possibly severe cracking. Hardpan, dense layers, or high water table conditions in coarse-textured soils are unfavorable for root development and plant growth, thus reducing the soil moisture supply available for plant use.

Soil salinity may increase water use by plants by making it necessary for growers to irrigate more frequently. Soils containing relatively high salt contents are not recommended for citrus production, because citrus trees are extremely susceptible to salt.

Irrigation Schedule

Since rainfall amounts and frequencies are less and evapotranspiration greater in the western end of the Valley, the interval between irrigation possibly should be closer to 20 to 30 days for citrus growing in that area. Irrigations are not recommended in December and January. About 5 to 7 irrigations are needed to properly irrigate citrus during an average year. This is assuming that rains in May and June will supply enough water for one irrigation and rains in late August and September will supply enough water for one irrigation.

A minimum of three irrigations is estimated as being necessary to keep citrus trees alive. These irrigations should be applied in February, July, and November. This schedule will supply water at the first sign of flushing in the spring, water in July during the peak moisture demand period, and water in November to prevent excessive defoliations as a result of mesophyll collapse during the fall and winter months.

Each irrigation should supply enough water to bring the soil to field capacity to a depth of 5 to 6 feet. Occasional over-irrigation to leach accumulated salt is desirable.

PRUNING

Bearing citrus trees in the Valley require little pruning. Generally all that is necessary is removal of dead limbs, headback or remove water sprouts, and trim low hanging limbs to a height so that tractor equipment will not injure the tree.

Close-planted groves may require hedging after they reach 15 to 20 years of age. Cutting back the tops of old trees will open up the center so that light penetrates and starts new wood growth and fruit production.

Where pruning is necessary, all cuts should be made flush with a limb or shoot and no stubs allowed to remain in the tree for wood rots and insects to enter. The tools used should be sharp and in good condition.

All cuts of ½ inch or larger should be covered with a good pruning compound to prevent drying, and entrance of disease and insects.

Do not prune heavy in the middle of the summer because of sunburn damage to wood that has not been exposed to the direct rays of the sun. Pruning should not take place late in the fall because it will start the trees growing and make them cold tender. Probably the best time of the year to prune is early in the spring or during September and early October.

CHEMICAL WEED CONTROL

The use of chemicals for the control of weeds and grasses in citrus groves has become important in California and Arizona during recent years. Experiments with various herbicides are underway in Texas, and while short-term results appear promising, not enough time has elapsed to determine comparative costs and long term residual effects on soils and trees.

Fig. 8. Pruning wounds larger than ½ inch in diameter should be protected with a weatherproof antiseptic paint of the asphaltom-carbolineum type.

As research information on chemical weed control in Valley citrus groves becomes available, specific recommendations will be released through appropriate channels.

AGRICULTURAL METEOROLOGY FOR CITRUS PRODUCTION

*Donald J. Haddock**

MINIMUM TEMPERATURE FORECAST PROGRAM

A minimum temperature forecast for fruit and vegetable interests for various locations throughout the Valley is prepared during the critical season by the Weather Bureau, and is issued daily at regular intervals.

Agricultural and public forecasts are also issued several times daily throughout the year. These forecasts contain information on maximum temperatures, cloud cover, wind direction and speed, rainfall coverage and amounts, dew intensity, and minimum temperatures for the next 36 hours, plus a general outlook for an additional 24 hours.

All weather forecasts and summaries are transmitted over the Weather Bureau teletype circuit. Television and most radio stations throughout the Valley are connected to this agricultural-meteorology circuit and thus can broadcast complete and up-to-date weather information.

AGRICULTURAL INTERPRETATION OF WEATHER FORECASTS

Farm weather summaries point out the effect that the predicted weather will have upon current citrus operations. The Weather Bureau Agricultural Service Office, the Texas Agricultural Extension Service, and the Texas Agricultural Experiment Station at Weslaco jointly prepare these farm advisories based upon the 36-hour specific weather forecast, and the more general 5- and 30-day weather outlooks. These summaries are issued on the agricultural-meteorology circuit, Monday through Friday, year around.

THERMOMETER CALIBRATION AND EXPOSURE

An accurate thermometer and a good instrument shelter are two valuable aids in cold protection of citrus. A small, economical and easily constructed shelter is needed by each citrus grower in the Valley as part of his standard grove equipment. By knowing the representative air temperature near his trees, a grower can properly decide when to begin or terminate cold protection operations.

A high-quality thermometer is worth the extra cost, when used in protecting high value crops such as citrus. A temperature difference of only one or two degrees within a critical temperature range for citrus may determine whether freeze losses will be great or small.

Before the cold season begins, thermometers should be calibrated for accuracy. This is necessary since damage to the thermometers may occur during summer storage or in field use.

An accurate thermometer must be exposed properly if it is to correctly indicate the representative air temperature in the immediate vicinity. The popular mercury or alcohol-in-glass thermometer will measure the desired air temperature only when the thermometer has a free circulation of air and is protected from direct exposure to the sky.

An instrument shelter made of wood with louvered walls, double roof with an air space, and small holes in the bottom will meet the foregoing qualifications. It should be painted white and be large enough that the thermometer, especially the bulb, will be at least 3 to 4 inches from the inside walls, and 6 to 8 inches or more from the ceiling and bottom. The shelter should be installed adjacent to the grove or between tree rows, firmly anchored so the wind will not shake the shelter, and at a height so the sensing element of the thermometer is 5 feet above the ground. Forecast and observed temperatures for various locations throughout the Valley are at the standard 5-foot height. A grower can determine the general temperature difference between his location and the nearest forecast station, and thus obtain a forecast for his own grove.

INTERVAL BETWEEN FREEZES

Severe freezes occurred in the Lower Rio Grande Valley in 1930, 1949, 1951, and 1962. These periods of unusually low temperatures caused freeze damage to the citrus trees, as well as the fruit. Low temperatures observed throughout the Valley during the latter three severe freezes are summarized in Table 6.

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Table 6. Extreme minimum temperatures observed during three severe freezes.

Station	Jan. 29-31 1949	Jan. 29-Feb. 3 1951	Jan. 9-12 1962
Baker Potts	21	20	
Brownsville	23	22	19
Donna	19	20	
Edcouch	21	21	
Edinburg	20	19	16
Elsa			13
Engelman Gardens	19	20	14
Goodwin Tract	21	18	
Hargill			14
Harlingen	21	21	14
Harlingen 6 NE		19	
La Sara	20	19	
Los Fresnos	21	20	13
McAllen	22	19	17
McCook	18	16	10
Mercedes 7 S			17
Mission	20	19	18
Mission 7 N		18	
Mission 10 N	20		
Monte Alto	20	20	12
Pharr	21	19	
Pride O' Texas	21	19	14
Raymondville	20	19	14
Rio Grande City	17	15	10
Rio Hondo 5 E		19	
Rio Hondo 7 NE			15
San Benito			16
Santa Rosa			12
Schuster Farms			12
Sebastian	19	17	
Weslaco	20	19	16

Growers can use the probability data of extreme minimum temperatures in Table 7, as a useful tool in deciding upon the establishment or rehabilitation of citrus groves. This table indicates the number of years expected between freezes of different severity for the 50 and 63 percent probability levels of occurrence for several Valley stations.

The number of years listed at the 50 percent level will be more useful to growers than those corresponding to the 63 percent level. For a given temperature, there is a 50 percent chance (100% − 50% = 50%) of *occurrence*, within the indicated interval as well as a 50 percent chance of *non-occurrence* within this period.

Values listed at the 63 percent probability level of occurrence are the average return periods (number of years) because of the peculiarity of the extreme value distribution. This particular level indicates that there is a 63 percent chance that a given temperature *will occur* within the listed interval. It also means that there is only a 37 percent chance (100% − 63% = 37%) that this same temperature *will not occur* within the interval.

For example, at Weslaco there is a 50 percent chance that a temperature of 20 degrees or lower *will occur* before 10 years. This also means that there is a 50 percent chance (100% − 50% = 50%) that this same temperature threshold *will not occur* within 10 years.

There is a 63 percent chance that this same temperature *will occur* within 15 years and only a 37 percent chance (100% − 63% = 37%) that it *will not occur* before 15 years.

The extreme minimum temperature of 20 degrees or lower was selected because this particular temperature threshold summarizes those that occurred at Weslaco in the severe freezes of 1949, 1951, and 1962, which were 20, 19, and 16 degrees, respectively.

TEMPERATURE-DURATION RELATIONSHIPS IN SEVERE FREEZES

Duration of freezing temperatures is one of the many factors related to freeze damage of citrus trees and fruit. The duration in hours of some tempera-

Table 7. Interval (number of years) between freezes of different severity for two probability levels of occurrence.

Lower Rio Grande Valley stations	Probability level	Winter extreme minimum temperature (°F.) equal to or lower than: 32	30	28	26	24	22	21	20	19	18	16
Brownsville*	50%	1	2	3	5	7	12	15	19	24	32	
	63%	2	3	4	7	11	17	22	28	35	46	
Harlingen*	50%	1	1	2	3	4	7	9	11	14	17	28
	63%	1	2	3	4	6	10	12	16	20	25	40
Weslaco	50%	1	1	2	2	4	6	8	10	14	18	30
	63%	1	2	2	3	5	9	11	15	20	26	44
Raymondville	50%	1	1	1	2	3	6	8	12	15	22	39
	63%	1	1	2	3	5	9	12	17	22	32	56
Rio Grande City*	50%	1	1	1	2	3	4	5	7	8	11	17
	63%	1	1	2	3	4	6	8	10	12	15	25

Note: Values listed at the 63% probability level of occurrence are the average return periods (number of years) because of the peculiarity of the extreme value distribution. Temperatures are for the five-foot height. Temperature data used in this study were for the 30-year period, November through March, 1933-34 through 1962-63; except for Raymondville, which was for the 24-year period, 1939-40 through 1962-63.

*Probability data were obtained from Webb (1963).

Table 8. Temperature-duration relationship for severe freezes (1949, 1951, and 1962) in the Lower Rio Grande Valley of Texas.

Temperature (° F.)		Duration (hours)
Extreme minimum	+0	0.9
Extreme minimum	+1	2.5
Extreme minimum	+2	4.1
Extreme minimum	+3	5.7
Extreme minimum	+4	7.3
Extreme minimum	+5	8.9
Extreme minimum	+6	10.5

Data in this table were obtained by a linear regression analysis of 366 duration observations of freezing temperatures ranging from the extreme minimum temperature to 6 degrees higher. Temperature records used were from 15 climatological stations in the Valley in the 1949 severe freeze, 20 in 1951, and 18 in 1962. The correlation coefficient is +.78. The regression equation is $y = .9 + 1.6x$ where y is the duration in hours and x is the difference between the observed and the extreme minimum temperature.

tures in reference to the extreme minimum for the severe freezes of 1949, 1951, and 1962 is shown in Table 8. The relationship found in these three freezes is only a general guide in estimating duration of the critical temperatures in future freezes because each freeze and related cold air mass differs greatly from another. But even a rough estimate will be valuable when growers are deciding on how many hours of cold protection equipment will be needed during the night.

For example, suppose that the forecast minimum temperature for a given night is 24 degrees, and a grower plans to light his heaters to maintain a grove temperature of 28 degrees. Thus, he would light them when the temperature had lowered to 4 degrees higher than the expected minimum ($28° - 24° = 4°$). By using Table 8, a duration of 7.3 hours was found for a temperature of the *minimum plus 4 degrees.* As a rough estimate, this means that sufficient fuel oil and labor will be needed for approximately 7 to 8 hours in protecting the citrus during the night.

COLD PROTECTION

*Roger Young, Price Hobgood, Norman Maxwell and Don Haddock**

PHYSIOLOGICAL ASPECTS OF FREEZE INJURY TO CITRUS

Curiously enough, after every severe freeze in a citrus growing area, several trees or groves of trees survive the freeze much better than most in the same area. There are logical explanations for the behavior of these more hardy trees in some cases, but in many cases there is no logical explanation. The lack of an obvious answer for this added hardiness indicates (1) the need for a better understanding of the physiology of citrus cold hardiness, and (2) with a better understanding the solution of the freeze problem becomes more definite.

It is reasonable to expect that the freeze problem in citrus can be solved since trees have been noted to survive very severe freezes with little injury.

Plant Responses During Freezes

The actual process of freezing in citrus tree parts is not clearly understood. But it is recognized that as water turns to ice within the tissues, heat is liberated and the tissue temperature rises to its freezing point. In Figure 1, the rise in temperature of a grapefruit leaf indicated that freezing had begun. At that time "water-soaking" became apparent in the leaf. The "water-soaking" was manifested as darker green areas on the tops and bottoms of the leaves. As the leaf temperature increased, the "water-soaking" became more general. The true freezing temperature occurred at 25.1 degrees F., at which point the leaf was completely "water-soaked." This freezing point represented an increase in the leaf temperature of 3.1 degrees F. from the minimum "under-cooling" temperature of 22.0 degrees F. The temperature of the leaf subsequently decreased, indicating that most of the solute within the leaf was frozen and that no further heat of crystallization was being released. This rise in tissue temperature as freezing progresses is characteristic in all tissues but in citrus has been recorded only in leaves and fruit. "Water-soaking" has been observed in leaves and green wood.

Figure 9 summarizes the temperature changes in a leaf on a plant which did not freeze. No temperature increase was noted, but rather a gradual decrease occurred. Leaves on this plant did not "water-soak" and remained uninjured. This plant exhibited what is commonly referred to as "supercooling." Supercooling is the process where tissues cool below their freezing point without freezing. Citrus tissues supercool before freezing. The amount and length of supercooling include rate of cooling, wind velocity, air temperature, and humidity and tissue condition. The fact that citrus tissues do supercool often is a factor in the amount of freeze injury incurred during a freeze. Tissues which remain supercooled longer before freezing generally sustain less injury since the time in the frozen state will be reduced.

Freeze injury in tissues occurs subsequent to ice formation. However, injury may result not only from ice formation, but may be related to the time the tissue is in the frozen state, the severity of the freezing temperature, and thawing conditions. In many freezes, leaves often recover after being completely "water-soaked" or frozen, which suggests that the formation of ice is not the sole cause of freeze injury.

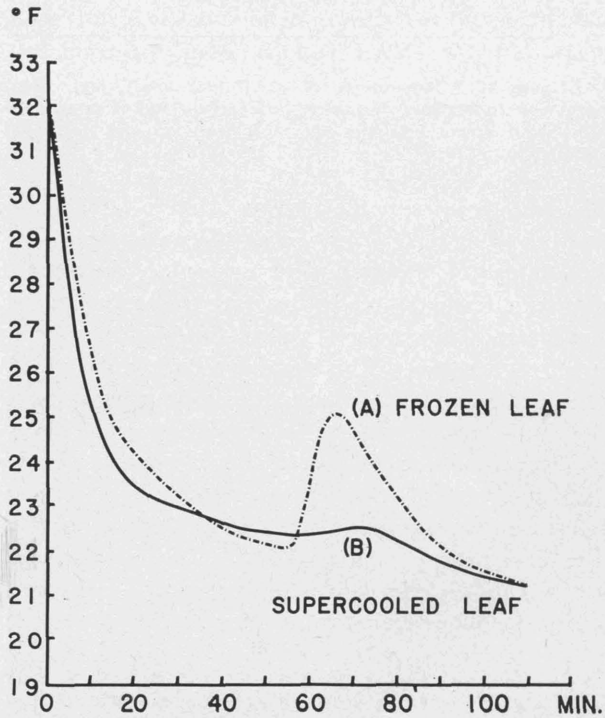

Fig. 9. Temperature changes of leaves during freezing and supercooling.

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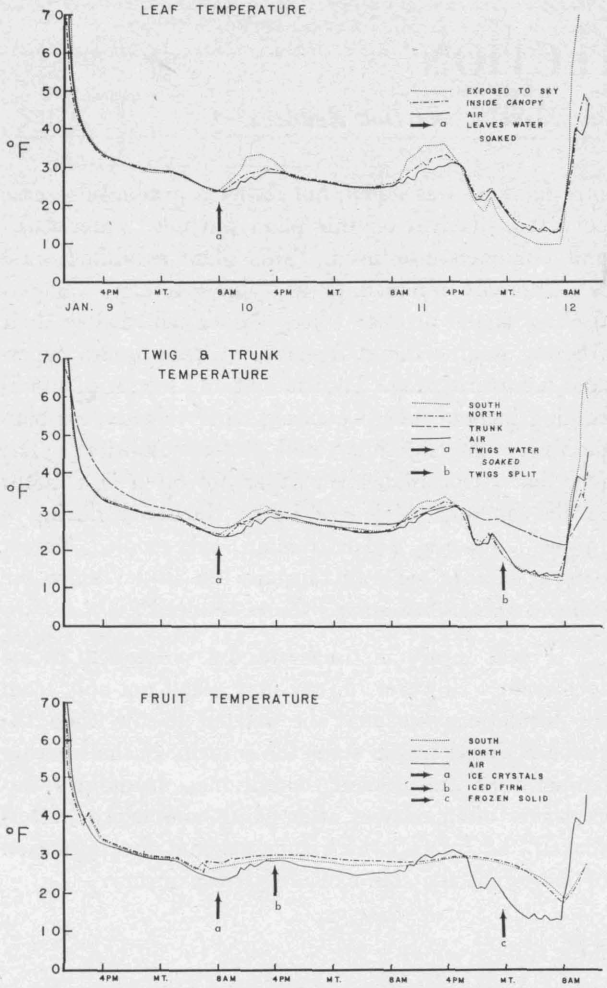

Figure 10. Temeratures of air (7-foot level), leaf, twig, trunk and fruit tissue recorded during the 1962 freeze in a 30-year-old Valenica orange tree in a grove 2 miles northwest of Monte Alto, Texas.

Tree tissue responses during a freeze (1962) are shown in Figure 10. Leaves on the outer surface of the canopy of the tree were warmed 6 degrees F. above air temperature by the sun's radiation during the day and cooled 0 to 4 degrees below air temperature by radiation to the clear sky during the night. The first two nights, where skies were overcast and the winds strong, exposed leaves did not cool below air temperature. The last night, where skies were clear and winds slight, leaves cooled 3 to 4 degrees below air temperature. Leaves inside the tree canopy were at air temperature or 1 to 2 degrees warmer than air during the entire freeze period. Twig temperatures followed air temperatures during the entire freeze.

Fruit and trunk temperatures were warmer than air temperatures during the freeze. Because of the size of these tissues, considerable heat was present and more time was required to remove it. Fruit and trunk temperatures never reached air temperatures, but critical temperatures were reached in the fruit.

Temperature changes in the various tissues during the 1962 freeze were typical for both a blowing-type freeze and a radiation-type freeze.

Freeze Injury

Freeze injury in tissues manifests itself in many ways. In fruit, injury may appear as dry segments and separated cell walls (Figure 12). In some cases, cell breakdown and crystal and gum deposits become apparent. In sweet oranges, hesperidin crystals may appear in the segment membranes several days after freezing. Hesperidin crystals are good indicators of freeze injury. Injury is generally greater in the stem end of the fruit, and smaller fruit sustain more injury than larger fruit. If fruit injury is severe enough, quality will be affected. Decreases in acid and juice usually occur in frozen fruit, and often severely frozen fruit will show a decrease in sugar content. The severity of freeze injury and the climatic conditions following the freeze generally determine the rate of change in fruit quality. Severely frozen fruit, as in the 1962 freeze, may show large changes in fruit quality within 2 to 5 days after the freeze. Slightly injured fruit may either show injury several months after the freeze, or may show hesperidin crystals and off-flavors immediately after the freeze and later recover good flavor. Cool weather generally slows the breakdown of frozen fruit whereas warm weather enhances it. Severely frozen fruit usually fall from the tree 7 to 14 days after freezing; some cases where the fruit stems are killed, the fruit may remain on the tree for longer periods. Following the severe 1962 freeze in Texas, fruit drop was heavy within 7 days after freezing.

Freeze injury to leaves may include all or only part of the leaf. Generally, leaves killed by freezing curl, dry, and abscise within a week. Partially injured leaves may remain on the tree, while those which are damaged more than 50 percent usually drop. Leaves killed by freezing need not turn brown after drying. Often they remain light green even though dead. Where weather conditions are cool and wet following the freeze, dead leaves may uncurl and appear normal for several days. As with fruit, weather conditions often control the rate of leaf drying and abscission. In severe freezes where terminal wood is killed, leaves may remain on the tree for several weeks. However, dead leaves remaining on a tree for 2 weeks or longer indicate only that the terminals subtending the leaves

Fig. 11. Freeze lesions (arrows) on large limbs and trunk of a Red Blush grapefruit tree.

were killed and does not indicate the severity of injury to larger wood.

Freeze-injury to terminal wood, 1/16 to 1/4 inch diameter, is usually manifested by browning and drying of the injured areas. When injury is severe, white speckling may be noticeable in the green wood several hours after thawing. As injury symptoms develop, and the entire twig becomes grayish-white, followed by browning in later stages. Injury to terminals may also involve splitting of the bark without killing the tissues. Freeze-injury symptoms on terminals usually are fully developed 10 to 14 days after freezing, although cool weather may prolong full development of injury symptoms.

Injury to wood larger than ¼ inch is difficult to assess several days after a freeze. Three weeks to several months may be necessary before full injury is realized. Weather conditions and severity of injury determine the time required for complete injury development. Wood need not have split to be killed, but splitting often occurs. Bark splitting usually will occur in weak areas of the limbs, particularly in the crotches. Splitting may occur either when the tissues are frozen or after the tissues have thawed and begun drying. Tissues split while frozen because of irregular expansion or contraction during freezing. These splits may heal. Splits which occur as the tissues dry because of tissue contraction usually will not heal, although callus formation underneath the dead bark may cover the area where the split occurred. Freeze injury on large limbs and trunks may appear as dead areas or "freeze cankers," ranging in size from an inch in diameter to an area several feet long which may encompass half or more of the circumference of a limb or trunk (Figure 11). These dead areas or "freeze cankers" may be large enough to render a limb or even a tree worthless.

Bark examination on large wood following a freeze may indicate the severity of freeze injury to the wood. Visual examination several days after a freeze usually does not reveal freeze injury, and one should wait a week or more before attempting bark examinations. Even then it is difficult to definitely detect freeze injury. Freeze-injured bark usually is dry and takes on a blotchy, olive green color in contrast to the normally straw colored bark. Dryness alone,

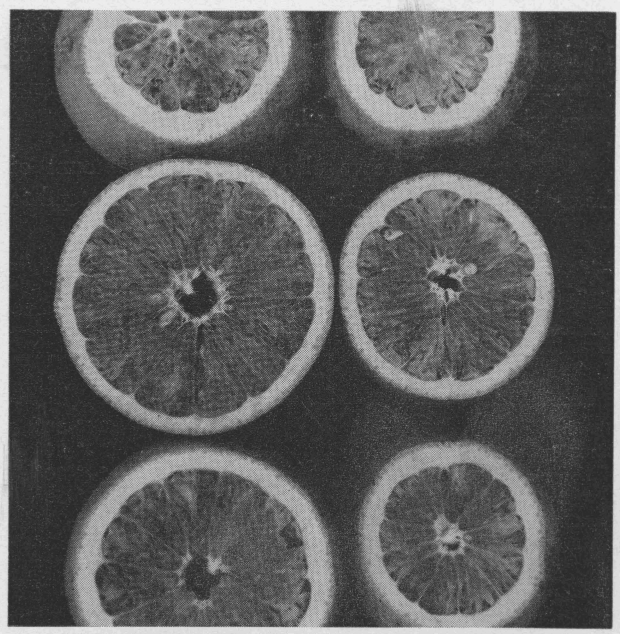

Fig. 12. Freeze injury to large and small grapefruit (top to bottom) in stem end, middle, and stylar end of fruit.

however, does not indicate freeze injury since normal bark may at certain times be dry. The wood proper may also be off-colored following injury by freezing.

Critical Tissue Temperatures

The critical temperatures of various tissues determines to a large extent the injury which may result from exposure to freezing temperatures. Tissue age, type, condition, and other factors, such as climate and nutrition, influence the freezing point of citrus tissues. For this reason, specifying certain critical temperatures for various tissues is difficult since conditions vary considerably. From experience, one can suggest certain temperature ranges for various Valencia orange, Red grapefruit, and Satsuma mandarin tissues to which exposure may cause injury (Table 9). These temperature ranges are suggested for nongrowing, healthy bearing trees during mid-winter. Trees weakened by various factors or in a growing condition may be injured by warmer temperatures.

On winter hardened grapefruit or orange trees during a normal winter, wood ¼ to 2 inches usually is killed by minimum temperatures ranging between 22 and 16 degrees F. Red grapefruit and Valencia orange tree limbs 2 inches in diameter have been killed by minimum temperatures of 18 degrees F. Some Red grapefruit and Valencia orange trees had little wood larger than ½ inch injured from exposure to 12 degrees F. in 1962. Mandarins have a several degree colder temperature range for the same size wood while lemons and limes have a several degrees warmer temperature range. Many mandarins had no injury to wood 1/16 to ¼ inch following exposure to 10 to 12 degrees F. in 1962. The severity and duration of temperatures often dictates the eventual tree tissue types which will be injured.

The type of freeze also affects the amount of freeze injury to citrus trees. Blowing freezes tend to

Table 9. Suggested critical temperature ranges for various tissues of oranges, grapefruit, and tangerines grown in the Rio Grande Valley based on observations during natural and artificial freezes.

Tissue	Valencia	Red grapefruit	Satsuma Mandarin
Bloom	29°-30°	29°-30°	29°-30°
Small green fruit	28°-29°	28°-30°	29°-30°
Half ripe fruit	27°-28°	26°-28°	29°-30°
Ripe fruit	25°-27°	24°-26°	28°-30°
Tender leaves	26°-28°	26°-28°	25°-27°
Mature leaves[1]	23°-25°	23°-25°	20°-23°
Tender twigs	23°-25°	23°-25°	22°-24°
Mature twigs[1]	21°-23°	21°-23°	16°-19°

[1]Mature leaves and twips assume also winter hardened tissues. Mature leaves and twigs unhardened would be injured at warmer temperatures.

remove much of the stored heat and moisture in the tree and ground. When enough heat is removed, even large wood may be cooled to the critical range and injury may result. This occurred in both the 1951 and 1962 freezes in Texas. Severe desiccation or water loss also may be adverse in that more injury may result. In the 1962 Florida freeze, trees in the direct path of the wind were injured more severely than protected trees although the exposure temperatures were similar.

In calm freezes, loss of heat and moisture from the tree and soil is not as rapid. Consequently, wood and fruit may not cool to as low a temperature and injury may be less or may not occur. The temperature of leaves and twigs, regardless of the type of freeze, usually remains similar to air temperatures since they have very little stored heat.

The occurrence of freeze injury to citrus in the simplest terms is influenced by a relationship between (1) the critical tissue temperature, (2) the severity and duration of freeze temperatures, (3) the amount of stored heat, and (4) the presence or absence of wind during the freeze.

Dormancy and Cold Hardiness

Growth of citrus is characterized by intermittent growth interrupted by periods of no visible outward activity. These periods of growth and nongrowth often occur during more or less constant environmental conditions. In the Valley, usually four growth flushes occur followed by periods of growth interruptions. These flushes occur in early spring, early summer, early fall, and late fall. When winter night temperatures fall below 55 and 50 degrees F., minimum temperatures for growth of oranges and grapefruit respectively, no flush of shoot growth occurs, and all buds remain dormant. If, however, night temperatures warmer than 55 or 50 degrees occur during the winter or early spring for a period of 5 to 10 days, bud growth may begin. Cambial activity in twigs and wood and root growth is almost continuous the year around, although in the winter, twig cambial activity usually ceases and wood cambial activity and root growth lessen.

In periods of nonbud growth during the growing season, buds are dormant. This dormancy is not climate-induced but results from certain physiological conditions, probably of hormonal nature, within the tree. This type of bud dormancy, more properly referred to as bud inhibition, often occurs during periods where environmental conditions are favorable for growth. In the winter, bud dormancy is temperature-induced, and the tree tissues that become dormant depend on the microclimate of the tree during the cold period.

Closely correlated with tree dormancy is tree cold hardiness. The more dormant a tree is the more cold hardy it is. Actively growing trees are very cold sensitive; thus, conditions during the winter which induce growth will reduce the tree's cold hardiness as was clearly pointed out in the 1951 freeze in Texas. Buds on trees which were defoliated by a frost which occurred in December 1950, were actively growing at the time of the freeze in January. Injury to those trees was severe and many large trees were killed. Trees not defoliated in December 1950 were not as severely injured in the freeze.

Climate has been shown to influence greatly the cold hardiness of citrus. In the Valley during the winter, ambient air temperatures at night usually do not fall much below 50 degrees F. for extended periods. Under these conditions, dormancy may be imposed on buds and twig cambium, but not on large wood cambium or roots. Citrus trees in the Valley usually acquire about 3 to 4 degrees cold hardiness during the winter. On the other hand, in California where ambient air temperatures at night fall below 40 degrees every night, roots, buds, and cambium of the entire tree may become dormant. Trees in California during the winter may acquire up to 10 degrees cold hardiness.

Cool temperatures during the winter are the major climatic factor responsible for the induction of cold hardiness in citrus. Ten-year-old grapefruit trees exposed to artificial temperatures of 23 degrees F. for 4 hours during various times in the 1960-61 winter, sustained varying degrees of injury (Table 10). Trees in November, before exposure to any cool winter temperatures, sustained the greatest tree and fruit injury. These trees were not dormant. Trees in December after 2 weeks of cool temperatures, showed much less tree injury and less fruit injury. In January, after 6 weeks of cool temperatures, very little tree injury occurred and much less fruit injury was found. Buds and small wood cambium were dormant on trees in January. In February, 10 days of warm weather above 50 degrees F. occurred and buds began to grow. Trees sustained more injury than in January although fruit were only slightly injured. Thus, large changes in tree cold hardiness may occur during the winter and are brought about by changes in temperature.

Although temperature is the major climatic factor influencing tree cold hardiness, soil moisture stress is also important. Trees slightly on the dry side become more dormant and are more cold hardy than those with adequate moisture. However, if trees are allowed to become too dry, cold hardiness may be affected adversely. Withholding moisture during the winter may induce more cold hardiness, but this practice is risky in the Valley. Winter rains on dry trees may supply enough moisture to induce bud growth which would greatly reduce the tree's cold hardiness. The lack of winter rains and low humidity during the winter also favors cold hardening. These conditions, however, are usually less effective than withholding irrigation water.

Varieties and Rootstocks

Following natural freezes, rather large differences in the cold hardiness of various citrus varieties have been noted. These differences can be explained in part by the degree of dormancy which the particular variety exhibits during the winter. Those varieties which stop growth at a higher night temperature usually exhibit more winter dormancy.

Following the 1962 freeze in Texas, freeze-injury records indicated that some varieties were much more cold hardy than others. Most mandarins, such as the Clementine and Kara, were very cold hardy; however, the Dancy and the Murcott were very cold sensitive. Washington navel, Texas navel, Jaffa, Parson Brown, and Hamlin oranges, although less hardy than Clementine mandarin, were the most hardy of the sweet oranges. Valencia orange followed navels in hardiness while Marrs and Pineapple oranges were the least hardy of the sweet oranges. Temple orange was variable in hardiness. Both Red and white grapefruit and Orlando and Minneola tangelos were slightly less hardy than the sweet oranges; Mexican limes, Eureka lemons, and Meyer lemons were the least hardy of the citrus varieties. Meyer lemon was the most hardy of the lemons and limes.

Table 10. Injury to Red Blush grapefruit trees and fruit after exposure to 23° F. for 4 hours in November and December, 1960, and January and February, 1961.

Date	Bark slipping twigs[1]	Tree injury: % defoliation	Tree injury: % twig injury	Number of segments injured per fruit
November	2.4	86	98	4.9
December	1.8	40	12	4.2
January	0.9	14	0	2.2
February[2]	3.0	39	11	0.8

[1]0 = bark does not peel; 1 = bark barely peels; 2 = bark peels easily; 3 = bark peels easily and is moist.
[2]Bud growth had started and buds were ¼" to ½" long.

Fig. 13. Freeze injury to and subsequent recovery of 8-year-old trees of (A) Red Blush grapefruit on Cleo, (B) Red Blush grapefruit on sour, (C) Valencia orange on Cleo, and (D) Valencia orange on sour. Pictures were made in April 1963.

Under Valley conditions, mandarins or varieties with mandarin or tangerine parentage generally are the most cold hardy of the commercial varieties. Limes and lemons, because of mild winters in the Valley, usually grow the year around and during the winter are very cold sensitive. Large plantings of limes or lemons are not recommended for the Valley.

Rootstocks also have a pronounced effect on the cold hardiness of the tree. Many rootstocks have been tested under Valley conditions and their cold hardiness behavior observed. In most plantings Cleopatra mandarin rootstock induced more cold hardiness to the top than did sour orange (Figure 13). These two rootstocks are commonly used in the Valley. Of the two, sour orange generally is preferred because it produces better fruit size, and the trees are less susceptible to iron chlorosis.

MECHANICAL COLD PROTECTION

Engineering Considerations

Grove heaters provide the most widely-used method of freeze protection. They heat the air immediately around the flame and immediately around the surfaces of the heater. This air in turn is dispersed by thermal movements or wind movements, and tends to warm the atmosphere in the immediate vicinity. Since warm air tends to rise, the heat from thermal convection will move upward and quickly out of the grove unless wind movement is sufficient to disperse it among the trees, or unless this heat is applied under the canopy of the trees, where its upward movement is restricted. High winds tend to move added heat out of the orchard very rapidly, making it virtually impossible to change the temperature appreciably.

The heater has a second means of supplying heat to the plants in that it radiates heat outwardly and this heat is absorbed only by the mass of the plant, soil or sky. In many cases, such as on clear, cold, still nights, this radiant energy can effectively prevent excessive freeze damage.

Young trees are best protected through the use of small heaters and by taking advantage of the convective heat that will filter up through the center of the tree. This method requires at least one heater per tree. When heaters are placed in this fashion, the radiant energy available normally is received only by the trunk, wood, and foliage in the near vicinity of the heat source. The convective heat is carried through the tree and can be retained in the orchard for effective use a little longer than it could if it were out in the space between trees.

Where the grove is composed of older trees, with wide canopies, fewer heaters often can be used satisfactorily by placing them in the space between trees, so that any wind movement will tend to carry the

Fig. 14. The University return stack heater is a popular unit for grove heating since it burns with a clean flame and can be used at variable burning rates.

heat across the grove. Heaters used in this fashion usually are large return stack heaters that give off considerable radiant energy as well as convective energy. The radiant energy will then be transferred to trees surrounding the heater to help protect them. This radiant energy is especially effective on cold, clear nights. The return stack heater is a rather popular unit for use in spaces between trees since it is readily available, effective, burns with a clean flame, and can be used at variable burning rates. On a still night with winds of from ½ to 1 miles per hour, approximately 9 million BTUs of heat were necessary to maintain a 10 degree temperature response in the grove when there was very little inversion. This quantity of heat would require 65 to 70 gallons of fuel oil per hour per acre, and would indicate the need for 50 to 60 return stack heaters per acre to maintain this 10 degree rise. A lower temperature response should be expected with a reduced number of heaters or burning rate.

Small areas and isolated groves are more difficult to heat successfully since there is a definite stack action created by the rising of the heated air and gases from the heaters. Cold air is drawn in from all sides of such an isolated area and may reduce the response to heat for as much as 10 to 15 rows from the edge. Higher rates of fuel input per acre cause increased grove stack action and indraft; therefore, it is important to operate the heaters, especially those within the plot, at the lowest rates which will give adequate protection. Border heaters should be distributed over the first two or three rows rather than concentrated on the outside of the grove. A good practice is to use one heater per tree on borders. Heaters with high radiant output are especially advantageous in border heating. The greatest concentration of border heaters should be on the up-wind side. Often heaters in combination with wind machines give extra response because the convective heat from the heaters can be pushed back into the grove more effectively. Table 11 gives results obtained from an orchard heating test conducted on avocados during a still radiant freeze. In that test with 70 University Return Stack heaters per acre burning at a rate of 2 gallons of fuel per hour, temperatures in the heated area were raised 5 to 9 degrees above the nonheated area. In Arizona, 45 Jumbo Cone heaters per acre burning fuel at 1 gallon per hour raised grove temperatures 3 to 5 degrees F. during several radiant freezes.

Freezes with high winds dissipate heat rapidly from the grove and conventional heaters are less effective. Heaters which emit more radiant heat are more effective in freezes with high winds. Radiant heat is not affected by wind. The University Return Stack and the Jumbo Cone heaters emit more radiant heat than other conventional heaters.

Table 11. Temperatures in degrees F. at various locations in heated and non-heated areas in an orchard heating test at Rio Farms, Inc., Texas, February 11, 1955.

Location No. and description		Thermometer No.[2]	Temperatures ° F. at indicated time				
			2 a.m.	3 a.m.	4 a.m.	5 a.m.	6 a.m.
			Heated area[1]				
1	East side	1	36	34	35	34	34
	Inside heated area	2	37	35	36	34	35
2	Inside heated	1	37	35	36	34	36
	area	2	38	35	36	35	35
3	Inside heated	1	37	35	36	30	31
	area	2	37	37	38	32	32
4	North	1	35	35	36	33	33
	perimeter	2	38	36	36	33	33
5	South perimeter	1	32	31	31	28	28
	Outside heated area	2	32	31	31	28	29
6	Inside	1	36	36	36	32	34
	tree	2	37	36	36	32	34
7	West side	1	39	38	37	32	32
	inside heated area	2	38	37	37	32	33
			Non-heated area[3]				
1	East side	1	31	30	30	28	28
		2	31	30	30	28	28
2	In the open	1	28	28	29	25	27
	not near any trees	2	30	28	28	26	26
3	North	1	31	31	31	27	28
	perimeter	2	31	30	31	27	28
4	Center of	1					
	plot	2	30	30	31	27	27
5	West side	1	33	31	30	26	26
	of plot	2	32	31	31	27	27

[1]Protected on north, south, and east sides by windbreak and heated wtih 70 University Return Stack heaters per acre. Very slight wind drift from N.E. to S.W.

[2]Thermometer No. 1 was located 3 inches above ground and thermometer No. 2 was located 3 feet above ground.

[3]Nonheated area was adjacent and west of the heated area and was not separated from it by a windbreak. There was a windbreak on the north and south sides of the nonheated area but not on the west.

The cost per acre to equip a grove with heaters varies with the type of heater and the number per acre. The University Return Stack heater costs approximately $8, the Jumbo Cone, $7, and others somewhat less. Assuming one uses the University Return Stack heater at 60 per acre, one might expect to incur the following initial costs on a 40-acre grove:

60 heaters per acre, $8.00 ea.	**$480.00**
9 gallons fuel, $0.12 per gal. × 60	**64.80**
	$544.80 × 40 = $21,792.00
12,000 gallon storage tank erected	**1,500.00**
One 500-gallon oil cart with pump	**575.00**
5 thermometers, $5.00 ea.	**25.00**
10 lighting torches, $6.00 ea.	**60.00**
	$23,952.00

The initial investment in this grove would average about $599 per acre. In case more heaters were used per acre, a higher initial investment would be necessary. Annual maintenance costs, fuel and labor costs during freezes, and depreciation have not been included. Maintenance costs plus fuel and labor costs may total $50 per acre per year.

Windmachines

The use of windmachines in Texas has not been fully evaluated. They are effective only in freezes where a strong temperature inversion up to 50 feet exists and the wind velocity is less than 3 miles per hour. In California and Arizona where the use of windmachines is recommended, freezes are still, radiant freezes with strong inversion air layers generally about 50 feet above the ground. Windmachines mix this warmer air with the cold air close to the ground surface and thereby raise the temperature in the orchard.

In Texas, less is known about temperature inversions during freezes. The inversion was measured at 20 and 40-foot levels during the entire 1962 freeze at Monte Alto. No inversion existed during the first two windy days and nights and only an 8 degree F. inversion existed at 40 feet on the last night where a still radiant-type freeze occurred. Under those conditions, one could expect no more than a 6 degree F.

Table 12. Occurrence of temperature inversions[1] during cold nights at various Valley locations.

Station and winter season	Minimum temperature (5' level)	Height where inversion measured	Number nights with indicated degrees of inversion 0°-4°	5°-10°	11°-15°
Harlingen:[2]					
1931-32	30-40	98'	8	2	0
1932-33	28-40	98'	9	0	0
1933-34	35-40	98'	3	0	0
Engleman Gardens:[2]					
1934-35	24-37	49'	5	1	0
1935-36	25-38	49'	12	3	0
Weslaco:[3]					
1960-61	34-39	26'	5	0	0
1961-62	18-32	26'	3	1	0
1962-63	24-33	26'	6	0	0
Monte Alto:[4]					
1961-62	12-28	40'	2	1	0
		20'	2	1	0

[1]Temperature inversions are defined as differences in temperature between that at 5 feet and at indicated height. No attempt was made to measure height at which a maximum inversion occurred.
[2]Data taken from a "Summary of fruit frost data obtained in Lower Rio Grande Valley district during five seasons beginning with the winter of 1931-32." Esek S. Nichols, U. S. Dept. of Agriculture, Fruit and Vegetable Frost Service of the Weather Bureau, Harlingen, Texas.
[3]Data from Texas Agricultural Experiment Station, Weslaco, Texas.
[4]Data from Weather Station belonging to U. S. Department of Agriculture, ARS, CRD, Weslaco, Texas.

(three-fourths the temperature inversion) rise in temperature with the most effective windmachine. Data in Table 12 indicate that most freezes between 1932 and 1937 had 0 to 4 degrees of inversion existing at levels between 26 and 49 feet.

In the 1962 Texas freeze, several groves in the Valley were equipped with windmachines and several had both windmachines and heaters. Observations following the freeze indicated that in one grove, a windmachine alone had no effect; one with heaters and a windmachine had little or no effect, another with 18 heaters per acre and a windmachine raised the grove temperature 3 to 4 degrees F.

The use of windmachines alone under Valley conditions appears, in most instances, not to be a practical method for freeze protection. General information indicates that temperature inversions at the effective level are weak and inconsistent.

The use of both heaters and windmachines depends largely on the temperature and wind conditions in each grove. With a strong temperature inversion and no wind, both heaters and windmachines would be effective. With a weak inversion, windmachines would be of value only in distributing heat from the heaters more uniformly throughout the grove. If light winds are present, which generally is the case in most radiant freezes in the Valley, the value of a windmachine would be nil.

Cost of windmachines varies with the size of machine and the acreage to be covered. Small machines which are not too effective average between $1500 to $2500. Larger machines equipped with two 100 H.P. engines which may cover 10 acres adequately, under optimum conditions, costs $5000 to $6000. Initial costs per acre run between $500 to $600 and do not include annual maintenance costs, fuel and labor costs during freezes, and depreciation.

Irrigation

Water has been applied on crops to prevent freeze damage many times in the Valley. Water is warmer than air and releases heat. As water freezes, heat is again released. Research in other areas shows that water cooled from 65 to 32 degrees F. will change the air temperature 2.5 to 4 degrees F. with an initial air temperature of 26 degrees. This could be a real aid in a freeze of short duration or if the temperature is not too low.

In Arizona and California, flooding orchards with water for freeze protection has been used. Generally, one can expect 1 to 4 degrees F. rise in grove temperature from flooding depending on the type of freeze and distance from the water source.

Flooding an orchard with water would not be too practical in the Valley. Due to the methods used in distributing water through canals by the districts, only a few growers could be serviced in any one night. Also, at the temperatures at which water gives protection, mature citrus trees probably would not receive much cold injury, provided the trees were not in a growth flush. If the freeze were more than one night duration, the soil would become waterlogged and injury to the trees could result.

Sprinkler irrigation for cold protection does not seem to be a practice to recommend to Valley citrus growers for several reasons. As with flooding, most citrus growers in the Valley do not have a large supply of water they can use on short notice. A lot of the freezes in the Valley are accompanied by high winds which would reduce the effectiveness of the sprinklers. On an evergreen tree like citrus, it would be difficult to get even distribution of the water on the tree, and if the freeze lasted very long the weight of ice on the limbs would cause as much or more damage from breakage as the freeze would have done.

The cost of sprinklers would vary depending on the number used per acre and the type of materials used for water distribution. Generally, a system adequate for both frost protection and irrigation will run between $600 and $1000 per acre initial investment.

Cultural Practices

Under Texas climatic conditions any cultural treatment to a citrus grove in the fall should be done with the thought of how it will affect dormancy and, consequently, the cold hardiness of the tree.

Young trees up through 3 to 4 years of age can be given winter protection by banking the trunks with trash-free soil in November. Banks should be up by the first of December although it is very seldom that a trunk-injuring freeze occurs before the tenth of December. The larger the bank the more wood is protected in case of a freeze. Some growers bank their trees into the framework limbs.

It is important to use trash-free soil that is not too wet or cloddy. Prior to bankings, trunks should be treated with a banking paint. The paint should contain a fungicide (neutral copper), an insecticide, and a sticking agent. Trees that are banked with a fine textured soil that is too wet will sometimes cause the bark to soften and rot. Banks in this condition should be taken down and the soil allowed to dry

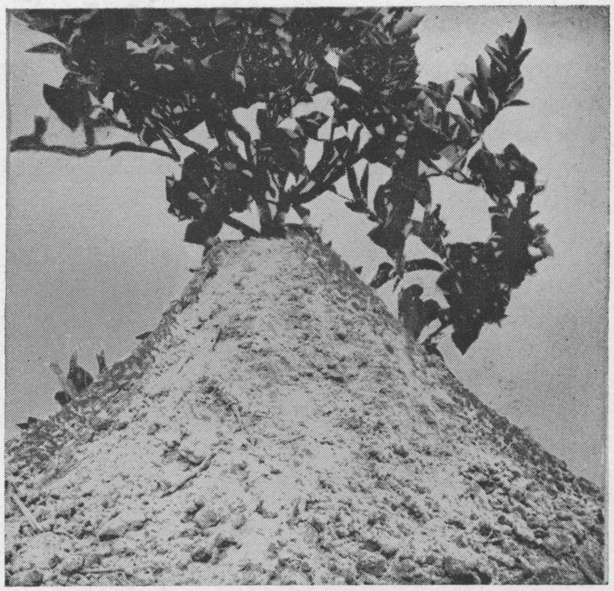

Fig. 15. Banking young citrus trees is a time-proved method of protecting them from cold temperatures during the winter.

before rebanking. Soil that is full of clods should not be used for banking because there will be air spaces left around the trunk for cold air to settle into in case of a freeze.

Soil banks can be safely taken down about March 1, after the danger of freezes is past.

Some growers use permanent banks around their trees. These are put on the first year after planting and allowed to remain as the tree grows. The materials generally used are cylinders of either mesh wire or roofing paper filled with some type of insulating material. Permanent banks gave good protection against freezing in the 1962 freeze. There are several disadvantages, however; ants and rodents will often build nests in them and sometimes cause bark damage, and the material does not dry out immediately after a rain, making the trunks susceptible to disease.

Either permanent or soil banks should be checked periodically through the winter months to ascertain that they are in good condition. High winds whipping young trees banked with soil sometimes will cause a cone to form around the tree trunk. Unless this hollow cone is filled with soil, cold air will flow into it during a freeze and damage the tree trunk.

Research shows that a bare, firm, moist soil absorbs more heat from the sun during the day and releases more radiant heat at night than soil that has a mulch or a cover crop, or that is loose or freshly disked.

Groves managed on a semiclean tillage should be disked for the last time in October. Groves in sod or in permanent borders with sod should have the sod cut as short as possible during the winter months. In both cases winter weeds should be controlled by mowing or shredding and the last irrigation should be applied in November.

It was observed in the Valley after the 1962 freeze, that many groves that were not seriously injured had not been cultivated since October or early November, while groves that had been cultivated in December generally had considerable cold damage. Application of water in December did not seem to have much influence on the amount of cold damage, provided the soil had not been cultivated.

Under Texas climatic conditions, groves irrigated in November usually will not require another irrigation until February when the spring flush of growth commences. The November irrigation is necessary to prevent moisture stress during the winter months. Orchards that are too dry in the winter months are more subject to mesophyll collapse damage from high velocity, dry north winds, and are usually more cold sensitive. Dry orchards will start growth if a rain occurs during the winter and will then be subject to severe cold injury in case of a freeze.

Winter cover crops should not be grown in Valley groves because the ground cover may cause the grove to be 3 to 5 degrees F. colder due to increased radiation of heat both during the day and night. The tall growth of a cover crop also can prevent free movement of air and cause a frost pocket to form.

Windbreaks

Windbreaks will decrease windblown sand, scarring of fruit, leaf injury, and mesophyll collapse damage in the fall, winter, and spring. They provide protection from freezing winds in the winter, and make heaters more efficient for freeze protection.

If orchard heaters are to be part of the cold protection system, windbreaks are a must. The windbreak should be planted at the same time as the orchard and it should receive care such as irrigation and fertilization. In some cases, systematic root pruning is also necessary to help alleviate root competition with the adjacent citrus trees. Top growth should be controlled so that the trees grow into strong well-shaped plants.

Few plants make good windbreaks for citrus groves in the Valley. A plant used as a windbreak must be easy to propagate, fast growing, adapted to alkaline soils and irrigation water with high salt content, and tolerant or immune to cotton root rot. It must have few insect pests, be cold hardy, evergreen, not create a fire hazard, and reach a height of at least 20 to 30 feet.

Observation following the 1951 freeze, indicated that Athel or salt cedar, *Tamarix articulata*, is most adaptable as a windbreak plant. It is, however, a vigorous feeder and will affect the growth of trees for several adjacent rows. In the Western states, Athel has become a serious pest because it established itself in drainage ditches and other areas where it was not wanted. If Athel is used, cuttings should be spaced about 4 feet apart.

Another plant that gave good wind protection in some Valley groves in the 1951 freeze was close planted fan palms, *Washingtonia robusta*. The palms do not grow as fast as Athel but once established in a staggered double row planting they give good wind protection. Palms used as windbreaks should not be trimmed other than when young to lessen the fire hazard. They should be planted 4 or 5 feet apart in the row with a second row about 5 feet away with the palms placed alternately in relation to the first row.

If a windbreak is planted on all four sides of an orchard, some system of freeze protection must be used because a frost pocket will be formed on still cold nights. Frost pockets may be avoided in unprotected orchards by wider spacing of the windbreak trees and leaving the lowest side of the orchard open for air drainage.

Each piece of land will present a different problem when planning to set out a windbreak. For this area, most damage comes from the southeast, north, and northwest winds. Care should be taken to insure continuity of the windbreak as missing trees will cause the wind to be funneled through the opening at an increased velocity.

CARE AND REHABILITATION OF FREEZE-DAMAGED CITRUS TREES

*Bailey Sleeth, Norman P. Maxwell, Morris Bailey and Roger Young**

YOUNG BANKED TREES

Young banked citrus trees with severely frozen tops should be pruned back to live wood after the banks are removed. The cut should be smooth and sloping with a bud at the upper part of the cut. The pruning wound should be painted immediately with a good asphalt wound paint containing a fungicide.

BEARING TREES

The time of pruning affects the rate and degree of recovery of citrus trees. Where it is not necessary to remove the head of the tree, the most satisfactory recovery is obtained by delaying pruning until the first flush of growth appears and is fairly well hardened. Trees pruned earlier than this generally have a lot of dieback that must be removed at a later date and the trees are temporarily stunted. Some dieback occurs on trees pruned after the first flush of growth but it is less than on early pruned trees.

A good recovery has been observed on trees pruned after the second flush of growth occurred, but these trees had to be whitewashed at the time of pruning to prevent sunburn. There was no advantage in recovery over the trees pruned after the first flush hardened and some dieback occurred which necessitated repruning.

Trees that were not pruned until fall, or until the following spring, did not recover as fast as those pruned after the first flush, although they eventually made satisfactory trees. At the time of pruning, on this class tree, it was difficult to remove the dead wood because of interference of new growth. Much green wood on weak limbs had to be pruned, thus reducing the size of the tree and delaying fruit production.

Generally citrus trees over 8 years of age that are killed back to the trunk do not have the necessary vigor to make a profitable citrus tree again. A new tree can be planted and brought into production quicker than trying to salvage the old tree.

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In pruning freeze-damaged trees, cuts should be made into sound green wood or below serious bark wounds involving a third or more of the limbs' circumference. Where it is possible, cuts should be made just above a shoot or branch to encourage callus growth to cover the wound and lessen the possibility of further dieback.

The need or good accomplished by repruning after the initial pruning on freeze-damaged trees in Texas is controversial. In the 10-year period after the 1951 freeze, most of the trees that were mature, unbanked and bearing during the freeze had deteriorated to such an extent that they were not profitable to the grower. At the time of the 1962 freeze, an estimated 500,000 trees were in this class in the Valley. Of this group, probably half or more were at the point to where it was advisable to replace them.

This rapid deterioration of the trees was due to large dead areas on the framework limbs, crotches, and trunks that were impossible for the tree to callus over in growth. After the top growth got to a certain size, the tree was no longer able to supply the necessary nutrients and water due to the partial girdling. There is considerable doubt whether it is economically advisable to spend more money in pruning when the tree will probably not live much over 10 years. However, if the framework limbs and trunk are sound with few to no dead areas, the grower probably is justified in spending more money for repruning.

FERTILIZATION AND IRRIGATION

Fertilization can be decreased and possibly eliminated the first year after a freeze. Reduced leaf surface on the trees from freeze damage in groves that have been on a regular fertilizer schedule will not require additional nutrients until the start of the second year. When fertilization begins, the amount applied should be adjusted to the general tree size rather than age.

EQUIPMENT FOR PRUNING

Pruning freeze-damaged citrus trees can be a very expensive operation because of the large amount of wood that must be cut and removed from the grove. Because of this, most growers use power saws for the initial pruning. At a later date, those groves that are in good enough condition to warrant the added expense of a second pruning may be repruned with hand or power tools.

A grower wishing to purchase power equipment should consider the price of the various types of saws, the labor he has available, and the amount of pruning required.

High speed circular saws powered by portable electric generators were used to prune most of the Valley citrus trees after the 1962 freeze. This type saw is very fast, light in weight, does not have many parts, blades are cheap, and the overall units are not too expensive. A circular saw used by an experienced operator will make fairly smooth cuts that heal if the area is not too large. The main disadvantage to this saw is the danger involved to the operator and nearby personnel, since it runs at very high speed and is not equipped with a blade guard.

Loppers and saws, powered by compressed air also perform satisfactorily, however, air compressors are expensive.

For trees that require additional pruning, slower, more versatile tools should be used.

Removing dead wood from the grove is a very expensive operation. The use of large fire boxes that burn the wood as the box is pulled through the grove has proved successful in the Valley. These boxes are constructed with heavy steel sides so that the fire is confined to the box and does not endanger nearby trees.

Other equipment used successfully in Texas includes large rakes drawn by tractors that pull brush to the edge of the grove and blades to push brush into piles.

WOUND PROTECTANTS

To protect pruned and bark-scarred citrus against entrance of decay and wood borers, cut surfaces and exposed wood should be painted with a good pruning paint. The ingredients and directions for making 2 gallons of low-cost, effective pruning paint follow. A larger amount may be made by proportionately increasing the materials used.

Asphalt, good grade	12 pounds
Kerosene, high grade commercial	1 gallon
Naptha (Mineral spirits)	1 quart
Penta, 4% pentachlorophenol	½ pint

(Penta 40% is a wood preservative or weed killer)

Use caution in melting the asphalt and adding the materials to the hot liquid asphalt.

To reduce fire hazard, make the paint outside of buildings, and some distance from flammable materials. A thicker paint may be made by increasing the amount of asphalt or reducing the amount of kerosene.

Steps in making paint follow:

Melt asphalt over fire in metal container. Remove the container to a safe distance from the fire; add kerosene and stir to get uniform mixture. When the mixture cools somewhat, add Penta and naptha, and stir until mixed thoroughly.

If the mixture is too thick, thin by adding naptha or by warming. The paint should be fairly thick when applied and a medium to stiff brush should be used to cover the wound surface. Pruning wounds should be painted immediately after making the cut.

Because of variability in paint ingredients, wound paints should be tested for plant toxicity by painting a few citrus leaves and young stem growth. If after 3 days, injury has not occurred, the paint is safe.

SUSCEPTIBILITY TO SUBSEQUENT FREEZES

Citrus trees previously injured by freezes are more susceptible to subsequent freezes, since freeze injury weakens a tree and prevents it from hardening during following winters.

MARKETING TEXAS CITRUS

*Harold B. Sorensen, Bruce Lime, Gordon Powell, and Ralph Petersen**

Basically, the marketing of citrus is the same as the marketing of any other agricultural product. In the old concept, marketing is the performance of all business activities involved in the flow of goods and services from the point of initial agricultural production until they are in the hands of the ultimate consumer. In the newer dynamic concept, it is the creation of products and services to meet consumer demands. Therefore, various production decisions also have marketing aspects of vital importance.

Meeting the demand for the right kind of supply of the right kinds of citrus is a major problem of Texas growers, wholesalers, and retail produce men. They must do their utmost to achieve perfection in meeting the daily market needs by adequate planning from the producing areas on forward to the final consumer. Also, the mechanics of the marketing system must be properly located and coordinated.

MARKETING ORGANIZATION

The three major citrus-producing areas in the United States are Texas, California-Arizona and Florida. Practically 100 percent of the citrus produced in the California-Arizona area is under an integrated production and marketing arrangement.

Most of the integrated production and marketing of Florida's citrus is through producer cooperatives. Two large organizations assist in marketing Florida citrus. A state commission, an agency of the Florida Department of Agriculture, serves in a capacity comparable with the super-cooperative in California-Arizona. Both producers and processors are represented in the state commission's program, since it deals with fresh fruit as well as processed citrus products.

Another major Florida organization operates as a merchandising and bargaining cooperative for growers in dealing with fresh fruit buyers and canning companies. Neither organization handles citrus fruit directly.

Management decisions in California on general marketing policy are the responsibility of the super-cooperative over the individual grower-cooperatives. In Florida, the state commission and the growers bargaining cooperative are the central controlling organizations.

A shipper's organization composed of Texas citrus packers and shippers in the Lower Rio Grande Valley seeks to develop higher quality standards for a select grade of Texas citrus for the fresh fruit market. The organization's primary objective is to help shippers improve their competitive positions in merchandising against the organized programs of Florida and California-Arizona.

A growers organization (Texas Citrus Mutual) in Texas also endeavors to further the growers' interests in the development of better crop estimates and useful marketing data.

Most Texas citrus growers are entirely independent of any packing house or processing organization.

In 1955, the Texas legislature passed a grapefruit branding law requiring that grapefruit be identified by a label indicating origin by state. These requirements, along with the high quality of grapefruit grown in Texas, should establish and maintain a reputation of premium fruit quality among retailers and consumers. Texas has a Federal citrus marketing order that is effective in regulating sizes, grades and containers. Federal marketing orders prohibit the use of promotional programs. Other states have state enabling acts that permit the collection of funds for promotional activities; these states have state marketing orders in addition to the Federal marketing orders for the collection of funds and for promotional work. Texas does not have an enabling act.

HARVESTING OPERATIONS

Citrus is harvested by contract picking crews assembled by the owners of trucks. These crews are supervised by the buyers or fieldmen of the packing or processing firm, but are controlled otherwise and paid by the contractor.

The harvesting contractor is paid by the firms on the basis of so much for picking and so much for hauling to the packing house. The picking rate varies with the type of fruit and method of picking. Early in the harvesting season, "ring picking" or the use of sizing rings is a common practice so that small fruit may be left on the trees to grow larger. This extra

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care by the picker results in a higher picking cost. Distance sometimes is considered in determining hauling rates but more often all contractors for a given firm operate on a fixed rate for the entire season. Harvesting and hauling costs for Texas citrus vary with the type of product—grapefruit or oranges—for fresh or processed fruit and for fresh fruit if it is ring picked for size or complete picking of tree. Currently, the costs may be as follows:

	Grapefruit	Oranges
	dollar/ton	
Fresh fruit for shipping		
High yielding trees	$ 5.50	$ 6.00
Low yielding trees	10.50	10.50
Processors	$ 4.25	$ 5.25

Diversification in the use of a product enhances its total consumption. Citrus may be utilized in several ways, such as fresh and processed. In the processed field, the product may be in the form of single strength juice, concentrated juice, chilled juice, sections or salad pieces and preserves. In addition, other byproducts such as dehydrated feed are made from citrus. Competition from these various outlets for the raw product enhances the grower's position in the marketing of his product.

PACKING HOUSE OPERATIONS

The operations performed at the citrus packing house for fresh grapefruit include degreening, dumping, washing, drying, waxing, grading, sizing, packing, and loading. As the fruit is moved over grading belts, fruits having disqualifying characteristics of size, shape or blemishes are removed and the market grades are separated before the identifying stamp is placed on the fruit

At one time, the machinery and plant arrangements for citrus packing houses were standardized and the only appreciable differences between plants were the number of units or machinery groups they contained. Since the mid-1950's, there have been several major innovations in the handling of fruit in the packing houses such as bulk handling (from the field and after grading and sizing before packing) and cold storage rooms to hold fruit in bulk bins until ready for packaging, thus allowing for packing on orders and for holding slow moving sizes.

Packing Costs

Costs and efficiency of handling citrus have become of increasing importance to the grower and shippers. Increases in total U. S. production of citrus have resulted in lower prices; however, costs have increased and materials and transportation have narrowed margins.

The cost of packing citrus has tended to be upward. The major increases in costs of packing are for administrative and selling expenses and materials. The increased administrative and selling expenses reflect an increased need for office personnel to keep records required for tax, wage and hour regulations and inspection.

There was a tremendous change in the wage scale in the Texas citrus area during the fifties. Early in the decade, the hourly wage was generally less than 50 cents per hour. The federal wage hourly law, affecting agricultural products which were entirely interstate shipment, became effective in 1949. This contributed materially to increased labor costs in the packing of citrus fruit.

During the 1950-51 season, use of piece rate for packing fruit was not fully established. The hourly wage rate for packing fruit was used to determine packing costs in some plants. By 1959-60, piece rate packing was used by the entire industry.

Total labor costs per unit were the only expenses that showed a decrease during the period 1950 to 1960. With an increase in wages, operations were closely watched and labor-saving devices were installed in packing houses.

Packing on orders gave the opportunity for more efficient use of labor and equipment by utilizing a more continuous running operation and reducing the amount of overtime hours. This phase of the operation partly eliminated the necessity of having to repack some of the fruit.

Containers

Citrus fruit size is commonly referred to by the number of fruit packed in a Bruce box (1 3/5 bushel), although most fruit is now packed in one-half box cardboard containers. The practice now is preferable since it enables uniformity in the shipping process.

PROCESSING

Citrus processing in Texas began as a single strength juice operation during the late 20's. During peak production in 1945-46, 7 million boxes of citrus were processed. This was approximately 25 percent of the total crop. The percentage of the total crop processed has decreased with production decreases following the freezes. This figure reached a low during the period from 1951-1956, when processing accounted for only 5 to 10 percent of the total citrus production. The amount of citrus being used in processed products was again on the increase at the time of the 1962 freeze, reaching nearly 20 percent during the 1959-60 season.

The future citrus processing industry of Texas not only will include single strength juice and sections, but will also include frozen citrus products such as concentrates and salads. At the time of the 1962 freeze, the Rio Grande Valley had four units of concentration equipment. With the consumers demanding higher quality and more convenient food items, there should be a demand for Texas frozen citrus concentrates and chilled juice.

The production of concentrates offers the processor the possibility of blending juices of various qualities throughout the season and from season to season to produce a product of uniform quality. The limiting factor of these blending operations is the amount of high-quality juice to blend with the juices of lower quality so that the end products will meet the desired standards. Excellent-colored, bitter, early red grapefruit juice will blend with poorly-colored, bland, late grapefruit juice to produce a tasty, good-colored juice concentrate. Concentrate from early orange varieties will blend with concentrate from Valencia oranges to produce concentrate having desirable color and flavor. At least 50 percent Valencia juice usually is required for these blends.

Fruit purchased for frozen concentrates usually is purchased on the basis of pounds of solids in the juice and the color of the juice. Pounds solids is influenced by the amount of sugar in the juice and the juice yield. External quality has little influence on prices paid for processing fruit. During periods of normal production, additional revenue is gained from the high quality of cattle feed purchased from the dried peel.

TEXAS CITRUS DISTRIBUTION

The distribution of Texas citrus for various regions throughout the United States and 5 Canadian cities in 1960 is shown in Figure 16. The comparison is made for grapefruit, oranges and mixed loads of citrus, also by type of transportation, truck and rail. The major regions receiving Texas citrus were West South Central, 33 percent; West North Central, 20 percent; and East North Central, 14 percent. Texas has a locational advantage over Florida on the distribution of citrus west of the Mississippi River. Figure 16 points up that about 75 percent of the Texas citrus unloads in 1960 was in this area. This area is also increasing rapidly in population. Competition from California normally would be a minimum because most of their citrus is marketed at a later season than Texas citrus. The extreme Northeast section of the United States receives the least Texas fruit. The rail and truck unloads of Texas citrus shown in Figure 16 include only a portion of the Texas shipment. It does not include the citrus unloaded at other cities.

During 1960, truck shipments accounted for about 78 percent of the Texas citrus movement and rail 22 percent. Rail movement was utilized mostly for long-distance shipments.

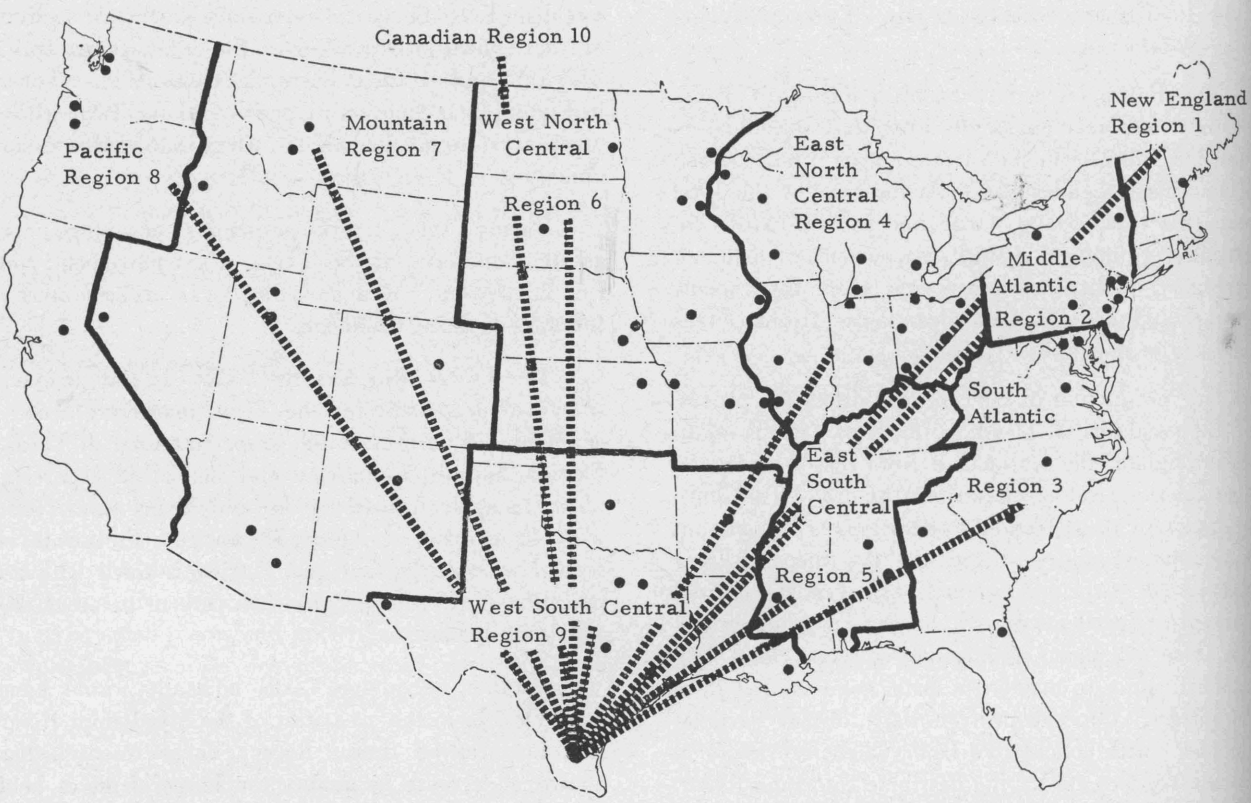
The Lower Rio Grande Valley is the primary source of grapefruit for the Texas marketing area—supplying 76 percent of the grapefruit used in Texas. Florida ships in 17 percent and California 7 percent of the grapefruit used in Texas. Texas ranks first with 41 percent of the fresh oranges; California is second with 36 percent and Florida is third with 23 percent. California provides 81 percent of other citrus (mainly lemons).

Another advantage Texas normally would have over Florida in the area west of the Mississippi River is transportation time. Recent Texas research has shown a decrease in quality the longer fruit is held after picking.

A 5 to 6-week cold storage period is not an unreasonably long period for grapefruit when considering the time required to move it from the tree through the marketing system. The normal period, from the moment the fruit is picked, hauled to packingshed, degreened, packed, and loaded on trucks or rail cars, usually is 2 to 5 days, depending on the amount of time needed for degreening.

Rail transport from the Texas citrus production area to Chicago or New York City usually takes 5 to 8 days. A recent survey in Texas indicates that the average wholesaler rotates his stock every 5 to 7 days or less frequently before it is moved to the retailer. Some national food chains consider the shelf life of citrus to be 4 days before it loses its "bloom." With minimum time lapse in each operation, it is possible for grapefruit to be in the marketing system for more than a 4-week period. This may be extended further by "shipping holidays" which is a method often used to reduce stocks of grapefruit on hand in the terminal markets.

The amount of time, labor, and expenses required to move the fruit from the growers' trees through the packing houses, transportation to terminal markets, wholesale outlets and the retail store helps to explain why today's grower prices are difficult to compare



Regions	Grapefruit		1960 Oranges		Mixed citrus		Total citrus	United States population
	Rail	Truck	Rail	Truck	Rail	Truck		
	Percent							
1	.15	.04	.95	.08			.08	5.9
2	7.15	.41	.95	.24	4.80		1.57	19.2
3	.15	.30	1.90	.15			.26	14.2
4	42.03	9.70	39.04	4.24	20.63		13.93	20.4
5	1.26	2.70	20.45	8.70	4.80	66.67	4.64	6.8
6	35.59	15.15	20.95	9.26	68.64		20.18	8.7
7	.60	16.62	.95	6.87	.28		10.55	3.9
8	2.10	20.60	.95	5.63			12.50	11.4
9	1.04	31.92	2.86	64.50	.85		33.38	9.5
10	9.99	2.56	10.50	.08		33.33	2.91	

Fig. 16. Percent rail and truck unloads of Texas citrus in 100 selected U. S. cities and 5 Canadian cities, 1960. (Source: Fresh fruit and vegetable unload totals in 100 cities. AMS-USDA.)

with the retail price. The purchase price, size, quality, and spoilage of the fruit plus transportation of package materials must be considered besides the normal handling and transportation charges. Thus, the supply available at production and consuming centers must be taken into account. The demand for the product and competitive products—fresh and processed—and created demand through advertising and price of the product all need to be considered in comparing grower prices with retail prices.

In addition to controlling the quality of the fruit which leaves the grove, quality control should be practiced throughout the marketing channel if consumers are to receive quality fruit from the Lower Rio Grande Valley.

The grower, shipper, wholesaler, grocer, consumer, and state regulations may have a different set of standards for evaluating quality. The grower judges quality by yield, size of fruit, and grade. The shipper and wholesaler are more interested in size, grade, and appearance. The grocer is concerned with the appearance of the fruit on his display shelves, its rate of spoilage and how well it sells. The consumer may determine quality by appearance, touch and taste.

WHOLESALE INDUSTRY

The wholesale produce dealer operates between the shipper and retailer since he depends on the shipper for his purchases and the retailer for his sales. The wholesaler's functions include purchasing fruit from producing areas, selecting types of transportation, storing, selling, and distributing merchandise to retailers.

During the past two decades, the importance of major wholesale fruit and vegetable markets has declined substantially. Many of the marketing functions and responsibilities formerly performed by auction markets and individual firms have been assumed by large integrated retailing organizations. The decline in volumes of fruits and vegetables handled through the wholesale markets has been offset by increases in volumes purchased directly from shipping points.

Structural changes in marketing create a need for information about whether fewer buyers making large purchases affect the competitive position both between Texas and Florida grapefruit and among the various varieties and types of fruit within producing areas. In many cases, the fruit and vegetable requirements of the large retailing organizations differ substantially from those of the smaller retailing units. For example, the merchandising practices and techniques employed by chain stores create the need for a product that lends itself to rigid standardization.

Generally, terminal firms do not specialize in the handling of Florida or Texas grapefruit in those markets where the two compete. A joint study with Florida revealed that 94 percent of the handlers reported they handled both Florida and Texas fruit at some time in the past, and 88 percent handled both types during the 1960-61 marketing season.

About 70 percent of the firms in Mid-West outlets purchase both Florida and Texas grapefruit from other handlers in the market, while only half of the firms purchased directly from shipping points. These firms buy from the shipping point, about 60 percent dealing directly with the shipper and about 30 percent purchase through their own buyer representative at the shipping point. Many factors are considered by terminal handlers when buying Florida or Texas grapefruit. Three, however, seem to be most important —price, quality, and customer preference.

RETAIL INDUSTRY

The retail produce grocer acts as the main representative of the fresh fruit and vegetable industry to the general public. Under the present market conditions, the prosperity of growers and wholesalers of fresh fruit and vegetable products depends almost entirely on the success of the retail produce dealer.

The retail produce man has many responsibilities, such as ordering in advance, the produce required by the consumers, storing, cleaning and trimming, displaying, pricing, and rotating stock to maintain a fresh display until the produce has been sold.

If the consumer is to receive the best quality citrus fruit, the industry must reduce the amount of time from tree to consumer and keep the fruit under the best storage conditions possible. Some of the national food chains realize this problem and are attempting to improve the handling and marketing of perishable products.

COSTS AND RETURNS OF PRODUCING TEXAS CITRUS

*Ralph Petersen and Rex Kennedy**

The odds against profit or loss in citrus production can be estimated only through costs and returns analysis. This analysis is especially critical in the case of citrus with its high capital investment and long-time period required to recover expenses.

STAGES OF GROVE MATURITY

In this section, costs of citrus production will be estimated for four stages of grove maturity. These stages are grove establishment—1st year; grove development—2 through 4 years of age; young grove—5 through 10 years of age; and mature grove—11 years of age and over. Age in this case means years after transplanting from a nursery. Operating expenses will be relatively constant within each of these stages, while yields will vary from year to year.

TREE SPACING AND VARIETY

Tree spacing has a direct effect on both costs and returns. A 25' x 15' tree spacing (116 trees per acre) is used as a basis for making the cost estimates shown. Species or type of fruit also has an effect on costs and returns. In this case, species means grapefruit, early and mid-season oranges or late-season oranges. While costs are not affected greatly by differences in variety, returns are affected by the variation in yield and price. Current recommendations for planting in the Valley are one-third grapefruit, one-third early and mid-season oranges and one-third late oranges, or one-half grapefruit, one-fourth early and mid-season oranges and one-fourth late oranges. In this section the one-third, one-third and one-third planting is assumed.

GROVE OWNERSHIP AND CARE

The type of grove ownership may have some effect on production costs. Many groves in the Valley presently are owned by absentee landlords and cared for by grove care companies, who also service many groves owned by Valley residents, especially where the size of grove does not warrant ownership of the required machinery. Where groves are owned and operated by the same individual, many operations, particularly application of insecticide, are done by custom operators. Whether a substantial savings to the owner could be made by caring for the grove himself has not been investigated at this time. However, certain observations can be made. One is that approximately two-thirds of the yearly costs of operation are for materials and taxes. In general, an owner-operator would not be in a position to obtain these items at much saving over a grove care company. The opportunity for savings is through lower costs of machinery operation, labor and supervision. To see much advantage, however, the owner-operator would need to own a relatively large grove or operate his grove in conjunction with some other farming operation. The following items of machinery would be required for grove care by an owner-operator:

	Initial price (1963)
Tractor	$3500
Rotary tiller	700
Border machine	175
Duster	700
Shredder	450
Terracer	285
Light disk	400
Total	$6210

The owner of a hypothetical grove such as the one depicted in this section, is assumed to do his own supervision, hire labor for jobs where no machinery is required and hire a grove care company to do the jobs where machinery is needed. Costs shown here will be similar to the rates charged by grove care companies except that no charge for supervision is made. This supervision charge normally is $12 per acre per year and will be included as a return to operator labor and management.

ANNUAL OPERATING EXPENSES

Annual costs of operation include grove care costs and taxes. These costs are broken down by operation and discussed for each of the stages of production defined above. While the costs shown in this section and in Table 13 are meant to be typical or average for Valley citrus groves, they are mere guidelines and should be adjusted for each specific situation.

Irrigation Costs

Most Valley citrus groves are irrigated with water from irrigation districts. Water costs from

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these districts normally are paid through a water tax on the land and a charge for each irrigation. The charge for each irrigation varies between districts, but a typical charge is $2 per acre per irrigation. For most areas of the Valley, the charge per irrigation is the same, regardless of the acre-inches of water. At present, there is a relative water shortage. Water retained in Falcon Lake has not been sufficient to meet irrigation requirements of all eligible acreage. More water than is normally allocated to 1 acre of eligible acreage is required for adequate irrigation of 1 acre of citrus. For example, during the 1962-63 season, water from 2 to 3 acres of land was required for 1 acre of citrus. If these conditions continue, the cost of owning surplus land to supply citrus with adequate water should be included in an estimate of irrigation costs.

Most Valley growers utilize tank watering during the first year following tree planting. If this method is used, trees should be watered every 2 weeks. Water for tanking is not charged against the water allotment of the land. In a normal year, the trees will require approximately 15 tank irrigations at 4 cents per tree per irrigation. For an acre consisting of 116 trees, tanking during the first year costs approximately $70 per acre. Constructing the basins and maintaining them throughout the first year will cost approximately $10 per acre.

During the remaining life of the orchard, five to seven irrigations are required each year. The cost of this water is $10 to $14 per acre per year. Labor costs for applying this water is $7 to $10 per acre. Costs of making and maintaining irrigation borders are approximately $7 per acre per year.

Fertilizer Costs

Fertilizer required during establishment is 1/8 pound of actual nitrogen per tree. Nitrogen currently costs approximately $.125 per pound. Application cost is approximately $.50 per acre. The total cost per acre is $2.31.

During the period of grove development, 2 through 4 years of age, the average fertilizer requirement is 1/2 pound of actual nitrogen per tree per year. The cost of nitrogen is approximately $5.80, and the cost of application is approximately $1 per acre. Total cost is $6.80 per acre.

The average fertilizer requirement for a young grove from 5 through 10 years of age is 1 1/4 pounds of nitrogen per tree per year. The cost of nitrogen is approximately $18.13 per acre, and the cost of application is approximately $1.50 per acre. Total cost is $19.63 per acre.

The requirement for a mature grove is 2 pounds of nitrogen per tree for a close planted grove. The cost of nitrogen is $29 per acre plus $2 per acre for application. Total cost is $31 per acre.

Spraying and Dusting

Spraying and dusting for scale and rust mite control are the main insecticide treatments for Valley citrus. In general, insecticide applications are not needed during establishment. During the remainder of the grove life, three dustings with sulfur and one spraying for scale would be required each year. During the period of grove development, the cost of sulfur dusting is $9 per acre and the cost of spraying with zineb, oil and sevin is $10.44 per acre. The cost per year is $19.44 per acre.

The annual cost for a young grove is $12 per acre for the sulfur and application of the dust. The cost of spray materials plus the spraying is $31.32 per acre per year. The total annual cost is $43.32 per acre.

The annual cost for a mature grove is $15 per acre per year for sulfur and application of the dust. The annual cost of spray materials plus the spraying is $52.20 per acre for mature groves. The total annual cost is $67.20 per acre.

Weed Control

Weed control normally is accomplished by disking and hoeing around the trees. Five diskings at $2.50 per acre per disking are required for newly established trees and trees ranging 2 through 4 years of age. Disking costs for a young or mature grove would be approximately $15 per acre per year. Hoeing around the trees can be done by hand labor or a rotor-tiller supplemented with hand labor. The cost of hoeing is approximately $16 per acre per year for trees 2 years old and over.

Tree Banking

Young trees require banking for cold protection. Costs of banking and unbanking is approximately $9 per acre per year for the first 4 years of tree life.

Pruning

Pruning costs normally are a minor expense on well managed groves. This cost will vary from $1 per acre in the first year to $4 per acre per year in a mature grove. The cost of major pruning required after a severe freeze is not included in these estimates.

Taxes

A charge of $10 per acre per year is made for water tax, state, county and school taxes. This cost is the same for different age groves.

Replacement Trees

A grove planted with good trees should require few replacement trees within the first 25 years of life. Approximately ½ of 1 percent of the trees would need replacement each year. This cost is estimated at $1, $2, $3, and $4 per acre for each of the respective stages of grove maturity. If trees were rehabilitated after a severe freeze, the level of replacement in following years would be much higher than the estimate shown here.

Table 13. Summary of operating expenses per-acre basis. 116 trees/ac. — 1963 prices

Operating costs	Stage of grove maturity			
	Establishment 1st year	Development 2-4 years	Young grove 5-10 years	Mature grove 10+ years
Irrigation water	$ 70.00	$ 12.00	$ 12.00	$ 12.00
Irrigation labor		9.00	9.00	9.00
Basin (construction and maintenance)	10.00			
Bordering		7.00	7.00	7.00
Fertilizer	2.31	6.80	19.63	31.00
Spraying and dusting		20.60	43.32	67.20
Weed control	12.50	28.50	31.00	31.00
Banking and unbanking	9.00	9.00		
Pruning	1.00	2.00	3.00	4.00
Taxes	10.00	10.00	10.00	10.00
Replacement trees	1.00	2.00	3.00	4.00
Total	$115.81	$106.90	$137.95	$175.20

CAPITAL INVESTMENT AND EXPENSE

The major items of capital expense are land, trees, and accumulated interest charges.

Level, well-drained land suited for citrus sells for $500 per acre in the Valley. Land will be considered an investment and the cost or expected return to land will be computed as 6 percent of the value. Since land prices in the Valley have increased substantially in the last decade, returns from land price changes have not been included.

The cost of preparing land and planting trees is also an important capital expenditure. Assuming that the land was in row crop cultivation prior to citrus planting, the land should be deep plowed, disked twice and floated before the trees are planted. Cost of this land preparation would be approximately $15 per acre. Strong, healthy trees can be obtained for $1.50 each. Tree planting and one tank irrigation is an additional cost of $.30 per tree. For 116 trees per acre, the cost of trees and planting is $209.

Table 14. Interest charges on investment.

Item	Establishment 1st year	Development 2-4 years	Young grove 5-10 years	Mature grove 11+ years
Value of land and trees	$42.54 ($709 x 6%)	$60 ($1000 x 6%)	$90 ($1500 x 6%)	$120 ($2000 x 6%)
Interest on ½ operating expense	3.47 ($115.81 x 6% x ½)	3.21 ($106.90 x 6% x ½)	4.14 ($137.95 x 6% x ½)	5.15 ($175.20 x 6% x ½)

The accumulated interest on money invested in developing a citrus grove is a sizeable expense. While interest charges are normally included as operating costs, interest and operating costs in the first years of grove development actually become invested in the grove. Under normal conditions, returns from a grove will not cover operating costs until the sixth year. As a consequence, interest charges and a portion of the operating costs will be accumulating for the first 5 to 6 years. These accumulated expenses are taken into account in the increased value of the trees in progressive stages of grove maturity. An estimate of land and tree values at each stage are: establishment, $709; development, $1000; young grove, $1500; and mature grove, $2000.

An additional charge is the annual interest on operating expenses. This charge is calculated as 6 percent of one-half of the annual operating expense. (Table 14).

Table 15. Summary table of production costs per acre. (116 trees/acre, 1963 prices)

Cost	Establishment 1st year	Development 2-4 years	Young grove 5-10 years	Mature grove 11+ years
Operating expenses	$115.81	$106.90	$137.95	$175.20
Interest on operating expenses	3.47	3.21	4.14	5.15
Operating labor and management	12.00	12.00	12.00	12.00
Production costs excluding interest on investment	131.28	122.11	154.09	192.35
Interest on value of land and trees	42.54	60.00	90.00	120.00
Total costs	$173.82	$182.11	$244.09	$312.35

RETURN TO OPERATOR LABOR AND MANAGEMENT

A fee of $12 per acre per year for supervision is charged by grove care companies. While this amount will be included as the return to operator labor and management, it would be a direct cost to absentee land owners instead of a return. Any additional return above specified costs and returns can be considered as profit on the investment or additional return to management.

COST OF REHABILITATING FREEZE-DAMAGED GROVES

The cost of rehabilitating one acre of citrus depends on several factors. The cost of removal and replacement of dead trees varies from $3 to $4 per tree for 4-to-7 and 10-to-15 year old trees, respectively. The cost per acre varies with the number of dead trees per acre.

The cost of pruning varies from 60 cents to 80 cents per tree depending on tree age and amount of pruning required. The cost per acre varies with the total number of trees per acre and the number of dead trees per acre.

YIELDS

Yield of fruit varies by variety, tree age, and number of trees per acre. Grapefruit, early and mid-season orange trees begin to bear at 3 years of age while late season oranges start bearing at 4 years of age. Yields increase steadily until the trees reach 12 to 14 years of age. Table 16 contains estimated annual yields for the different species.

PRICES

Price estimation is perhaps the most difficult, but important, part of costs and returns analysis. This estimation should be based on expected production in other areas and expected changes in consumer preferences. Prediction of this nature is beyond the scope of this study, but these factors should be kept in mind when evaluating the returns computed in this section. Average prices for past seasons are used in the estimation of returns.

Table 16. Yield per acre for Texas citrus. (116 trees per acre)

Age in years	Grape-fruit (tons/acre)	Early and mid-season orange (tons/acre)	Late-season orange (tons/acre)
3	1	0.7	0
4	2.5	1.2	0.4
5	6.5	3.0	1.3
6	10.0	5.5	3.0
7	16.0	8.0	5.0
8	18.0	10.0	7.0
9	19.0	12.0	9.0
10	20.0	14.0	10.0
11	21.0	15.0	11.0
12+	22.0	16.0	12.0

Table 17. Returns per acre of grove. Receipts by species.[1]

Tree age	Grape-fruit (1/3 acre)	Early and mid-season orange (1/3 acre)	Late-season orange (1/3 acre)	Gross receipts[1] (per acre)
	— — — —	dollars	— — — —	
3	8.42	8.56	0.00	16.98
4	21.05	14.68	6.07	41.80
5	54.73	36.70	19.72	111.15
6	84.20	67.28	45.50	196.98
7	134.72	97.86	75.84	308.42
8	151.56	122.32	106.18	380.06
9	159.98	146.79	136.52	443.29
10	168.40	171.25	151.69	491.34
11	176.82	183.48	166.86	527.16
12 (+)	185.24	195.72	182.03	562.99

[1]Assumes 116 trees per acre and the prices and yields developed in previous paragraphs of this section.

The average on-tree price for Texas oranges from 1954 through 1962 was $1.79 per box or $39.78 per ton based on a value of 30 million, 515 thousand dollars for 17 million and 40 thousand boxes.

The volume of early and mid-season oranges exceeded the volume of late-season oranges by 80 percent during this period. At the same time, the on-tree price in Florida for late-season oranges was 24 percent higher than the on-tree price for early and mid-season oranges. Assuming that this factor was the same in Texas and that Texas orange production was divided evenly between early and late-season oranges, the estimated price is $36.70 per ton for early and mid-season oranges and $45.50 per ton for late-season oranges.

The price for Texas grapefruit, during the same time period, was $1.01 per box or $25.35 per ton with a value of 29 million, 614 thousand dollars for 29 million, 340 thousand boxes.

RETURN FROM CITRUS

Gross receipts from an acre consisting of one-third grapefruit, one-third early and mid-season orange, and one-third late-season orange are shown in Table 17.

Net returns from an acre of citrus are shown in the following table. The returns in Table 18 are based on the costs and returns developed in previous paragraphs.

Table 18. Costs and returns per acre of grove.

Column	1	2	3	4	5
Tree age, years	Gross receipts from Table 17	Production costs excluding interest on investment from Table 15	Return to investment in land and trees (Column 1 minus 2)	Interest on investment in land and trees from Table 14	Profit (Column 3 minus 4)
	— — — — —	dollars	— — — — —		
1	0.00	131.28	—131.28	42.54	—173.94
2	0.00	122.11	—122.11	60.00	—182.11
3	16.98	122.11	—105.13	60.00	—165.13
4	41.80	122.11	— 80.31	60.00	—140.31
5	111.15	154.09	— 42.94	90.00	—132.94
6	196.98	154.09	42.89	90.00	— 47.11
7	308.42	154.09	154.33	90.00	64.00
8	380.06	154.09	225.97	90.00	135.97
9	443.29	154.09	289.20	90.00	199.20
10	491.34	154.09	337.25	90.00	247.25
11	527.16	192.35	334.81	120.00	214.81
12 (+)	562.99	192.35	370.64	120.00	250.64

CAPITAL REQUIREMENTS FOR GROVE DEVELOPMENT

It takes a large amount of capital to establish and develop a citrus grove. Annual operating expenses and annual interest charges on investment in land and trees accumulate during the early years of grove life. In each of the first 6 years, costs of production exceed returns. Capital employed in the grove is at a peak after the sixth year. The grove owner has employed approximately $1,550 in developing the grove to this point. In succeeding years, income from the grove exceeds annual production costs and interest charges on investment. After the 12th year, income from the grove has paid for development of the grove plus a return on investment in land. One additional year of production is required for payment of the initial cost of land. The annual costs, returns, and capital requirements are estimated for the first 13 years of grove life in Table 19.

GROVE VALUE ESTIMATION

The value of a resource or combination of resources, such as a citrus grove, is based normally on the net income which the resource can be expected to produce during the remainder of its effective life and the salvage value of the resource at the end of its life. The stream of annual net incomes and salvage value of the resources are discounted back to the present to estimate current or present value. Discounting is a process by which incomes received at some future time are converted to present values. For example, the present value of $25 ten years from now, in the form of a United States Government bond, is $16.89. This is obtained by discounting the $25 future return at a 4 percent rate of interest. The discount rate which is used can be an expected rate of return or the interest rate charged on borrowed money.

A procedure referred to as present value estimation, can be used for estimating the value (at present) of a citrus grove. This procedure estimates the amount of money which could be paid for a grove at present and still receive a reasonable return on capital invested. Obviously, the procedure cannot predict the future; however, it can be used to obtain estimates for different situations which may be expected to exist in the future. For example, present grove values can be estimated for various fruit prices, fruit yields and levels of freeze damage.

Table 19. Estimated costs, returns and capital investment in one acre of grove.

Column No.	2	3	4	5	6	7
Grove age, years	Capital invested	Interest on capital invested (Col. 2 x 6%)	Annual production costs excluding interest (From Table 15)	Total costs (Column 3 plus Col. 4)	Gross returns (From Table 17)	Additional capital required in succeeding year (Col. 5 minus Col. 6)
	— — — — —	— — — — —	— — — —	— dollars —	— — — — —	— — — — —
1	709.00	42.54	131.28	173.82	0.00	173.82
2	882.82	52.97	122.11	175.08	0.00	175.08
3	1057.90	63.47	122.11	185.58	16.98	168.60
4	1226.50	73.59	122.11	195.70	41.80	153.90
5	1380.40	82.82	154.09	236.91	111.15	125.76
6	1506.16	90.37	154.09	244.46	196.98	47.48
7	1553.64	93.22	154.09	247.31	308.42	— 61.11
8	1492.53	89.55	154.09	243.64	380.06	—136.42
9	1356.11	81.37	154.09	235.46	443.29	—207.83
10	1148.28	68.90	154.09	222.99	491.34	—268.35
11	879.93	52.80	192.35	245.15	527.16	—282.01
12	597.92	35.88	192.35	228.23	562.99	—334.76
13	263.16	15.79	192.35	208.14	562.99	—354.85
14	— 91.69					

Table 20. Estimated present value of investment in 1-acre mixed orchard.[1]

Grove age at present (years)	Tree age at time of freeze (years after establishment) 8	10	12	14	18
0 (at establishment)	58.78	372.32	701.91	1025.93	1571.13
4	559.72	955.21	1370.66	1779.85	2468.11
8		818.85	1343.82	1888.99	3728.31

[1] ⅓ grapefruit, ⅓ early and mid-season orange, ⅓ late-season orange.
Rate of return = 6 per cent.
Salvage value = $450 per acre.
Lost ⅓ of the grapefruit crop and ¾ of late-season orange crop through freeze damage in last year.

Present values were estimated by this procedure for groves of various ages and life expectancies. In Table 20, a 6 percent rate of return, salvage value of $450 per acre and the annual returns shown in column 3, Table 18, were used in estimating present values. In this case, the grove was assumed to be frozen out at various ages. The $450 salvage value is calculated by subtracting $50 per acre, for removing dead trees, from the $500 per acre land value. The price of land was assumed to remain constant. Since the grove was assumed to be frozen out, one-third of the grapefruit crop and three-fourths of the late-season orange crop was assumed to be lost through freeze damage in the last year of ownership.

Earlier, the cost of establishing a grove was estimated to be $709 per acre. In Table 20, present value at the establishment of a grove which is expected to be frozen out at 12 years of age, is $701.91. A comparison of these figures shows that the returns from this grove would be $7.09 ($709.00−$701.91) per acre short of yielding the owner of the grove a 6 percent return on his investment. In other words, a citrus grove which is frozen out before the twelfth year would not justify its establishment.

The resale or salvage value is important in estimating a grove's present value. When the grove can be sold before a severe freeze has damaged the trees, the resale value of the grove should be much higher than the $450 per acre salvage value used above. Estimates of the resale values which could be expected are as follows:

Tree age (years)	Resale value ($/acre)
6	1500
8	1700
10	1900
12-18	2000

If these resale values are received when the groves are sold, the present value estimates for these groves would be much higher than the estimates in Table 20. Present value estimates shown in Table 21 are based on high resale values, a 6 percent rate of return and the annual returns shown in column 3, Table 18. Crop losses in the last year are not included in these estimates, since no freeze damage is assumed.

The present value of a grove at establishment is $671.58/acre if sold after the 6th year and $924.62/acre if sold after the 8th year. A rough estimate of the present value of the grove if sold after the 7th year is $800/acre. Since the cost of land, trees and planting is $709/acre, the grove is expected to yield a 6 percent return on investment plus $91/acre profit if sold after the 7th year. The $91/acre profit is for the full 7-year period, not on an annual basis. In comparison, a grove which is killed by a freeze and sold for $450/acre is expected to yield a 6 percent return on investment only if the freeze is incurred in the twelfth year or later.

COLD PROTECTION VALUE ESTIMATION

The annual payment for cold protection which can be economically justified is determined chiefly by two factors—effectiveness of the cold protection system, and annual costs and returns from the grove.

Effectiveness is an important factor in determining value of a cold protection system. Costs and returns from the grove also have a substantial effect on the value of a cold protection system. During a period when freezes keep U. S. production at relatively low levels, fruit prices will be high and the cold protection system will be more valuable than in periods when fruit prices are low.

Numerous procedures may be used in estimating the maximum allowance for cold protection. The most practical procedure is to allow profit or income in excess of a reasonable return to be used for cold protection. Profit, in this case, should be estimated for a series of years rather than an individual year. Present value estimates may be used in estimating this profit. For example, the present value of a grove at establishment is $2184.55 if the grove is sold for $2,000 in its eighteenth year. This present value is shown in Table 21, and is based on the costs and returns developed in this section. The cost of land, trees, and planting is $709; therefore, $1475.55 ($2184.55−$709) is discounted profit in excess of 6 percent return on the capital invested. It is assumed that effective cold protection will be started in the

Table 21. Present value estimates for land and trees in one-acre of grove.[1] (High resale value.)

Present age of grove (years)	Grove age at time of resale 6	8	10	12	14	16	18
0	671.58	924.62	1279.31	1577.41	1808.52	2014.45	2199.15
(establishment)				2474.67	2767.92	3049.55	3260.08
4	1332.16	1653.34	2100.16	2738.25	3136.40	3435.07	4728.32
8			2263.26		2465.15	2881.15	3250.24
12							
16							2465.15

[1]Resale values: 6 years of age—$1500/acre.
8 years of age— 1700/acre.
10 years of age— 1900/acre.
12-18 years of age— 2000/acre.
Rate of return = 6 percent.
⅓ grapefruit, ⅓ early and mid-season orange, and ⅓ late-season orange.

fifth year and that the 14 annual payments for the fifth through eighteenth years will be of equal value. The maximum annual payment which could be justified is $200.30 per acre. The discounted sum of 14 annual payments of $200.30 per acre is $1475.55. The cold protection systems must be able to save both trees and fruit in order to justify $200.30 per acre per year payment.

Maximum annual payments for cold protection can be estimated by the same procedure for other levels of return. For example, the grove owner may require a 6 percent return on investment plus $50 per acre per year profit or return to management. In this case he could afford to pay approximately $130 per acre per year for effective cold protection.

Costs and returns in this section were developed to represent groves planted 116 trees per acre with one-third grapefruit, one-third early and mid-season orange and one-third late-season orange trees. The production costs are above the average costs for the Valley due to the assumed close spacing and improved practices. However, the expected yields are also above the Valley average and more than offset the increase in production costs. A grove to which these costs and returns apply must be kept in production without major freeze damage through the thirteenth year after establishment, if the owner is to pay for the land and trees and receive a 6 percent return on his investment. If freeze damage was not a problem, the grove owner could expect an additional return from the increase in grove value. However, this return from grove value increases would probably be offset by high, annual payments for cold protection once an effective system is designed. At present, it appears that the grove owner will be able to pay from $100 to $200 per acre per year for effective cold protection, dependent upon the rate of return required by the individual.

REFERENCES

ADAMS, R. L., Protecting Citrus Groves from Frost—Costs and Benefits to Growers. Calif. Agr. Exp. Sta. Bul. 730.

ADVANCES IN AGRONOMY, Vol. 11, Edited by A. G. Norman. 1959.

BATCHELOR, L. D. AND H. J. WEBBER, Editors, The Citrus Industry, Vol. 2, Production of the Crop. 1948.

BLOODWORTH, M. E., Some Principles and Practices in the Irrigation of Texas Soil. Texas Agri. Exp. Sta. Bul. 937. 1959.

BRANSON, R. E. AND T. PRATER, Vertical Integration in Texas Agriculture—Citrus Fruits. Texas Agr. Exp. Sta. and Ext. Ser. L-488. 1960.

BRANSON, R. E., CARTER PRICE AND H. V. COURTENAY, Consumer Panel Test of Texas Fortified Red Grapefruit Juice. Texas Agr. Exp. Sta. MP-481. 1961.

BROOKS, F. A., An Introduction to Physical Microclimatology, University of California at Davis, Syllabus No. 397. 1960.

BUCK, WILBUR F. AND H. B. SORENSEN, Marketing Adjustments Made by the Texas Citrus Industry to Freezes of 1949 and 1951. Texas Agr. Exp. Sta. MP-328. 1959.

BURDICK, EVERETTE, Symptoms of Freeze Damage in Citrus Fruit. Jour. Rio Grande Valley Hort. Soc. 5: 117-120. 1951.

THE CITRUS INDUSTRY, Vol. 2, Edited by L. D. Batchelor and H. J. Webber. 1948.

CLEMMONS, W. ELTON, Grove Heating—A Method of Protecting Florida Citrus. The Citrus Industry 44 (6): 18,20,24. 1963.

Cooper, William C., Cold Hardiness in Citrus as Related to Dormancy, Proc. Florida State Hort. Soc. 72: 61-66. 1959.

Cooper, William C., and Bruce J. Lime, Quality of Red Grapefruit on Old-Line Grapefruit Varieties on Xyloporosis—and Exocortis-tolerant Rootstocks. Jour. Rio Grande Valley Hort. Soc. 14: 66-76. 1960.

Cooper, William C., and Edward O. Olson, Norman Maxwell, and Arthur Shull. Orchard Performance of Young Trees of Red Grapefruit on Various Rootstocks in Texas. Proc. Amer. Soc. Hort. Sci. 70: 213-222. 1957.

Cooper, William C., and Ascension Peynado. Screening Citrus Rootstock Seedlings for Tolerance to Calcareous Soils. Jour. Rio Grande Valley Hort. Soc. 8: 100-105. 1954.

Cooper, William C., and Ascension Peynado, Boron Accumulation in Citrus as Influenced by Rootstock. Jour. Rio Grande Valley Hort. Soc. 9: 86-94. 1955.

Cooper, William C., and Ascension Peynado, Chloride and Boron Tolerance of Young-Line Citrus Trees on Various Rootstocks. Jour. Rio Grande Valley Hort. Soc. 13: 89-96. 1959.

Cooper, William C. and Ascension Peynado, Winter Temperatures of 3 Citrus Areas as Related to Dormancy and Freeze Injury of Citrus Trees. Proc. Amer. Soc. Hort. Soc. 74: 333-347. 1959.

Cooper, William C., Ascension Peynado, and J. R. Furr, Effects of 1961-62 Winter Freezes on Valencia Oranges in Florida, Texas, and California. Proc. Florida State Hort. Soc. 75: 82-88. 1962.

Cooper, William C., and A. V. Shull, Salt Tolerance of and Accumulation of Sodium and Chloride Ions in Grapefruit on Various Rootstocks Grown in a Naturally Saline Soil. Jour. Rio Grande Valley Hort. Soc. 7: 107-117. 1953.

Cooper, William C., Sam Tayloe, and Norman Maxwell, Preliminary Studies on Cold Hardiness in Citrus as Related to Cambial Activity & Bud Growth. Jour. Rio Grande Valley Hort. Soc. 9: 1-15. 1955.

Delcurto, J. M., Halstead, E. W., and Halstead, H. F., The Citrus Industry in the Lower Rio Grande Valley of Texas. Texas Dept. Agri. Bul. 75. 1923.

Fawcett, Howard S., Citrus Diseases and Their Control. 2nd ed. 656 pp. McGraw-Hill Book Company, Inc. New York. 1936.

Friend, W. H., The Joppa Orange. Jour. Rio Grande Valley Hort. Soc. 3: 63. 1948.

Friend, W. H., History of the Meyer lemon in the Valley. Jour. Rio Grande Valley Hort. Soc. 8: 32-33. 1954.

Furr, J. R. and W. W. Armstrong, Jr., Breeding Citrus for Cold Hardiness. Proc. Florida State Hort. Soc. 72: 66-71. 1959.

Furr, J. R., J. B. Carpenter, and A. H. Hewitt, Breeding New Varieties of Citrus Fruits and Rootstocks for the Southwest. Jour. Rio Grande Valley Hort. Soc. 17: 90-107. 1963.

Gerard, C. J., Bloodworth, M. E. and Cowley, W. R., Effect of Tillage, Straw Mulches and Grass upon Soil-Moisture Losses and Soil Temperatures in the Lower Rio Grande Valley. Texas Agri. Exp. Sta. MP-382. 1959.

Gerard, C. J. and Sleeth, B., The Use of Tensiometers as an Aid in the Irrigation of Citrus Groves. Jour. Rio Grande Valley Hort. Soc. 14: 47-52. 1960.

Harrison, D. S., and S. E. Dowling, Frost Protection of Citrus with Sprinkler Irrigation. Paper presented at 17th Annual Gulf Citrus Institute, Dade City, Florida. 1962.

Hildreth, R. J. and Orton, R. B., Freeze Probabilities in Texas. Texas Agr. Exp. Sta. and Ext. Ser. MP-657. 1963.

Hilgeman, R. H., and L. H. Howland, Report on the Frost Situation and Effect of a Wind Machine on Temperatures During 1954-55. Arizona Citrus Institute 1: 9-15. 1955.

Hilgeman, R. H. and D. R. Rodney, Commercial Citrus Production in Arizona. Special Report No. 7, Agr. Exp. Sta. and Ext. Ser., Univ. of Arizona. 1961.

Hilgeman, R. H. and L. H. Howland, When to Irrigate Citrus Trees. Progressive Agriculture in Arizona, College of Agriculture. University of Arizona. 1955.

Hudson, A. C. and H. B. Sorensen, Texas Wholesale Citrus Industry. Texas Agr. Exp. Sta. MP-336. 1959.

Hume, Harold H., Citrus Fruits in Texas. Texas Dept. of Agri. Bul. 3. 1909.

Kepner, Robert A., The Principles of Orchard Heating. Calif. Agr. Exp. Sta. Cir. 400. 1950.

Klotz, L. J. and H. S. Fawcett, Color Handbook of Citrus Diseases. Univ. of California Press. 1941.

Knorr, L. C., R. F. Suit, and E. P. DuCharme, Handbook of Citrus Diseases in Florida. Florida Agr. Exp. Sta. Bul. 587. 1957.

KREZDORN, A. H., AND NORMAN MAXWELL, Fruit Quality Studies of Eight Strains of Red-Fleshed Grapefruit on Two Rootstocks. Jour. Rio Grande Valley Hort. Soc. 13: 54-58. 1959.

KREZDORN, A. H., AND R. F. CAIN, Internal Quality of Texas Grapefruit. Jour. Rio Grande Valley Hort. Soc. 6: 48-52. 1952.

LIME, BRUCE J., AND DONALD M. TUCKER, Seasonal Variation in Texas Hamlin and Marrs Orange Juice, 1961-62. Jour. Rio Grande Valley Hort. Soc. 16: 78-82. 1962.

MANELY, WILLIAM T., W. FRED CHAPMAN, JR., GEORGE L. CAPEL AND H. B. SORENSEN, Competitive Practices in Marketing Florida and Texas Grapefruit. U. S. Dept. of Agr. Eco. Research Ser. 1963.

MARTSOLF, J. DAVID, The Protective Value of Wind Machines. The Citrus Industry. 44 (6): 29-30. 1963.

MAXWELL, NORMAN P., Citrus Varieties in the Rio Grande Valley of Texas. Jour. Rio Grande Valley Hort. Soc. 3: 63-67. 1948.

MAXWELL, NORMAN P., Production of Red Grapefruit Trees Through Nine Years of age in the Lower Rio Grande Valley. Jour. Rio Grande Valley Hort. Soc. 15: 41-43. 1961.

MAXWELL, NORMAN P., AND GEORGE OTEY, Orchard Heating Test in the Lower Rio Grande Valley of Texas. Texas Avocado Soc. Yearbook. 31-32. 1954.

NICHOLS, ESEK S., Summary of Fruit-Frost Data Obtained in the Lower Rio Grande Valley District During Five Seasons Beginning with the Winter of 1931-32. U. S. Dept. of Agr. Fruit and Vegetable Frost Ser. of the Weather Bureau, Lower Rio Grande Area, Harlingen, Texas. 1937.

OLSON, E. O., The Marrs Orange, a Navel-Orange-Sport Variety Popular in Texas. Jour. Rio Grande Valley Hort. Soc. 17: 80-85. 1963.

OLSON, E. O., W. C. COOPER, N. MAXWELL, AND A. V. SHULL, Survival Size and Yield of Xyloporosis- and Exocortis-Infected Old-Line Red Grapefruit Trees on 100 Rootstocks. Jour. Rio Grande Valley Hort. Soc. 16: 44-51. 1962.

OLSON, E. O. AND BRUCE J. LIME, The Parson Brown Compared with the Pineapple Orange in Texas. Jour. Rio Grande Valley Hort. Soc. 17: 86-89. 1963.

OLSON, E. O., AND A. V. SHULL, Size and Yield of 12-year old Valencia Orange Trees on Various Rootstocks in Presence or Absence of Exocortis and Xyloporosis Viruses Jour. Rio Grande Valley Hort. Soc. 16: 40-43. 1962.

ORTON, R. B., Letter correspondence on Freeze Probabilities for the Lower Rio Grande Valley, September 11, 1963.

PEYNADO, A., ROGER YOUNG, AND WILLIAM C. COOPER, A Comparison of Three Major Texas Freezes and a Description of Tissue Temperatures of Valencia Tree Parts During the January 9 to 12, 1962 Freeze. Jour. Rio Grande Valley Hort. Soc. 17: 15-23. 1963.

PRICE, W. C., Editor, Proceedings Second Conference Citrus Virologists. Univ. Fla. Press, Gainesville, Fla. 1961.

RICHARDS, L. A. (Editor), The Diagnosis and Improvement of Saline and Alkali Soils, USDA Handbook 60, 1954.

SLEETH, BAILEY, AND E. O. OLSON, Release of Texas Virus-Indexed Citrus Budwood. Jour. Rio Grande Valley Hort. Soc. 15: 19-24. 1961.

SORENSEN, H. B., Some Factors in Appraisal of Citrus Groves. Jour. of the Rio Grande Valley Horticultural Soc. 15: 32-40. 1961.

SORENSEN, H. B., Changes in the Cost of Packing Grapefruit, 1950-51 Season versus 1959-60 Season. 1962 Jour. of the Rio Grande Valley Hort. Soc.

SORENSEN, H. B., Citrus V-A-L-U Computer. Texas Agri. Ext. Ser. MP-653. 1963.

SORENSEN, H. B. AND C. K. BAKER, Methods and Costs of Handling Texas Citrus, 1946-51. Texas Agr. Exp. Sta. Bul. 771. 1953.

SORENSEN, H. B. AND E. E. BURNS, Grapefruit Quality Deterioration in the Marketing System—Storage and Shelflife. Texas Agr. Exp. Sta. PR-2151. 1950.

SORENSEN, H. B., AND E. H. HAMMOND, Types of Grapefruit Available in Texas Stores. Texas Agr. Exp. Sta. PR-1942. 1957.

SORENSEN, H. B., J. M. WARD AND L. H. HAMMOND, Sales Response of Pink and White Grapefruit Offered in Bulk and Bags at Varying Prices. Texas Agri. Exp. Sta. PR-1871. 1946.

THURMOND, R. V., How to Estimate Soil Moisture by Feel. Leaflet No. 355. Texas Agr. Ext. Ser. 1957.

TURRELL, F. M., AND S. W. AUSTIN, Factors Influencing Wind Machine Operation. The California Citrograph 46 (2): 38, 52, 53, 54. 1960.

TURRELL, F. M., S. W. AUSTIN, AND R. L. PERRY, Frost Control. Western Fruit Grower. September. 21-22. 1960.

TURRELL, F. M., S. W. AUSTIN, AND R. L. PERRY, Temperature Control in Orchards. Yearbook of the Calif. Macadamia Soc. 6: 51-58. 1960.

TURRELL, F. M., S. W. AUSTIN, AND R. L. PERRY, Water, Heaters, and Wind Machines. The California Citrograph 46 (5): 154-160. 1961.

TURRELL, F. M., S. W. AUSTIN, AND R. L. PERRY, Protecting Orchards Against Cold. The California Citrograph 48 (11): 379, 397. 1963.

UNIVERSITY OF ARIZONA, Agr. Ext. Ser. and Agr. Exp. Sta. Chemical Weed Control Recommendations for Irrigated Areas of Arizona Bul. A-1. 1962.

UNIVERSITY OF CALIFORNIA AGR. EXT. SER. Weed Control Recommendations. 1963.

UNIVERSITY OF FLORIDA AGR. EXT. SER. Chemical Weed Control in Citrus Groves. Cir. 224. 1962.

VESTAL, C. K., Fitting of Climatological Extreme Value Date. Climatological Services Memorandum No. 89, U. S. Weather Bureau. 1961.

WAIBEL, CARL, Varieties and Strains of Citrus Originating in the Lower Rio Grande Valley of Texas. Jour. Rio Grande Valley Hort. Soc. 7: 18-24. 1953.

WALLACE, J. M., Editor, Citrus Virus Diseases, Proceedings First Citrus Conference, citrus virologists, Riverside, Calif., Univ. of Calif., Div. of Agri. Sciences, Calif. 1959.

WALLIS, WARREN R., Effectiveness of Freeze Protection During the Freeze of Dec., 1962. The Citrus Industry 44 (6): 3, 21, 22. 1963.

WEBB, A. C., Winter Extreme Minimum Temperature Probability Graphs for Brownsville, Harlingen and Rio Grande City. Unpublished. 1963.

WOODRUFF, R. E., AND E. O. OLSON, Effects of Rootstocks on Physical Characteristics and Chemical Composition of Fruit of Six Citrus Varieties in Texas. Jour. Rio Grande Valley Hort. Soc. 14: 77-84. 1960.

YOUNG, FLOYD D., Frost and the Prevention of Frost Damage. U. S. Dept. of Agr., Farmers' Bul. No. 1588. 1947.

YOUNG, FLOYD D., AND WAYNE E. HARMAN, Protecting the Citrus Orchard Against Frost. Chapt. 17. The Citrus Industry, Vol. 2, Production of the Crop, edited by Leon Dexter Batchelor and Hubert John Webber, Univ. of Calif. Press, Berkeley and Los Angeles. 1948.

YOUNG, ROGER, Climate-cold Hardiness-citrus. Jour. Rio Grande Valley Hort. Soc. 17: 3-14. 1963.

YOUNG, ROGER, HERBERT DEAN, A. PEYNADO, AND JACK C. BAILEY, Effects of Winter Oil Spray on Cold Hardiness of Red Blush Grapefruit Trees. Jour. Rio Grande Valley Hort. Soc. 16: 7-10. 1962.

YOUNG, ROGER, AND ASCENSION PEYNADO, Effects of Artificial Freezing on Red Blush Grapefruit. Jour. Rio Grande Valley Hort. Soc. 15: 68-74. 1961.

YOUNG, ROGER, AND ASCENSION PEYNADO, Seasonal Changes in the Cold-hardiness of ten-year-old Red Blush Grapefruit Trees as Related to Dormancy and Temperature. Jour. Rio Grande Valley Hort. Soc. 15: 59-67. 1961.

YOUNG, ROGER, AND ASCENSION PEYNADO, Freeze Injury to Citrus in the Rio Grande Valley in 1963 in Relation to 1961 and 1962 Freeze Injury. Jour. Rio Grande Valley Hort. Soc. 17: 43-54. 1963.

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