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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 419 DECEMBER, 1930

DIVISION OF HORTICULTURE

Citrus Production in the Lower Rio Grande Valley of Texas

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†As of December 15, 1930.
**In cooperation with U. S. Department of Agriculture.

Citrus fruit production in the Lower Rio Grande Valley, especially grapefruit, has increased at a rather rapid rate during the past few years. More than 5,000,000 citrus trees were set in orchard form in the Lower Rio Grande Valley up to July, 1929. The proportion of the acreage which is being set to grapefruit indicates that growers and shippers have found the grapefruit to be the most profitable type of citrus fruit for this region. Of the grapefruit varieties now available, Marsh and Thompson are obviously the most desirable types for commercial planting. Sweet oranges are apparently not as well adapted to local conditions as are grapefruit but are being grown to a limited extent. Until a variety of sweet orange is developed or introduced which will combine early maturity and good "keeping quality" with excellence of flavor and prolific bearing capacity, this industry will not keep pace with grapefruit production.

The problem of root stocks for citrus in the Lower Rio Grande Valley is not a problem of major importance at the present time. The commonly used sour-orange stock appears to be a very desirable type for use in propagating most of the commercial forms.

The soils on which citrus are usually grown in the Lower Rio Grande Valley are very fertile, and experiments with fertilizers on the Victoria fine sandy loam soil, up to the present time, indicate that soil fertility has not become a limiting factor in grapefruit production, under the conditions of these experiments. However, these results should not be interpreted as meaning that fertilizer should be withheld after the trees reach bearing age. Moderate applications of fertilizer along with other beneficial orchard practices, throughout the development and maintenance of the orchard, will tend to keep the original fertility of the soil unimpaired.

As citrus fruits are grown under irrigation in this region, the physical nature of the soil must be given due consideration. Leguminous cover cropping and mulching has been found to exert a beneficial effect on the soil as shown by the increased production from plats where these practices were followed. It seems desirable to recommend a system of seasonal, leguminous cover cropping, rather than the usual method of clean cultivation with only sporadic natural cover crops. Plowing the soil to a depth of six inches once each season was not found to be of practical value.

The size attained by Valley grapefruit trees makes the close spacing practiced in some of the older citrus-producing areas impracticable in this region. Apparently a spacing distance of 25x25 feet is desirable with grapefruit trees in the Lower Rio Grande Valley.

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BULLETIN NO. 419 DECEMBER, 1930

CITRUS PRODUCTION IN THE LOWER RIO GRANDE VALLEY OF TEXAS

HAMILTON P. TRAUB* AND W. H. FRIEND

The preliminary experiments concerning citrus fruit production at Substation No. 15, Weslaco, in the Lower Rio Grande Valley, from 1924 to 1930, are summarized in this report. It is realized that experimentation over a much longer period will be required to settle definitely many of the points raised in the present report. This publication serves a double purpose: it gives an evaluation of the work in progress, and also makes available to the Valley citrus grower such tentative conclusions as the results warrant up to the present.

The citrus industry in the Lower Rio Grande Valley, as shown in Table 1, although of recent growth, takes a high rank among the horticultural industries of the State. Nationally, the Valley ranks among the three leading citrus-producing areas; in grapefruit production, it ranks second only to Florida.

From an output of approximately 15 carloads of grapefruit in 1921 the citrus industry of the Valley has expanded to a production of more than 4,000 carloads in 1929-30. The data given in Table 1 are conservative, since shipments by express and truck are not included. The rapid increase shown in the table gives an accurate indication of the trend.

The total number of citrus trees planted in the Lower Rio Grande Valley up to July 1, 1929, as shown in Table 2, numbered 5,118,981; of these 72 per cent were grapefruit, 13 per cent of which were 5 years of age or older (37).†

While the greater part of the Texas citrus acreage of bearing age is located in the Lower Rio Grande Valley, plantings have been made in the Laredo and Winter Garden districts and the Upper Gulf Coast region (20). The present report is concerned only with the industry in the Lower Rio Grande Valley.

Although experiments in citrus fruit production have been conducted in other producing areas, it does not follow that results obtained elsewhere are directly applicable to conditions in the Lower Rio Grande Valley. Soil and climatic factors differ greatly from those found in California, Florida, and Arizona (39, 40, 42, 7, 31, 41). It is therefore necessary to conduct fundamental experiments under the conditions found in the Lower Rio Grande Valley in order to determine the most profitable practices to be followed in growing citrus fruit in this region.

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†Numbers in parentheses refer to literature citations, p. 58.

Table 1. Car-lot shipments of citrus fruits from the Lower Rio Grande Valley by rail

Shipments by express and truck not included

1921-22 to 1929-30, inclusive†

Year	Railroad	Car lot shipments					
		Grapefruit	Oranges	Lemons	Mixed citrus	Totals on each railway	Grand total
1921-22...	Mo. Pac.	7	1	0	5	....	13
1922-23...	Mo. Pac.	44	0	0	7	....	51
1923-24...	Mo. Pac.	107	0	1	7	....	115
1924-25...	Mo. Pac.	508	1	1	11	....	521
1925-26...	Mo. Pac.	290	1	0	0	....	291
1926-27...	Mo. Pac.	706	11	0	39	....	756
1927-28...	Mo. Pac.	903	27	0	86	1016	
	So. Pac.*					140*	1156
1928-29...	Mo. Pac.	1311	28	0	112	1451	
	So. Pac.*					299*	1750
1929-30...	Mo. Pac.	2898	114	0	365	3377	
	So. Pac.*					604*	3981

†Data furnished by Missouri Pacific and Southern Pacific Railways.
*Reported as total carlots not classified.

Table 2. Citrus planting in the Lower Rio Grande Valley of Texas as of July 1, 1929

Totals for Cameron, Hidalgo, and Willacy counties (37)

Class	Number of growing citrus trees of different ages						Total
	Under one year	One year	Two years	Three years	Four years	Five years and over	
Grapefruit.......	1,319,103	916,334	458,232	297,084	224,662	487,334	3,722,749
Oranges..........	367,236	280,298	181,100	157,434	138,802	195,744	1,320,614
Other citrus......	13,485	7,638	5,717	8,923	10,580	29,275	75,618
Total.......	1,699,824	1,204,270	645,049	463,441	394,044	712,353	5,118,981

Soils. The soils on which citrus fruits are grown in the Lower Rio Grande Valley vary considerably as to their physical and chemical properties, ranging from the rather light sandy loam soils of the Brennan and Victoria series to the heavier clay loams of the Rio Grande and Laredo series. It is generally conceded that the well-drained, deep sandy loam soils such as Victoria, Brennan, and Hidalgo fine sandy loams, are best suited to citrus fruit production (4, 10, 11, 14, 15). However, some excellent orchards are found growing on Victoria clay loam where natural drainage is adequate. Most of the soils of the Valley which are used for crop production compare very favorably, as regards fertility, with the principal types used for crop production in other parts of the state (10).

Climate. The climatic conditions in the Lower Rio Grande Valley are in general favorable for crop production. The annual rainfall amounts to approximately 23 inches, the greater portion of which falls during the periods from May to June, inclusive, and from September to November, inclusive (21, 38). Because distribution is not satisfactory it is usually necessary to supplement the rainfall with irrigation water.

The growing season is relatively long in this region, extending from February to December, and temperature favorable for the growth and development of citrus trees is the usual condition during this period. From April 1 to November 1, the monthly mean temperature ranges above 70 degrees. Critically low temperatures are occasionally experienced during the months of December, January, February, and March.

The prevailing direction of the wind is from the southeast, and the moisture-laden air from the Gulf usually maintains the humidity at about 75 per cent, which is favorable for plant growth (38).

Scope of Publication. Since the various classes of citrus fruits are rather closely related genetically and the cultural requirements are similar, the experimental results concerning some factors in citrus-fruit production in the various classes are treated in a single publication. The subject matter is conveniently grouped under the following heads,—(a) Citrus Variety Standardization, (b) Citrus Root-stocks, and (c) Grapefruit Orchard Management.

CITRUS VARIETY STANDARDIZATION

Probably the most important benefit to be derived from standardization of citrus varieties is the elimination of various inferior forms which make it difficult to maintain a constant supply of a relatively few varieties of special merit which can be grown in sufficient quantities, and which the consumer will recognize and demand. An added advantage is that standardization will simplify the problems of both the grower and the nurseryman since it will enable them to specialize on the production of a relatively few forms. In this connection the needs of the industry must be given first consideration. Varieties should be introduced or developed which mature their fruit relatively early (prior to December 15), in order to avoid possible loss due to low temperature. Since consumers have decided preferences as to the size of fruit which they purchase, this character should receive due consideration. Also, it should be indicated that the factors responsible for quality in citrus fruits are probably of more importance than is generally recognized. The proportion of rind and "rag," the number of seeds per fruit, and the quality of the juice in terms of solids to acids ratio, or a still better measure if it can be found, must be considered. The capacity of the fruit to hold up well in transit and storage is also of primary importance.

The experience of growers during the past has shown that up to the present time the grapefruit is more profitable than other classes of citrus in the Valley. This greater relative importance is apparently due to the wider adaptability range of grapefruit as compared with other classes of citrus fruits. (See Table 3.) This fact, however, does not preclude the possibility of the introduction or development of forms in other classes of citrus which will be equally well adapted.

The data presented in this section under citrus variety standardization are concerned with (a) the systematic study of the plant as a whole as it responds to the environmental conditions of the Valley, and (b) the factors which affect quality and other standards in citrus fruits.

Plan of Standardization Experiments

The standardization experiments, located on Victoria fine sandy loam soil, may be conveniently grouped into ecological studies and quality studies.

Ecological Studies. The method followed in determining the sum total of environmental factors as affecting citrus plants consisted in growing, whenever possible, 3 or more trees of each item studied under the usual orchard practices in the Valley. The trees were planted in orchard form and the following records were taken: "ripening season," degree of frost resistance, keeping quality, and a general adaptability rating. These terms are explained in detail under "Explanation of Terms." Yield records are not included in the present report, since most of the trees are relatively young.

Quality Studies. In these studies it was the aim to study the quality of citrus fruits under the conditions of normal orchard practices as now followed in the Valley. The physical characters of the entire fruit and the quality of citrus juice were subjected to detailed analysis. The following determinations were made in the case of the entire fruit: total weight in grams and the proportion of "rag," juice, and seeds; thickness of rind, diameter of pulp in millimeters, and the number of seeds. The quality of the juice was studied on the basis of total soluble solids, kind of sugars, total acids, effective acidity (pH), Van Slyke buffer index, protein, and ash. The methods of procedure have been published elsewhere (34, 35, 36). The terms used are defined under "Explanation of Terms."

Sampling. The constants for fruit character are based upon random samples of commercial grade fruit. Whenever possible, ten or more fruits were utilized as a sample.

Explanation of Terms

The experimental data have been summarized in Tables 3, 4, and 5. The statistical analysis of the data given in Tables 4 and 5 are presented elsewhere (34, 35, 36). The facts concerning adaptability of cultivated forms of citrus from various sources, grown under Valley conditions, from 1924 to 1930, are shown in Table 3. The cultivated forms have been grouped according to the classification by Swingle (2, 16).

The following definitions of special terms apply to the data presented in Tables 3 and 4.

"Ripening season" refers to the period when the major portion of the crop reaches maturity and may be harvested; "Early" refers to the period between October 15 and December 1; "Mid-season," December 1 to January 1; and "Late," January 1 to March 1.

The term "Frost Resistance" is used as a measure of the capacity of the plant to withstand temperatures below 28 degrees F. The sign "+" is used to designate varieties commonly uninjured at 28 degrees F.; "++" refers to varieties that are uninjured at 23 degrees F.; "—" designates forms which are injured at 28 degrees F.

"Keeping quality" is a broad term used to distinguish rather conspicuous differences in perishability as observed by packers and shippers.

"Adaptability rating" is a general term used to indicate the effect of the sum total of environmental factors as found in the Lower Rio Grande Valley on citrus plants. Three degrees of adaptability are recognized: "good,"—vigorous and prolific forms; "fair,"—medium vigorous and prolific forms; and "poor," —forms not vigorous, unproductive or unable to survive.

"Rag" is that portion of the fruit remaining after the juice has been extracted by means of a conical citrus-fruit extractor, and after the rind and seeds have been removed.

The physico-chemical characters of citrus juice presented in Table 5 were determined as follows: total soluble solids, by means of a Brix spindle at room temperature, correcting for temperature variations and expressed at 22 degrees C.; sugars, protein, and ash, by direct analysis; total acids, by titration with 1/10 normal alkali solution, and expressed as anhydrous citric acid; pH or effective acidity, on an electric hydrogen ion apparatus to three decimal places; buffer index (Van Slyke), based on pH determination after adding 1 equivalent of acid to 1000 cc. of juice. The procedure in each case has been described fully in another publication (36).

The pH scale is used to measure the degree of effective acidity or alkalinity of a given solution. On this scale the neutral value,

Table 3. Citrus variety standardization; adaptability rating, 1924-30

Species and cultivated form	Rootstock	Date planted	No. of trees	Ripening season*	Frost Resist.†	Keeping quality	Adaptability rating‡	Remarks
GRAPEFRUIT								
Citrus paradisi								
Marsh	Sour orange	1925	3	Mid-season	+	Good	Good	Excellent quality
Marsh	Calamondin	1925	3	"	+	"	Fair	Trees dwarfed
Marsh	Rough lemon	1925	3	"	+	"	Good	
Marsh	Sour orange	1926	10	"	+	"	"	Excellent quality
Marsh	"	1929	102	N. F.	+	....	"	
Marsh	"	1929	65	N. F.	+	....	"	
Marsh	"	1929	97	N. F.	+	....	"	
Marsh	Thomasville citrangequat	1929	5	N. F.	++	....	"	Vigorous
Marsh	Rusk citrange	1929	5	N. F.	++	....	"	
Marsh	Cleo. mandarin	1929	2	N. F.	+	....	Fair	
Thompson	Sour orange	1925	3	Mid-season	+	Good	Good	Pink flesh, similar to Marsh
Thompson	Cleo. mandarin	1925	3	"	+	"	Fair	One tree dead
Thompson	Sour orange	1929	6	N. F.	+	....	Good	
Thompson	"	1929	3	N. F.	+	....	"	
Thompson	Rusk citrange	1929	5	N. F.	++	....	"	
Duncan	Sour orange	1925	3	Early	+	Good	"	Prolific, seedy
Duncan	Rough lemon	1925	3	"	+	"	"	1 tree died of root rot
Duncan	Sour orange	1926	10	"	+	"	"	Seedy, prolific
Duncan	"	1926	25	"	+	"	"	Seedy, prolific
Duncan	"	1927	1	"	+	"	"	Seedy
Connor's Prolific	"	1926	2	"	+	"	"	Seedy
Foster	"	1925	3	Mid-season	+	"	"	Pink flesh, seedy
McCarty	"	1925	3	Early	+	"	"	Seedy
McCarty	"	1926	1	Early	+	"	"	Seedy
Triumph	"	1925	3	"	+	Fair	Fair	Poor quality
Triumph	"	1926	3	N. F.	+	....	....	....
Walters	"	1926	3	N. F.	+	....	Good	Similar to Duncan
Inman's Late	"	1926	2	N. F.	+	....	"	Seedy
Little River Seedless (Davis Seedless)	"	1929	5	N. F.	+	....	"	
Cecily Seedless	"	1930	3	N. F.	....	....	"	Promising
SHADDOCK								
Citrus maxima								
Cuban Shaddock	Seedlings	1927	10	N. F.	—	....	Good	Vigorous brittle wood

SWEET ORANGE *Citrus sinensis*								
Lue Gim-Gong	Sour orange	1925	3	Late	+	Good	Good	
Lue Gim-Gong	"	1926	2	"	+	"	"	
Valencia	"	1925	6	"	+	"	"	
Valencia	"	1926	4	"	+	"	"	
Valencia	"	1926	25	"	+	"	"	Prolific
Joppa	"	1926	3	Early	+	Poor	"	Similar to Pineapple
Pineapple	"	1925	3	Mid-season	+	"	Excellent	Prolific
Pineapple	"	1926	3	"	+	"	"	Prolific
Ruby	"	1925	3	"	+	Fair	Good	No blood markings
Ruby	"	1926	1	"	+	"	"	
Parson Brown	"	1925	3	Early	+	Poor	"	Similar to Pineapple
Hamlin (Norris)	"	1926	3	"	+	"	"	
Hamlin (Norris)	"	1929	5	N. F.	+	....	....	
Washington Navel	"	1925	3	Mid-season	+	Good	Poor	Poor quality; shy bearer
Washington Navel	"	1926	3	"	+	"	"	Poor quality
Washington Navel	"	1926	2	"	+	"	"	Poor quality
S. P. I. 37783	"	1925	1	"	+	"	"	Navel orange
S. P. I. 37766	"	1925	3	"	+	"	"	Navel orange
S. P. I. 37788	"	1925	2	"	+	"	"	Navel orange
S. P. I. 37769	"	1925	3	"	+	"	"	Navel orange
S. P. I. 37758	"	1925	3	"	+	"	"	Navel orange
S. P. I. 36636	"	1925	3	"	+	"	"	Navel orange
Buckeye Navel	"	1926	3	"	+	"	Fair	Quality variable
Thompson Navel	"	1926	1	"	+	"	"	Quality poor
Mediterranean Sweet	Calamondin	1925	2	"	+	Poor	Fair	Seedy, similar to Pineapple
Homossasa	Sour orange	1926	3	"	+	"	"	Seedy
Pervis	"	1926	3	Late	++	Good	Good	Prolific, hardy
Raymondville	"	1926	1	Mid-season	++	"	"	Thorny, hardy
Raymondville	"	1925	3	"	++	"	"	Trees thorny
Golden Buckeye	"	1926	3	"	+	"	Fair	Quality variable
Malta Blood	"	1926	1	"	+	Fair	"	Quality variable
Chamoudi	Sweet lime	1928	2	N. F.	—	....	Good	Promising
Chamoudi	Sour orange	1929	3	"	+	....	"	
Seville	"	1929	1	"	+	....	"	
TEMPLE ORANGE *Citrus sinensis x C. nobilis deliciosa*								
Temple	Sour orange	1925	3	Late	—	Poor	Good	Less hardy than sweet orange
Temple	Calamondin	1925	3	"	—	"	"	Trees slightly dwarf
Temple	Sour orange	1926	1	"	—	"	"	
Temple	"	1926	25	"	—	"	"	Tender to cold

Table 3. Citrus variety standardization; adaptability rating, 1924-30—Continued

Species and cultivated form	Rootstock	Date planted	No. of trees	Ripening season*	Frost Resist.†	Keeping quality	Adapta-bility rating‡	Remarks
KING ORANGE								
Citrus nobilis								
King	Sour orange	1925	3	Late	+	Poor	Poor	Tender to cold
King	Rough lemon	1925	3	"	+	"	"	Tender to cold
King	Sour orange	1926	1	"	+	"	"	Tender to cold
MANDARIN OR TANGERINE ORANGES								
Citrus nobilis deliciosa								
Dancy	Sour orange	1925	6	Mid-season	+	"	Good	Subject to drying
Dancy	"	1926	10	"	....	"	Poor	
Cleopatra	Cuttings	1925	5	N. F.	—	....	Fair	Tender to cold
Cleopatra	"	1927	10	"	....	....	"	Tender to cold
Willow Leaved Mandarin	Sour orange	1926	3	"	++	....	Good	
Clementine (Algerian)	"	1927	8	"	++	....	"	Excellent quality
Clementine (Algerian)	"	1927	3	Early	++	Poor	"	Excellent quality
Clementine (Algerian)	"	1927	7	N. F.	++	....	"	Promising
Clementine (Algerian)	Thomasville Citrangequat	1929	2	"	++	....	"	
Swatow	Sour orange	1928	1	"	++	Poor	"	Very hardy to cold
Warnuco	"	1929	3	Mid-season	—	"	"	Promising
SATSUMA ORANGE								
Citrus nobilis unshiu								
Owari	Trifoliata	1925	3	....	....	....	Poor	Died, 1925
Owari	Calamondin	1925	3	Early	— —	Poor	"	Subject to drying
Owari	Rusk citrange	1926	3	"	— —	"	Good	Poor quality
SOUR ORANGE								
Citrus aurantium								
Sour orange	Seedlings	1925	2	....	+	....	Good	Hardy, prolific
Sour orange	"	1924	1015	....	+	....	"	Hardy, prolific
Sour orange	"	1925	1000	....	+	....	"	Hardy, prolific
Sour orange	"	1929	88	....	+	....	"	Hardy, prolific
CALAMONDIN ORANGE								
Citrus mitis								
Calamondin	Seedlings	1924	1	Mid-season	++	Poor	Good	Hardy, prolific
Calamondin	Sour orange	1926	10	....	....	....	Poor	All died, 1926
Calamondin	Seedling	1927	10	N. F.	++	....	Good	Hardy

KUMQUAT								
Fortunella margarita								
Nagami	Rough lemon	1925	3	Early	++	Poor	Good	Hardy, prolific
Nagami	Calamondin	1925	3	"	++	"	"	Hardy, prolific
Fortunella japonica								
Marumi	Rusk citrange	1927	1	"	++	"	"	Hardy, prolific
Fortunella crassifolia								
Meiwa	Rusk citrange	1927	3	"	++	"	"	Hardy, prolific
LIME								
Citrus aurantifolium								
Mexican (Key)	Thomasville citrangequat	1929	5	June to Dec.	+	Good	Poor	Tender to cold
Mexican (Key)	Calamondin	1925	1	June to Dec.	—	"	Good	
Mexican (Key)	Sour orange	1925	10	Died	—		"	All killed by cold
Sweet Lime-Sweet Lemon	Seedlings	1929	12	N. F.	—	....	Fair	Vigorous, tender
Sweet Lime-Sweet Lemon	Sour orange	1925	1	July to Dec.	—	Good	Good	Prolific, poor quality
Sweet Lime-Sweet Lemon	Seedling	1927	15	N. F.	—	....	Fair	Tender to cold
Sweet Lime	Sour orange	1925	1	July to Dec.	—	Good	Good	Prolific, poor quality
Tahiti	"	1926	1	July to Dec.	—	"	Poor	Quality excellent
Tahiti	Rusk citrange	1926	1	July to Dec.	—	"	Good	Quality excellent
Rangpur	Sour orange	1926	10	Oct. to June	+	Poor	"	Poor quality
LEMON								
Citrus limonia								
Eureka	Sour orange	1924	10	Died, 1925	—	....	Fair	Tender, subject to disease
Meyer	Cuttings	1925	203	June to Dec.	+	Good	Good	Hardy, prolific
Meyer	Thomasville citrangequat	1929	5	June to Dec.	+	"	Fair	
Rough Lemon	Seedlings	1929	2	N. F.	—	....	"	Tender to cold
ICHANG LEMON								
Citrus ichangensis								
Ichang	Seedlings	1927	10	N. F.	++	....	Good	Vigorous, hardy
Ichang	"	1929	4	"	++	....	"	Vigorous, hardy
CITRANGE								
(*Citrus sinensis x Poncirus trifoliata*)								
Rusk 11540	Cuttings	1924	25	N. F.	++	....	"	Vigorous, hardy
Rusk 11540	"	1924	24	"	++	....	"	Vigorous, hardy
Rusk 11540	"	1927	15	"	++	....	"	Vigorous, hardy
Rusk 1716	Seedlings	1929	1	"	++	....	"	Vigorous, hardy
Rusk 2602	Cuttings	1929	15	"	++	....	"	Vigorous, hardy

Table 3. Citrus variety standardization; adaptability rating, 1924-30—Continued

Species and cultivated form	Rootstock	Date planted	No. of trees	Ripening season*	Frost Resist.†	Keeping quality	Adaptability rating‡	Remarks
CITRADIA								
(*Citrus aurantium x Poncirus trifoliata*)								
Citradia 51090	Cuttings	1924	6	N. F.	++		Poor	Chlorotic
Citradia 41398	"	1924	6	"	++		"	Chlorotic
Citradia 50880	"	1924	5	"	++		"	Chlorotic
CITRANGEQUAT								
{*Citrus sinensis x Poncirus trifoliata*} *x Fortunella margarita*								
Savage 2774		1929	10	N. F.	++		Good	
Thomasville 48010	Seedlings	1924	25	"	++		"	Fairly Vig., hardy
Thomasville 48010	Cuttings	1924	25	"	++		"	Fairly Vig., hardy
Thomasville 48010	"	1924	5	"	++		"	Fairly Vig., hardy
Thomasville 48010	"	1927	15	"	++		"	Fairly Vig., hardy
Thomasville 48010	"	1929	2	"	++		"	Fairly Vig., hardy
LIMEQUAT								
(*Citrus aurantifolia x Fortunella margarita*)								
Eustis	Sour orange	1926	6	June-Dec.	+	Good	Poor	
Eustis	Cuttings	1928	2	"	+	"	"	One died, one chlorotic
Eustis S. P. I. 48798	"	1927	7	"	+	"	"	
TANGELO								
Citrus maxima x Citrus nobilis deliciosa								
Sampson	Calamondin		3	Oct.-Jan.	+	Fair	Good	Prolific, poor quality
Thornton	*Sour orange*		3	"	+	"	"	Prolific, quality excellent
MISCELLANEOUS								
Suen Kat S. P. I. 10158	Cuttings	1927	10	N. F.	+		Good	Fairly Vig., hardy
Severinia buxifolia	"	1929	5	"	++		Good	Dwarf
Citropsis schweinfurthi	Seedlings	1929	2	"	+		Poor	Dead

*(Season)—Early (Oct. 15 to Dec. 1); Mid-season (Dec. 1 to Jan 1); Late (Jan. 1 to Feb. 28).
N. F. (No fruit).

†(Frost Resistance): ++ (very resistant); + (fairly resistant); — (tender).

‡(Adaptability Rating)—Good (vigorous and prolific); Fair (medium vigorous and fairly prolific); Poor (not vigorous and unproductive, or unable to survive).

	Date	No. of fruits	Mean weight in grams					Per cent of total weight			Mean			
			Whole fruit	Rind	"Rag"	Juice	Seed	Rind	"Rag"	Juice	Thickness of rind, m.m.	Diameter of pulp, m.m.	Number of locules per fruit	Number of seeds per fruit
GRAPEFRUIT														
Marsh	10/ 5/29 to 12/ 3/29	32	466.2	110.6	96.1	255.3	1.3	23.7	20.6	54.7	6.0	90.4	13.3	3.9
Thompson	11/19/29 to 12/ 3/29	14	449.3	98.7	83.6	264.8	2.1	22.0	18.6	58.9	5.4	90.3	13.7	6.5
Foster	11/26/29 to 12/ 3/29	7	521.1	109.6	96.7	296.7	17.8	21.0	18.6	56.9	5.1	93.7	13.2	54.7
Duncan	9/30/29 to 10/14/29	14	468.5	107.0	105.8	241.5	21.8	22.8	22.6	51.5	6.2	88.0	13.2	63.0
McCarty	12/16/29	4	505.8	114.0	107.5	262.9	21.1	22.5	21.2	51.9	5.4	100.8	11.8	53.0
Triumph	12/16/29	4	419.8	118.3	131.0	150.8	19.8	28.1	31.2	35.9	5.6	96.5	12.0	51.8
SWEET ORANGE														
Valencia	12/16/29 to 2/13/30	16	220.6	49.9	49.3	108.6	2.8	22.6	22.3	49.2	3.3	73.7	11.3	10.6
*Valencia	3/ 4/30	6	152.8	24.9	22.7	99.8	1.3	16.2	14.8	65.3	2.2	58.8	10.8	5.0
Lue Gim Gong	12/16/29 to 2/13/30	15	182.5	35.1	40.1	104.5	1.6	19.2	22.0	57.3	2.9	68.3	10.2	6.9
Joppa	12/16/30	6	172.5	32.75	30.5	106.4	2.9	18.9	17.6	61.7	2.3	64.0	11.3	10.3
Pineapple	12/16/29	8	201.4	41.9	46.9	106.3	6.2	20.8	23.3	52.8	3.3	66.6	11.3	29.0
*Pineapple	3/ 4/30	16	160.3	37.8	18.4	87.3	6.6	23.5	11.4	54.5	3.3	59.4	10.4	22.6
Hamlin (Norris)	2/13/30	10	175.3	41.7	28.5	96.6	2.1	23.8	16.2	55.1	3.4	61.8	10.5	5.8
St. Michael	2/13/30	10	119.8	32.4	28.4	42.0	4.8	27.0	23.6	35.1	3.2	62.9	12.1	18.5
Parson Brown	12/16/29	16	221.3	47.9	53.4	114.3	5.0	21.6	24.1	51.6	3.1	69.9	11.3	18.0
Ruby	12/16/29	8	201.6	47.9	43.9	114.9	3.0	23.7	21.7	57.0	3.6	66.8	11.0	13.5
*Washington Navel	3/ 4/30	10	212.7	60.8	24.6	117.3	0.5	29.9	12.1	55.1	4.2	64.3	9.9	2.0
TEMPLE ORANGE	12/16/29	4	287.0	67.4	49.6	166.0	4.0	23.4	18.5	57.8	3.5	77.8	12.8	25.0
TANGERINE OR MANDARIN ORANGE														
Dancy	12/16/29	4	98.5	20.3	**	77.2	1.1	20.5	....	78.4	2.1	56.8	10.3	11.5
Clementine (Algerian)	12/16/29	5	102.1	23.7	....	76.7	1.7	23.2	....	75.2	2.1	57.0	10.5	15.2
TANGELO														
Thornton	12/16/29	5	227.6	61.5	**	162.9	3.2	27.0	....	71.6	4.5	69.4	11.0	17.6
LEMON														
Eureka	9/30/29	10	106.7	23.5	16.7	64.4	2.3	21.9	15.6	60.4	2.4	49.4	10.9	20.8
Meyer	9/30/29	10	151.5	24.0	29.9	102.2	1.2	15.8	17.1	67.5	2.1	58.3	10.9	12.0
LIME														
Mexican	9/30/29	8	39.9	11.9	11.9	27.3	0.7	28.9	29.6	68.3	1.7	38.1	8.6	4.4
Rangpur	9/30/29	8	57.7	10.5	9.5	37.5	1.3	18.2	16.6	65.0	1.0	43.1	10.0	17.0
KUMQUAT														
Meiwa	2/13/30	32	10.4	4.1	**	**	0.8	40.3	....	....	**	**	5.6	6.8
Nagami	2/13/30	5	7.2	4.3	**	**	0.3	58.8	....	....	**	**	....	2.8
Marumi	2/13/30	16	2.7	1.2	**	**	2.8	43.8	....	....	**	**	3.8	3.0

*Stored fruit; harvested in December, 1929.

**Character not determined.

Table 5. Citrus variety standardization; physico-chemical characters of citrus juice, 1929-30. Samples—10 fruits

Cultured form	Date	Per cent of juice					Ratio: Solids, acids	pH	Buffer index	Per cent of juice		Flavor
		Total soluble solids	Reducing sugar	Non-reducing sugar	Total sugar	Total acids				Protein	Ash	
GRAPEFRUIT												
Class 1.												
Marsh	10/14/29	10.47	3.37	2.69	6.06	1.36	7.69	3.17	1.070	**	0.24	Tart
Marsh	10/30/29	10.47	3.51	2.52	6.03	1.18	8.87	3.17	1.040	**	**	Tart
Marsh	11/19/29	10.02	**	**	**	1,13	8.22	3.17	1.000	**	0.24	Tart
Marsh	12/16/29	9.10	3.27	2.76	6.03	1.09	8.34	3.20	1.000	0.49	0.21	Tart
Marsh	2/13/30	9.05	3.81	3.23	7.04	0.98	9.23	3.23	0.877	0.53	0.24	Tart
Thompson	11/19/29	8.32	3.35	2.32	5.67	1.02	8.15	3.24	0.990	**	0.25	Tart
Thompson	11/26/29	8.33	3.29	2.80	6.09	1.01	8.24	3.30	0.909	*	0.24	Tart
Thompson	11/30/29	8.40	3.38	2.84	6.22	0.97	8.65	3.29	0.943	**	0.19	Tart
Thompson	12/16/29	8.35	3.16	2.78	5.94	0.96	8.69	3.24	0.980	0.42	0.20	Tart
Duncan	12/16/29	9.87	3.49	3.21	6.70	1.24	7.95	3.22‡	0.980	0.52	0.27	Tart
Foster	11/30/29	9.19	3.43	3.19	6.62	1.16	7.92	3.29	0.952	**	0.20	Tart
Foster	12/16/29	9.37	3.23	3.26	6.49	1.13	8.29	3.29	0.917	0.52	0.28	Tart
†Foster	3/ 4/30	9.76	4.06	2.72	6.78	1.09	8.95	3.16	**	0.42	0.26	Tart
McCarty	12/16/29	9.37	3.15	3.23	6.38	1.21	7.74	3.18	1.07	0.53	0.30	Tart
Class 2.												
Triumph	12/16/29	8.98	1.80	4.53	6.33	0.73	12.30	3.65	0.795	0.52	0.34	Almost sweet
SWEET ORANGE												
Class 1.												
Valencia	12/16/29	10.33	3.01	4.31	7.32	1.03	10.02	3.45	0.877	0.65	0.31	Excellent
Valencia	2/13/30	11.08	3.22	4.12	7.34	0.78	14.20	3.53	0.763	0.77	0.33	Excellent
†Valencia	3/ 4/30	13.22	4.25	5.03	9.28	0.80	16.52	3.24	**	0.68	0.31	Excellent
Lue Gim Gong	12/16/29	9.64	2.90	3.52	6.42	1.38	6.98	3.16	1.14	0.63	0.31	Tart
Lue Gim Gong	2/13/30	11.04	3.32	3.92	7.24	0.86	12.83	3.43	0.813	0.63	0.28	Excellent
Joppa	12/16/29	11.37	3.81	4.61	8.42	0.76	14.96	3.43	0.806	0.69	0.27	Excellent
Pineapple	12/16/29	10.90	3.20	4.77	7.97	0.50	21.80	3.39	0.934	0.62	0.29	Mild
†Pineapple	3/ 4/30	14.53	4.62	6.10	10.72	0.56	25.94	3.95	**	0.59	0.37	Mild
Hamlin (Norris)	12/13/29	11.58	3.04	4.42	7.46	0.92	12.58	3.69	0.934	0.93	0.43	Excellent
St. Michael	12/13/29	12.29	3.82	4.35	8.17	0.62	19.82	3.84	0.609	0.75	0.33	Excellent
Class 2.												
Parson Brown	12/16/29	8.84	2.45	3.87	6.32	0.78	11.33	4.24	0.518	0.51	0.36	Excellent
Ruby	12/16/29	7.74	1.88	3.31	5.19	0.45	17.20	4.31	0.518	0.68	0.38	Mild
†Washington Navel	3/ 4/30	14.54	4.63	5.79	10.42	0.37	39.29	4.32	**	0.94	0.36	Insipid
TEMPLE ORANGE												
Temple	12/16/29	10.92	3.46	4.36	7.82	1.19	9.17	3.44	0.884	0.58	0.34	Excellent
*Temple	3/ 4/30	12.36	4.19	4.85	9.04	0.82	15.07	3.39	**	0.44	0.27	Excellent

MANDARIN OR TANGERINE ORANGE												
Dancy	12/16/29	9.23	2.74	4.51	7.25	0.49	18.83	3.83	0.657	0.42	0.22	Fair
Algerian	12/16/29	12.60	2.70	5.66	8.36	0.70	18.00	3.88	0.657	0.69	0.31	Excellent
TANGELO												
Thornton	12/16/29	9.73	3.41	4.19	7.60	0.59	16.49	3.81	0.671	0.50	0.21	Excellent
LEMON												
Eureka	12/16/29	**	**	**	**	**	**	2.33	**	**	**	Excellent
Meyer	9/30/29	**	2.74*	0.64*	3.38*	4.33*	**	2.52	**	**	0.19*	Excellent
LIME												
Mexican	9/30/29	**	**	**	**	**	**	2.13	**	**	**	Excellent
Rangpur	9/30/29	**	**	**	**	**	**	2.34	**	**	**	Good
KUMQUAT												
Meiwa††	2/12/30	**	12.12	1.90	14.02	**	**	**	**	1.97	0.69	Excellent

*Analysis, Fall 1926.
**Character not determined.
†Stored fruit.
††Fat, 0.42%; crude fiber, 1.98%; water, 72.7%; potash, 0.29%; phosphoric acid, 0.07%. Analyses include seeds, which were 7.6% of total weight.
‡Duncan grapefruit juice, 9/30/29, pH 3.25; 10/8/29, pH 3.28; 10/8/29, pH 3.34.

when a solution is neither acid or alkaline, is 7.0. Values higher than 7.0 up to 14.0 represent increasing degrees of alkalinity; and values lower than 7.0 down to 0.0, represent increasing degrees of acidity. An increase of effective acidity is therefore associated with a decrease in the pH value.

The Van Slyke buffer index is used as a measure of the degree of protection possessed by a solution against relatively great changes in acidity or alkalinity. Plant juices usually contain buffer substances, weak acids, weak bases, etc., which neutralize strong acids or bases which may be added. The buffer capacity of citrus juice has been measured by determining the pH or effective acidity of the juice before, and after the addition of acid.

Interpretation of Results

While this work has not extended over a sufficient period of years to warrant definite conclusions in most cases, certain facts have come to light in regard to dessert quality of citrus fruit and such characters as resistance to cold, season of maturity, keeping quality of the fruit, and adaptability of the plant, as a whole, to local conditions. As shown in Table 3, the grapefruit and sweet orange varieties are relatively more hardy to cold than are commercial varieties of limes and lemons. Some of the mandarin oranges such as the commercial tangerines are more hardy than the more common varieties of sweet orange and grapefruit. Limequats are relatively not as hardy to frost as are kumquats but are more frost-resistant than green-fleshed limes.

The relative merits of the cultivated forms under the various classes of citrus fruits, as grown in the Lower Rio Grande Valley, are conveniently treated under the respective classes: grapefruit, sweet orange, mandarin or tangerine orange, lemon, lime, and other citrus fruits.

GRAPEFRUIT

This section is devoted to the particular standards for cultivated forms of grapefruit.

It will be seen in Table 3 that there is some variation in the season of maturity of the various varieties. The outstanding early forms are Duncan, Conner's Prolific, McCarty, and Triumph. The more important midseason sorts are Marsh, Thompson, and Foster. From the standpoint of possible loss of fruit due to low temperature, a part of the midseason crop may be affected, but in this connection the quality of the fruit must be taken into consideration, as will be pointed out later. When varieties at present available are considered, it is undoubtedly advisable to set the larger portion of future plantings to midseason, "seedless" forms rather than to the early, "seedy" sorts.

As regards keeping quality, there is little varietal difference, except that Triumph is more perishable than the other forms.

Grapefruit of size "70" to "80" per box are in greatest demand, for the retail fruit dealer is enabled to sell fruit of this size to greater advantage. At ten cents per fruit, the dealer realizes seven to eight dollars per box on 70's and 80's, while larger fruit, 54's and 64's, must either be sold at a higher price per fruit, or at less profit to the dealer by the box. The figures in Table 4 show that the mean weights of Marsh and Thompson grapefruit are 466 grams and 449 grams, respectively, which would grade about size "70." The Duncan fruits included in the study show that fruits of this variety weighed about 468 grams. In general, Duncan fruits average larger than size 70's.

Grapefruit Quality

The composition of mature grapefruit juice is fairly constant for the principal commercial varieties, such as Marsh, Thompson, and Duncan, included in the experiment, as shown in Table 5. The outstanding difference in the fruits is apparently in the number of seeds per fruit.

The proportion of "rag" varies somewhat, being lower in Marsh and Thompson and higher in Duncan. Amount of "rag" is not the only measure of the relative importance of this character, since the nature of the "rag" must also be considered. Observations show that the "seedy" types of grapefruit have a relatively greater proportion of fibrous tissue than is found in the fewer-seeded types.

Palatability of citrus fruit juice is usually measured by the ratio of soluble solids to acids, as determined by titration (36). A completely satisfactory explanation of the principles involved has not been discovered. Work conducted to date (34, 36) seems to indicate that there is a decline in total solids as the fruit matures. The amount of acids also declines relatively more than that of total solids, which brings about a gradual rise in the solids to acids ratio as the season advances. It should be pointed out in this connection that originally the ratio of total sugars to acids was used. The amount of sugar present is, however, directly correlated with the total solids content of the juice (34). It is, therefore, permissible to utilize the relatively more simple total solids determination by the specific gravity method (hydrometer) in place of the more expensive and cumbersome direct sugar determination method.

The importance of the protein and ash fractions as affecting palatability of grapefruit juice has not been explored. Figures shown in Table 5 indicate that the fractions are relatively small and are subject to but slight variation.

The effective acidity, as measured by the hydrogen ion concentration in pH units, and the buffer capacity, as measured by the Van Slyke Buffer Index, show that the pH rises slightly as the season advances, giving a decrease in effective acidity. The buffer index decreases as the fruit matures indicating that the original buffered nature of the grapefruit juice is lowered (36).

Standards for Maturity

Legal maturity standards for citrus, including grapefruit, have been established in California, Florida, and Texas (6, 9, 32). The California law with reference to grapefruit requires a minimum of 6 parts of total soluble solids to 1 part of anhydrous citric acid (determined by titration) for District No. 1, and 5½ to 1 for District No. 2; except that after June 1st, until the crop is sold, all fruit is considered mature irrespective of the analysis of the juice. The Florida law as applied to grapefruit sets up a decreasing minimum ratio of solids to acids with increasing total soluble solids of the juice:

Per Cent Total Soluble Solids*	8.5	9.0	10.0	11.0	12.0
Minimum Ratio,* Solids Acids	7:1	6½:1	6:1	5½:1	5:1

*Tolerance Factor—0.2

The Texas law regulating maturity standards for grapefruit requires a minimum total soluble solids content of 10 per cent and a ratio of 7 parts of soluble solids to 1 part of acid, except for early, "seedy" varieties after October 15th, for which the requirements are the same as those set up in the table for Florida, beginning with the second column, with 9 per cent total soluble solids and a ratio of 6½ parts of solids to 1 part of acid. It will be seen that the Texas standard is the more exacting. It should be noted that the solids to acids ratio, in the samples of Marsh grapefruit reported in Table 5, was above 7 to 1 and in one case reached a ratio of 9 to 1, toward the latter part of the season. The Thompson and the Foster varieties show a trend similar to that of Marsh.

Description of Grapefruit Varieties

Grapefruit varieties have been grouped in two classes by Traub (35) on the basis of effective acidity. Detailed descriptions of the main varieties are given under the two classes.

Class 1. Varieties with relatively high effective acidity, below pH 3.5.

Marsh. This variety is planted more extensively in the Valley than any other form of citrus. The trees are quite prolific and mature their fruits at such a time (November and December) that they may be harvested before the frost-danger period. Some objection has been raised to the relatively smaller size of Marsh grapefruit, but a large part of this objection can be overcome by proper orchard management. Specimens studied averaged medium to large in size (466 grams).* As is common with practically all commercial forms of grapefruit, shipping quality is good. The proportion of "rag" is approximately 20 per cent; seeds average 4 in number; ratio of solids to acids ranges from 7 to 1 in October and 9 to 1 in February; and the effective acidity varies from pH 3.1 to pH 3.2. Because of its relative "seedlessness" and delightful flavor, this is by far the most desirable type for commercial planting. Marsh grapefruit, as grown in the Lower Rio Grande Valley, has created a distinctive demand in the consuming centers, and it is logical that the high standards set by this variety should be capitalized to the extent of eliminating as far as possible the inferior varieties.

Thompson. A pink-fleshed bud mutation of Marsh (36) that is practically identical with this excellent variety, except as regards flesh color. This variety will in all probability become the leading commercial sort in the Valley in years to come. The attractive pink-flesh color coupled with the excellent dessert quality has an immediate appeal to the consumer.

Walters. Trees are quite prolific and are apparently well adapted to the region. Fruits are quite seedy; possess a relatively high proportion of "rag"; and lack the appealing flavor of Marsh. Not recommended for general planting.

Foster. A pink-fleshed bud mutation of Walters. Trees are prolific and well adapted to local conditions and mature their fruit relatively early. The fruits are large in size (521 grams); with 18 per cent to 20 per cent rag; seeds average 54 in number; solids to acid ratio reached, 8 to 1 in November, 1929; and effective acidity ranged from pH 3.1 to pH 3.2. A characteristic feature of the fruit is the pink blush on the outside of the fruit. Because of its seedy nature Foster is not recommended for general planting in the Valley.

Duncan. Probably the most widely planted commercial form of the early, seedy type of grapefruit. Trees are very prolific and well adapted to Valley conditions. The fruits are in general larger than those of Marsh (468 grams). "Rag" averages 22 per cent; seeds are 63 in number; solids to acids ratio approxi-

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*Quantitative measurements indicated in parentheses refer to data presented in Tables 4 and 5 for the dates indicated.

mately 8 to 1 in December; effective acidity, pH 3.2. Probably this variety is the best of the "seedy" types.

McCarty. This variety is quite similar to Duncan.

Conner's Prolific and Innman's Late. These varieties are similar to Duncan in many respects. Fruit characters have not been studied, as trees of these varieties in the Station collection are not of bearing age.

Little River Seedless, and Cecily Seedless. These are "seedless" types of rather recent introduction. It is claimed that they are earlier than Marsh.

Class 2. Varieties with relatively low effective acidity, above pH 3.5.

Triumph (Royal). A very distinct type of grapefruit that differs markedly from the varieties included under Class 1.

Total solids increase and total acids decrease as the season advances, as shown by Porto Rico analyses (34), causing a very marked increase in the solids to acids ratio with increasing age. Solids to acids ratio was 12 to 1 in December under Valley conditions. Effective acidity is relatively low, pH 3.6 in December. Fruits are medium in size; have approximately 31 per cent "rag"; and contain on an average of 51 seeds. Flavor is almost sweet and lacks the typical grapefruit character.

These marked differences have caused some to believe that this variety is a grapefruit-sweet orange hybrid. This variety is not to be recommended for commercial planting because of its insipid flavor, and general low quality.

SWEET ORANGE

The Valencia is the most extensively planted variety of sweet orange in the Lower Rio Grande Valley, followed by Pineapple. Other varieties such as Parson Brown, Washington Navel, and Temple have been planted in a limited way.

Most of the commercial sweet orange varieties grown in the Rio Grande Valley, as shown in Table 3, are sufficiently mature to be marketed before there is danger of loss from frost. Varieties which may be harvested without encountering frost hazards are: Parson Brown, Pineapple, Ruby, Joppa, Washington Navel, and similar types. Varieties such as Valencia, Lue Gim Gong, and Temple ripen at a relatively later date and may encounter frost hazards worthy of consideration.

Valencia, Lue Gim Gong, and Washington Navel hold up better in transit and storage than do varieties like Pineapple, Parson Brown, Joppa, Ruby, and Temple.

Navel oranges, as grown under Valley conditions, are relatively larger in size than other commercial types. Ranked according to size the other varieties would be listed as follows: Temple, Valencia, Lue Gim Gong, Pineapple, Parson Brown, Ruby, Joppa, and St. Michael. The relative size of the different varieties of oranges according to weight in grams is shown in Table 3.

Sweet Orange Quality

The proportion of "rag," number of seeds, and palatability of juice are the principal factors affecting the popularity of the different varieties so far as the consumer is concerned.

The sweet orange varieties may be conveniently grouped on the basis of number of seeds per fruit into three classes: (a) varieties with 2 to 10 seeds represented by Washington Navel, Valencia, Joppa, Lue Gim Gong, and Hamlin; (b) varieties with 11 to 15 seeds represented by Ruby; and (c) varieties with 16 to 30 seeds represented by Parson Brown, Pineapple, St. Michael, and Temple. In general, as shown in Table 3, the proportion of "rag" is relatively less in the first class than in the other two classes.

The legal maturity standards as they relate to oranges are comparatively uniform where such standards are in force. In Florida and Texas (9, 32) an unqualified solids to acids ratio of 8 to 1 is in force. In California (6) a qualified ratio has been set up. When the fruit is 25 per cent colored (on the tree) the 8 to 1 ratio applies; however, fruit showing 75 per cent color may be deemed mature when it shows a ratio of $6\frac{1}{2}$ to 1. No fruit may be artificially colored which shows a ratio lower than 8 to 1.

Figures shown in Table 5 indicate that Valley-grown oranges, in so far as the solids to acids ratio is concerned, are well above the 8 to 1 standard. The data show only one exception, this being in the case of an immature lot of Lue Gim Gong oranges collected December 16, 1929.

Under Texas conditions, high dessert quality in oranges is apparently associated with relatively greater effective acidity, commonly expressed in pH units. The commercial types have been placed in two groups by Traub (35) on the basis of this character. The first group represented by Lue Gim Gong, Valencia, Joppa, Pineapple, Hamlin, and St. Michael show a pH range of 3.1 to 3.8. The second group represented by Parson Brown, Ruby, and Washington Navel shows a pH range of 4.2 to 4.3. The oranges of the first group having a relatively higher effective acidity are more "tart" in flavor than those in the second group. Oranges of the second group are, in general, rather insipid in flavor as grown under Valley conditions. The Temple orange, possibly a hybrid type (16), shows a pH range of 3.1 to 3.4, and should be placed with the first group.

Description of Sweet Orange Varieties

The work on the standardization of sweet-orange varieties may be conveniently summarized under the two classes described:

Class 1. Varieties having relatively high acidity: below pH 4.0.

Valencia. This variety is well adapted to conditions in the Lower Rio Grande Valley. The fact that it matures late in the season subjects the crop to some hazard from frost. Fruits are of medium size (150 to 190 grams) and hold up well in storage and transit. From the standpoint of proportion of "rag" and number of seeds (6 to 10) this variety is highly desirable. Solids to acids ratios varied from 10 to 1 in December to 16 to 1 in February. This variety, in spite of its lateness, is of superior dessert quality and is probably the best sort available to Valley planters at the present time.

Lue Gim Gong. A variety of Florida origin that is quite similar to Valencia. The fruit is slightly more acid than Valencia. Solids to acids ratios varied from 6 to 1 in December to 12 to 1 in February.

Pineapple. Trees of the Pineapple variety are well adapted to local conditions and mature their crop of fruit relatively early in the season (November and December). Fruits are small to medium in size (160 to 200 grams). From the standpoint of shipping quality this variety is inferior to varieties like Valencia. The proportion of "rag" is relatively high (23 per cent). Number of seeds varies approximately from 22 to 29, which would place this variety in the seedy class; dessert quality is excellent, solids to acids ratios varying from 21 to 1 in December to 25 to 1 in March. Next to Valencia this variety is being planted more extensively in the Valley than any other sort.

Joppa. This variety is quite similar to Pineapple.

Hamlin (Norris). The Hamlin orange was introduced under the name of "Seedless Pineapple" and in many respects it is similar to Pineapple. It differs from the latter variety chiefly in the average number of seeds (5 per fruit). The fruit shows a low percentage of "rag" (16 per cent) but does not hold up well in transit and storage. Apparently this variety should be given preference over Pineapple.

St. Michael. One of the blood oranges that has never been very widely planted. Apparently, it is not suited to Valley conditions. It is a midseason sort, small in size, and of poor keeping quality. Dessert quality is good, being similar to Pineapple in many respects. Solids to acids ratio was 19 to 1 in December. Not recommended for commercial planting.

Temple. This apparently hybrid type from Florida shows some promise because of its superior dessert quality. However, it is one of the most perishable types. Sizes range from medium to large (200 to 280 grams). The proportion of "rag" is relatively low (13 to 18 per cent). The fruit is rather seedy, having 21 to 25 seeds. Solids to acids ratios ranged from 9 to 1 in December to 15 to 1 in March. Not recommended for general commercial planting.

Class 2. Varieties having relatively low acidity: below pH 4.0.

Parson Brown. An early, prolific type that has been rather extensively planted in spite of its limitations. It is one of the earliest sorts, ranking with Hamlin in this respect. The fruits are rather small in size and quite perishable. The proportion of "rag" is high (24 per cent), and the number of seeds is intermediate, 12 per fruit. The solids to acids ratio was 11 to 1 in December. Because of its appealing mild flavor, this variety has enjoyed unwarranted popularity. Hamlin, a less seedy sort, should be given preference over this variety where early sorts are desired.

Ruby. This variety is planted to a limited extent in the Valley. It is one of the blood oranges, but does not show red-flesh pigmentation as grown in the Lower Rio Grande Valley. It is quite similar in many respects to Parson Brown.

Washington Navel. A variety apparently not adapted to Valley conditions. Trees are not regular, annual bearers, and rank low from the standpoint of productive capacity. Fruits are large in size (212 grams) and are usually rather irregular in shape. Fruits ripen later than those of varieties such as Hamlin and Pineapple. The fruit has excellent shipping quality. The proportion of "rag" is low (12 per cent) and the average number of seeds is the lowest of any of the cultivated forms (2 per fruit). The flavor is insipid, which can be explained by the relatively low effective acidity, pH 4.3, and the relatively high solids to acids ratio. This variety is not to be recommended for general planting.

Other Sweet Oranges

Various other varieties of sweet oranges are included in the variety standardization collection at Substation No. 15. Most of these varieties are of the Mediterranean type and are in general inferior to varieties like Valencia and Hamlin. A number of oranges of the Navel type are included in the collection, but most of these trees are not of bearing age.

MANDARIN OR TANGERINE ORANGES

Tangerine oranges have not been extensively planted in the Lower Rio Grande Valley. The trees are apparently well adapted to the Valley and bear heavy crops of fruit, but the perishable nature of the fruit has prevented the rapid extension of this industry.

Dancy. This tangerine orange is the most widely planted commercial sort at the present time. The trees are well adapted, prolific, and fairly hardy to cold. The fruits are small in size (98 grams) and ripen during December. The seeds are rather numerous for such small fruit (11 per fruit). The quality of the fruit is only fair. Solids to acids ratio was 18 to 1 in December, the effective acidity on this same date being rather low, pH 3.8. The fruit deteriorates rather quickly after reaching maturity and is subject to "drying" at the stem end.

Clementine (Algerian). A variety quite similar to Dancy in many respects, except that the fruit matures considerably earlier and the trees are more hardy to cold and the fruit is of higher quality. This variety should be given preference over Dancy.

Other Tangerines. Several other varieties of tangerines are included in the variety collection but the trees are not of bearing age. Among this lot are: Willow Leaved Mandarin, Swatow, and Warnuco.

KING AND SATSUMA ORANGE

These species, closely related to the mandarin or tangerine oranges, are not of much commercial importance in the Lower Rio Grande Valley.

King Orange. Trees of this variety are tender to cold and the fruit has little commercial value except in special markets.

Satsuma Orange. As previously indicated, the growing of this variety of orange in the Valley has been limited by the lack of a suitable root-stock species. Due to its extreme earliness, the Satsuma orange offers some promise from a commercial standpoint.

LIMES AND LEMONS

Neither limes nor lemons are grown on an extensive scale in the Rio Grande Valley on account of the relative tenderness of these forms to cold. Trees are prolific bearers but in the case of lemons are also quite subject to disease.

Mexican Lime (Key). Trees of this variety are heavy producers of fruit but are quite tender to cold. The fruits are small in size, and mature for the most part during the season of greatest demand (June to December). The flesh is green in color and quite free of "rag." Seeds average few in number (4 per fruit). The effective acidity of the juice is the highest of any of the citrus fruits studied, pH 2.1. The flavor is quite distinctive, differing rather markedly from Rangpour, and Limequats. Useful for home planting.

Tahiti (Bearss Seedless) Lime. This lime is similar to Mexican in some respects, but the fruits are too large for commercial use. The wood of the trees is quite brittle, and trees are therefore subject to severe breakage.

Sweet Lime. A form cultivated to some extent in Mexico, and used as a root stock for certain commercial sorts. The juice of the fruit is insipid and lacks tartness. Not of any commercial value as a fruiting plant.

Rangpur Lime. Possibly a hybrid form which partakes of the character of the tangerines in that the nature of the rind is similar. It is relatively larger in size than Mexican (57 grams) and is more seedy (19 per fruit). The effective acidity is the same as that of commercial lemons (pH 2.3). The flesh is tangerine-colored.

Eureka Lemon. This is the most commonly propagated variety of commercial lemon in the Valley at the present time. The trees are not particularly well adapted to local conditions, being subject to frost hazards and disease. Fruits are medium in size (106 grams); "rag" percentage is about 21 per cent; number of seeds average 20. The effective acidity (pH 2.3) is higher than that of Meyer. No recommended for commercial planting.

Meyer Lemon or Dwarf Chinese Lemon. A rather recent introduction that offers some promise as a variety for home plantings. Trees are much more hardy to cold than are varieties like Eureka and are about as hardy as grapefruit. Trees are more resistant to disease than are other forms. Size is of no particular significance, as fruits may be harvested at any time after fruit has attained minimum size for commercial use.

The shape of these lemons differ from that of types like Eureka in that many of the fruits are round or globular. The proportion of "rag" is 15 per cent; number of seeds, 12 per fruit; and the effective acidity is pH 2.5. The juice is not so acid as that of Eureka, and has a very distinctive flavor. The variety offers some promise, provided the public can be educated to accept a round lemon instead of an oblong one.

KUMQUATS AND HYBRIDS

Kumquats. This type of citrus is well adapted to the Valley, but so far no commercial outlet for the fruit has been found. The trees are hardy and very prolific. Three types have been studied and all of them appear to be adapted to local conditions. These are Nagami, an oval-fruited type; Marumi, a round-fruited type; and Meiwa, an intermediate form. Meiwa fruits are largest in size (10 grams), followed by Nagami (7 grams); Marumi fruits are smallest (2.5 grams).

Hybrids. Of the hybrids, special attention should be called to the tangeloes, segregated individuals from grapefruit-tangerine crosses. The trees are prolific, but are more tender to cold than grapefruit. Like the tangerines most varieties of tangeloes are poor keepers. It is claimed that there are varietal differences in this respect, and other sorts are being studied in the hope that a commercial variety may be discovered.

The Thornton tangelo bears a fruit of superior quality but which is too perishable to be of commercial value. In size, the fruit is nearer that of the grapefruit than that of the tangerine (227 grams). The solids to acids ratio and effective acidity approach those of the tangerine, being 16 to 1 and pH 3.8, respectively. Seeds average 16 in number.

Trees of Sampson tangelo are quite prolific but are rather tender to cold. The fruit is smaller in size than Thornton, and is quite seedy. The flavor of the juice is distinctive and is not pleasing.

Trees of other hybrid forms in the standardization orchard,—Citrange, Citradia, Citrangequat, and Limequat,—are not of bearing age.

MISCELLANEOUS FORMS

The following miscellaneous forms are included in the standardization collection,—

Shaddock. A form closely related to grapefruit, but used to a very limited extent as a dessert fruit.

Sour Orange. The fruit of sour orange is used to a limited extent in certain countries in the manufacture of citrus by-products. Not of commercial importance in the United States, except as a root-stock plant.

Calamondin Orange. Calamondin trees are hardy and highly productive. The fruit is extremely acid and has a distinctive flavor.

Ichang Lemon. A species native to the Ichang region of China. Has not fruited in the Rio Grande Valley up to the present.

Other Types. Suen Kat, *Severinia buxifolia* and *Citropsis schweinfurthi* are citrus types in the Station collection the adaptability of which has not been determined.

CITRUS ROOT-STOCKS

Early plantings of citrus fruits in the Rio Grande Valley were made on *Poncirus trifoliata* root-stock, but these attempts were unsuccessful, probably on account of the susceptibility of this plant to root diseases (foot-rot and cotton root-rot). Practically all of the present commercial plantings are on sour-orange and rough-lemon root-stocks. The trees on rough-lemon stock were practically all imported from Florida, and in most instances the purchaser was not aware of the fact that he was receiving such stock. Many of the trees propagated on rough-lemon root-stock are now in a state of decline or have died.

Although the sour orange is apparently a most satisfactory stock for grapefruit and sweet oranges, it is entirely possible that other stocks may be discovered which will be better adapted to other commercial forms like kumquats, tangerines, limes, and lemons. It has been pointed out that inferiorities due to incompatibility with root-stock may not be apparent for a number of years, especially in the case of lemons budded on sour orange (5, 43).

With such practical consideration in mind, experiments dealing with root-stocks were started in 1925, and enlarged in succeeding years.

The work with citrus root-stocks was planned to include (a) a study of the adaptability of the various root-stock plants to the conditions in the Lower Rio Grande Valley; and (b) a study of the compatibility between root-stock and scion.

Plan of Experiment

The plant material used in the root-stock studies, located on Victoria fine sandy loam soil, is being grown under the conditions of normal orchard culture in the Valley. Whenever possible, 10 or more individuals are used for each type of union studied.

In the adaptability studies an attempt is being made to determine the effect of the sum total of climatic and soil factors on the root-stock plants. In arriving at the "adaptability rating," such factors as general vigor, resistance to disease, prolific bearing capacity, adaptability to soil conditions as evidenced by foliage coloration (presence or absence of chlorosis), and resistance to low temperatures were considered. The facts are presented in Table 6.

Under the second line of investigation it is the purpose to determine the degree of compatibility between the root-stock and scion. In determining the degree of compatibility, failure of the scion to persist after a short period, dwarfing, unequal growth of root-stock and scion, and chlorosis were used as evidence. Rate of decline if any over a relatively long period of years should be considered but has not been included in the present report on account of the short time the experiment has been in progress. The facts are summarized in Table 7.

Interpretation of Results

The results are briefly discussed under the chief classes of citrus grown in the Valley.

Root-stocks for Grapefruit. As shown in Table 7, the standard varieties of grapefruit are compatible with sour orange, rough lemon, Cleopatra mandarin, Rusk citrange, and Citrangequat. Since grapefruit are apparently well adapted to the commonly used sour-orange root-stock, it would not seem advisable to recommend any changes at this time.

Root-stocks for Sweet Oranges. Sweet oranges are commonly grown on sour-orange root-stock and this combination appears to be well adapted to local conditions. The experiments show that the sweet orange is also compatible with sweet lime and calamondin.

Root-stocks for Other Citrus Fruits. Tangerines are commonly grown on sour-orange root-stock but are compatible with types like Rusk Citrange and Thomasville Citrangequat.

Satsuma oranges are not grown in the Valley on a commercial scale, apparently on account of the fact that no adapted root-stock plant has been discovered. Rusk Citrange, however, appears to be a promising root-stock plant for this type. *Poncirus trifoliata* stock as explained above is not successful under Valley conditions even though the union is congenial.

Kumquats are not compatible with sour-orange root-stock and are commonly budded on rough lemon roots. They appear to be congenial with rough lemon, calamondin, and Rusk Citrange.

Limes and lemons, except Meyer lemon, may be grown on sour orange and appear to be compatible with Thomasville Citrangequat and Rusk Citrange. Meyer lemon is best grown on its own roots. Limes budded on Calamondin show overgrowth of scion and may develop chlorosis.

The Time Factor. In an experiment of this nature the time factor must be given due consideration. Work must extend over a relatively long period of time in order that a more accurate measure of compatibility may be obtained. Only the more marked incompatibilities have come to light thus far. The success or failure of these unions must be followed through the development of the trees to maturity before final recommendations may be based upon the experiments.

Recommendations. At the present time the following root-stocks are recommended for the Valley: (a) grapefruit, sweet orange, tangerines, and limes on sour orange; (b) Satsumas on Rusk Citrange; (c) Meyer lemon on its own roots; and (d) Kumquats on rough lemon or Rusk Citrange.

Table 6. Citrus rootstocks; adaptability rating, 1924-30

Species and cultivated form	How propagated	Date planted	No. of trees	Adaptability rating	Remarks
SOUR ORANGE					
Citrus aurantium.....................	Seedling	1924	2	Good	Vigorous—prolific
	"	1924	1015	"	Vigorous—fairly hardy
	"	1925	100	"	Vigorous—fairly hardy
	"	1929	88	"	Vigorous—fairly hardy
LEMON					
Citrus limonia					
Rough............................	"	1929	2	"	Tender to cold
Meyer............................	"	1924	200	"	Dwarf—hardy to cold
Sweet............................	"	1927	15	Fair	Tender to cold
ICHANG LEMON					
Citrus ichangensis					
Ichang............................	....	1929	4	Good	Vigorous and hardy
Ichang............................	Seedling	1927	....	"	Vigorous and hardy
CALAMONDIN ORANGE					
Citrus mitis..........................	"	1924	1	"	Hardy and prolific
	"	1927	10	"	Hardy and prolific
SHADDOCK					
Citrus maxima					
Cuban............................	"	1927	10	"	Vigorous but tender to cold
MANDARIN OR TANGERINE					
Citrus nobilis deliciosa					
Cleopatra.........................	Cutting	1924	5	"	Fairly vigorous, tender to cold
	"	1927	10	Fair	Tender to cold
LIME					
Citrus aurantifolia					
Sweet lime........................	Seedling	1929	12	"	Vigorous but tender to cold
TRIFOLIATE ORANGE					
Poncirus trifoliata..................	Seedling	1924	25	Not adapted	All trees died first season
HYBRIDS					
Citrange					
(*Citrus sinensis x Poncirus trifoliata*)					
Rusk..........................	Cutting	1924	25	Good	Hardy, vigorous grower
Rusk..........................	"	1924	24	"	Vigorous and hardy to cold
Rusk..........................	Seedling	1927	15	"	Vigorous and hardy to cold
Rusk..........................	"	1929	1	"	Vigorous and hardy to cold
Rusk..........................	"	1929	15	"	
Citradia					
(*Citrus aurantium x Poncirus trifoliata*)					
	"	1924	6	Very poor	Chlorotic, died 1926
	"	1924	5	"	Chlorotic, died 1926
			6	"	Chlorotic, died 1926

Table 6. Citrus rootstocks; adaptability rating, 1924-30—Continued

Species and cultivated form	How propagated	Date planted	No. of trees	Adaptability rating	Remarks
HYBRIDS—Continued					
Citrangequat					
{ *Citrus sinensis x* }					
{ *Poncirus trifoliata* } *x*					
Fortunella margarita)					
Thomasville	Seedling	1924	25	Good	Fairly vigorous and hardy
Thomasville	"	1924	25	"	Fairly vigorous and hardy
Thomasville	"	1924	5	"	Fairly vigorous and hardy to cold
Thomasville	"	1927	15	"	Fairly vigorous and hardy
Thomasville	"	1929	2	"	Fairly vigorous and hardy
Savage	"	1929	10	"	Fairly vigorous
LIMEQUAT					
Eustis	....	1926	2	Poor	Chlorotic
Eustis	Cutting	1927	7	Unadapted	
VARIOUS SPECIES					
Citropsis schweinfurthi	Cutting	1929	2	Undetermined	Died
Atalantia distascha	Seedling	1929	2	Undetermined	
Suen kat	Cutting	1927	10	Good	Fairly vigorous and hardy
Severinia buxifolia	"	1929	5	Undetermined	Dwarf

Table 7. Citrus rootstocks; compatibility between rootstock and cion; 1924-30

Species and cultivated form	Rootstock	Date planted	No. of trees	Degree of compatibility	Remarks
GRAPEFRUIT					
Citrus paradisi					
Marsh	Calamondin	1924	3	Incompatible	Overgrows stock; dwarfed
Marsh	Rough lemon	1924	3	Compatible	
Marsh (33-3)	Thomasville citrangequat	1929	5	"	
Marsh (33-3)	Rusk citrange	1929	5	"	
Marsh (33-3)	Cleopatra mandarin	1929	2	"	
Marsh	Sour orange	1926	10	"	
Marsh	"	1925	3	"	
Marsh (33-3)	"	1929	102	"	
Marsh (37-5)	"	1929	65	"	
Marsh (37-6)	"	....	97	"	
Thompson	"	1924	3	"	
Thompson	"	1929	6	"	
Thompson	"	1929	3	"	
Thompson	Cleopatra	1924	3	"	One tree died
Thompson	Rusk citrange	1929	5	"	
Duncan	Sour orange	1924	6	"	
Duncan	Rough lemon	1924	3	"	
Duncan	Sour orange	1926	10	"	
Duncan	"	1926	25	"	
Duncan	"	1927	1	"	
Conner's prolific	"	1926	2	"	
Foster	"	1924	3	"	
McCarty	Rough lemon	1924	3	"	
McCarty	Sour orange	1926	1	"	
Triumph	"	1924	2	"	
Triumph	"	1926	3	"	
Walters	"	1926	3	"	
Inman's Late	"	1926	3	"	
Little River Seedless	"	1929	5	"	

Table 7. Citrus rootstocks; compatibility between rootstock and cion; 1924-30—Continued

Species and cultivated form	Rootstock	Date planted	No. of trees	Degree of compatibility	Remarks
SWEET ORANGE					
Citrus sinensis					
Lue Gim Gong	Sour orange	1924	3	Compatible	
Lue Gim Gong	"	1926	2	"	
Valencia	"	1924	6	"	
Valencia	"	1926	4	"	
Valencia	"	1926	25	"	
Joppa	"	1926	3	"	
Pineapple	"	1924	3	"	
Pineapple	"	1926	3	"	
Ruby	"	1924	3	"	
Ruby	"	1926	1	"	
Parson Brown	"	1924	3	"	
Parson Brown	"	1926	3	"	
Norris (Hamlin)	"	1924	3	"	
Norris (Hamlin)	"	1926	3	"	
Norris (Hamlin)	"	1929	5	"	
Washington Navel	"	1924	3	"	
Washington Navel	"	1926	3	"	
Washington Navel	"	1926	2	"	
S. P. I. Navel	"	1924	1	"	
S. P. I. Navel	"	1924	3	"	
S. P. I. Navel	"	1924	2	"	
S. P. I. Navel	"	1924	3	"	
S. P. I. Navel	"	1924	3	"	
S. P. I. Navel	"	1924	3	"	
Mediterranean Sweet	Calamondin	1924	2	"	
Homosassa	Sour orange	1926	3	"	
Pervis	"	1926	3	"	
Raymondville	"	1924	3	"	
Raymondville	"	1926	1	"	
Golden Buckeye	"	1926	3	"	
Buckeye Navel	"	1926	3	"	
Malta Blood	"	1926	1	"	
Thompson Navel	"	1926	1	"	
Seville	"	1927	1	"	
Chamoudi	Sweet lime	1928	1	"	
Chamoudi	"	1928	1	"	
Chamoudi	Sour orange	1929	3		
TEMPLE ORANGE					
Citrus sinensis x					
c. nobilis deliciosa					
Temple	"	1924	3	Fairly compatible	Trees show mottle leaf
Temple	Calamondin	1924	3	Fairly compatible	Trees show mottle leaf
Temple	Sour orange	1926	1	....	
Temple	"	1926	25	Compatible	
KING ORANGE					
Citrus nobilis					
King	"	1924	3	"	
King	Rough lemon	1926	3	"	
King	Sour orange	1926	1	"	
MANDARIN OR TANGERINE					
Citrus nobilis					
var. *deliciosa*					
Dancy	"	1924	6	"	
Dancy	"	1926	10	....	Dead
W. L. Tangerine	"	1926	3	Compatible	
Clementine (Algerian)	"	1927	8	"	
Clementine (Algerian)	"	1926	3	"	
Clementine (Algerian)	"	1929	7	"	
Clementine (Algerian)	Thomasville citrangequat	1929	2	"	
Swatow	Sour orange	1928	1	"	
Warnuco	"	1929	3	"	

Table 7. Citrus rootstocks; compatibility between rootstock and cion; 1924-30—Continued

Species and cultivated form	Rootstock	Date planted	No. of trees	Degree of compatibility	Remarks
SATSUMA ORANGE					
Citrus nobilis unshiu					
Owari	Trifoliata	1924	3	Compatible	Died, 1925
Owari	Calamondin	1925	3	"	
Owari	Rusk citrange	1926	3	"	
CALAMONDIN ORANGE					
Citrus mitis					
Calamondin	Sour orange	....	....	Uncongenial	All died
KUMQUAT					
Fortunella japonica					
Nagami	Rough lemon	1924	3	Compatible	
Nagami	Calamondin	1926	3	"	
Marumi	Rusk citrange	1927	1	"	
Nagami	Sour orange	1924	25	"	Died, 1924
Meiwa	Rusk citrange	1927	3	"	
LIME					
Citrus aurantifolium					
Mexican	Thomasville citrangequat	1929	1	"	Killed by cold, 1930
Mexican	Calamondin	1926	1	Cion overgrows stock	
Mexican (Key)	Rough lemon	1926	1	Compatible	
Sweet Lime	Sour orange	1924	1	"	
Sweet Lime	"	1925	1	"	
Tahiti	"	1926	1	"	
Tahiti	Rusk citrange	1926	1	"	
LEMON					
Citrus limonia					
Meyer	Sour orange	1924	10	Incompatible	Failed to survive
Meyer	Thomasville citrangequat	1929	5	Compatible	
Eureka	Sour orange	1929	10	"	Killed by cold, 1925
Lisbon	"	1924	10	"	Killed by cold, 1925
LIMEQUAT					
Eustis	"	1926	10	Uncongenial	Chlorotic, died
TANGELO					
Sampson	Calamondin	....	3	Compatible	
Thornton	Sour orange	....	3	"	

GRAPEFRUIT ORCHARD MANAGEMENT

In the other grapefruit-producing areas of the United States the orchard practices vary markedly (39, 40, 42, 7, 31, 41). In the Lower Rio Grande Valley of Texas grapefruit trees are usually spaced 21x21 feet to 30x30 feet, and as a general rule a combined system of cultivation, irrigation, fertilization, cover cropping, and mulching is followed in maintaining bearing grapefruit orchards. The procedure naturally falls into four periods:

(a) **From December to February, inclusive.** Winter weeds are allowed to grow. Between February 1 and 15 from 8 to 20 pounds of a 5-15-5 fertilizer mixture (or its equivalent) is applied. The actual amount is determined on the basis of 1½ pounds per tree for each year of age up to a 20-pound maximum. Irrigation water, at the rate of about 3 acre-inches, is applied previous to the flowering period, from February 15 to 28.

(b) **From March to April, inclusive.** Winter weeds are incorporated into the soil by disking to a depth of about 4 inches. The area disked varies with the size of the trees and is usually 12 to 14 feet wide where trees are planted 25x25 feet. During this period it may become necessary to apply irrigation water; the amount applied will vary from 3 to 4 acre-inches.

(c) **From May to August, inclusive.** Cover crops are usually grown during this period and may consist of crops such as cowpeas or native weeds. These crops are disked under when the first seeds are matured, usually in July. Irrigation water at the rate of 3 to 4 acre-inches per application is given at rather frequent intervals, 4 to 5 applications being made per season, depending upon the amount of rainfall. Volunteer cover crops are allowed to grow during August and September.

(d) **From September to November, inclusive.** During this rainy season no attempt is made to keep weeds under control by disking; and in case of occasional droughts it may become necessary to apply irrigation water.

Young Orchards. In maintaining the young orchard until the bearing stage is reached, a system of intercropping is followed. It is a common practice to grow such money crops as snap beans, potatoes, tomatoes, vine crops, corn and root crops in rotation with soil-improving crops such as cowpeas and yellow annual Sweet Clover, *Melilotus indica*. Fertilizers are not ordinarily used in developing young citrus orchards, since the rate of growth is usually quite satisfactory.

Scope of Cultural Experiments. The scope of the orchard management investigations includes studies concerning the influence of (a) cultivation, cover cropping, and mulching; and (b) the application of inorganic and organic fertilizer mixtures to the soil upon the yielding capacity of grapefruit trees.

ORCHARD PLAT TECHNIC

The orchard utilized in these experiments, located on Victoria fine sandy loam soil, was planted in May, 1920. After removal of native vegetation, chiefly Mesquite, Opuntia, etc., the virgin soil was plowed, leveled off, and graded so as to permit the application of irrigation water. The land was then planted to grapefruit trees. Trees of the Marsh variety, one year old, were purchased from a California nursery, and were set 21x21 feet apart. The plan of the orchard showing contours is presented in Figure 1. The trees were cared for by a tenant from the time they were set until the property was acquired by the Texas Agricultural Experiment Station in September, 1923. It has been given the usual care of a commercial orchard in the Lower

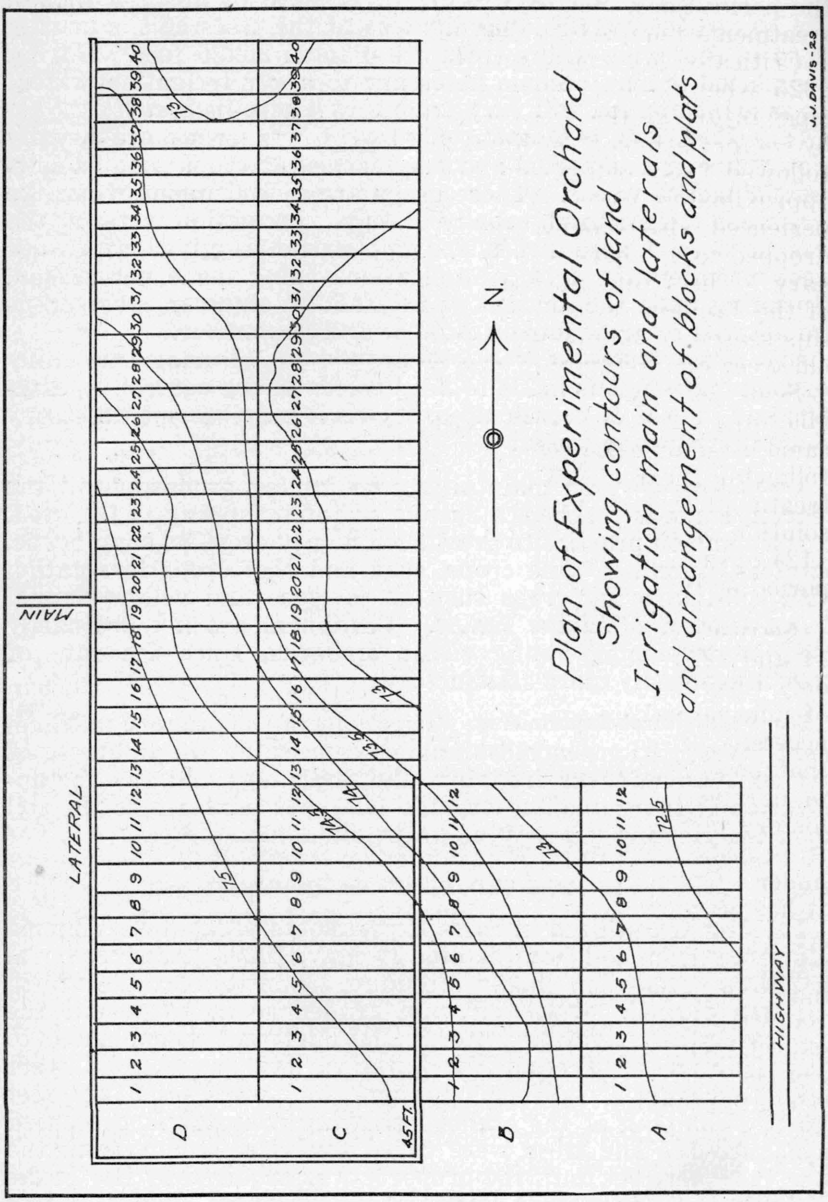
Plan of Experimental Orchard
Showing contours of land
Irrigation main and laterals
and arrangement of blocks and plats
LATERAL
MAIN
HIGHWAY
N
A
B
C
D
45 FT.
J.J. DAVIS-29

Figure 1

Rio Grande Valley as described above both previous to and during the period covered by this work, excepting where experimental treatments required a variation in this routine.

Critically low temperatures were experienced in December, 1925, when the temperature dropped to 25 degrees F. The principal injury to the trees was in the nature of breakage caused by ice formation on the limbs and leaves. Only slight defoliation followed this cold period and most of the trees recovered in approximately two years. Critically low temperatures were experienced also during 1929-30, when the temperature again dropped to 25 degrees in December and to 22 degrees F. in January. The fruit had been removed from the trees at the time of the January freeze and yields were, therefore, unaffected for this season. Only slight bark injury was noted on the 11-year-old trees and defoliation was so slight as to be negligible.

Scale activity during the season of 1926-27 caused considerable injury to some trees in the orchard. The gum diseases became a factor of primary importance during the season of 1926 following the 1925 freeze. By using the recommended surgical treatment for this disease and then painting the wound with a solution of denatured alcohol, bichloride of mercury, and rosin (12), practically all of the affected trees recovered within a period of two years.

Normality of Yields. In considering the data presented in Tables 11 and 12, it should also be realized that out of the five years, only three have been normal as to yield, primarily on account of unusual seasonal influences in two seasons. This shows the necessity of caution in interpreting the results. This indicates that more weight should possibly be given to results obtained in normal years than to a five-year mean, for instance. The history of the orchard would indicate that the season 1929-30 is probably the most typical of the behavior to be expected under the condition of experiment as to yields secured to date. It has been pointed out that during the season 1925-26 the trees were unduly affected by low temperatures during December, which caused marked injury to some trees on account of breakage from ice accumulation on foliage, limbs, and fruit; the following seasons were fairly representative of what one could expect from trees recovering from the injury of 1925-26. During the fourth year, 1928-29, the ravages of scale insects led to partial defoliation of a considerable number of trees. In 1929-30, no undue seasonal influences were encountered before the crop was harvested.

Yields from Abnormal Trees. The yields from abnormal trees were discarded for the purpose of this experiment on the following basis: yields of broken, diseased, and insect-damaged trees, where such damage obviously affected yields, were omitted; annual yields were also discarded if the trees were unduly affected by sporadic attacks of red scale.

Yield Records. As a measure of performance, the total yield per tree was taken to the tenth pound. It became apparent later that such a measure was too refined, and the yield data have therefore been uniformly expressed as 100-lb. boxes per tree, which is the logical measure for grapefruit. The smallest unit used is a tenth of such a 100-lb. box, and is therefore equal to 10 pounds.

Table 8. Blank experiment with grapefruit, entire orchard, 1924-25

Before differential treatments were begun

Plat	Mean yield per tree* 100-lb. boxes	Plat No.	Mean yield per tree* 100-lb. boxes	Plat No.	Mean yield per tree* 100-lb. boxes	Plat No.	Mean yield per tree* 100-lb. boxes
A- 1	0.3	B- 1	0.9	C- 1	0.3	D- 1	0.8
2	0.6	2	0.8	2	0.4	2	0.7
3	0.4	3	1.2	3	0.5	3	0.6
4	0.3	4	1.0	4	0.9	4	0.7
5	0.4	5	1.2	5	1.3	5	0.9
6	0.4	6	1.0	6	1.3	6	0.8
7	0.6	7	1.3	7	1.3	7	0.8
8	0.5	8	1.7	8	1.3	8	0.5
9	0.6	9	1.6	9	1.3	9	0.8
10	0.6	10	1.2	10	1.1	10	0.7
11	0.7	11	1.1	11	1.2	11	0.7
12	0.7	12	1.4	12	1.4	12	0.9
				13	1.7	13	1.1
				14	1.6	14	0.8
				15	1.6	15	1.0
				16	0.9	16	1.0
				17	1.5	17	1.0
				18	0.9	18	1.2
				19	1.5	19	1.6
				20	1.0	20	1.3
				21	1.7	21	1.2
				22	1.7	22	1.0
				23	1.0	23	0.8
				24	1.6	24	0.8
				25	1.2	25	1.1
				26	1.5	26	0.8
				27	1.6	27	1.1
				28	1.8	28	1.0
				29	1.3	29	0.9
				30	1.5	30	0.9
				31	2.0	31	0.7
				32	1.5	32	0.7
				33	2.0	33	0.8
				34	2.1	34	1.6
				35	1.5	35	1.2
				36	1.7	36	0.6
				37	1.4	37	0.7
				38	1.2	38	1.0
				39	1.4	39	1.4
				40	1.0	40	0.8

*Yield on 5 tree plat basis, and expressed as mean per tree.

Table 9. Blank experiment with grapefruit, 1924-25; continuity plats C-13 to 29, and D-13 to 29

Plat No.*	Mean yield per tree,* expressed in 100-lb. boxes					
	1924-25	1925-26†	1926-27	1927-28	1928-29‡	1929-30
C 13	1.67	1.45	1.91	2.28	1.01	4.38
14	1.63	1.48	1.46	2.09	1.01	4.06
15	1.65	....	1.83	2.41	1.16	3.65
16	0.88	....	1.45	2.67	1.29	4.26
17	1.53	....	1.53	3.29	1.78	4.71
18	0.92	....	2.04	3.31	2.35	4.66
19	1.48	....	2.63	3.54	2.72	5.49
20	1.02	....	1.91	2.91	1.47	4.34
21	1.68	....	1.60	2.83	1.76	5.79
22	1.71	....	1.08	3.27	2.60	5.58
23	1.00	....	1.05	3.11	2.56	4.91
24	1.60	....	1.10	4.09	1.92	6.39
25	1.24	....	2.06	4.09	2.94	5.79
26	1.55	0.54	0.81	3.40	1.38	5.37
27	1.63	0.45	1.37	3.71	1.70	6.43
28	1.82	0.68	1.75	4.36	2.53	5.32
C 29	1.33	0.84	2.21	4.54	2.50	5.78
D 13	1.08	1.49	1.94	2.84	2.13	4.49
14	0.78	....	1.85	1.96	2.03	3.74
15	0.99	....	1.92	2.46	2.38	4.63
16	1.01	....	2.34	2.45	2.28	5.40
17	0.96	....	1.27	2.88	2.04	4.81
18	1.18	....	1.37	3.03	1.42	5.13
19	1.59	....	2.45	3.11	1.59	6.46
20	1.27	....	2.26	2.69	1.82	3.22
21	1.22	....	1.84	2.45	2.10	5.73
22	0.97	....	0.90	2.27	1.78	5.07
23	0.76	....	0.82	2.42	2.07	5.81
24	0.80	....	2.49	3.26	1.57	4.52
25	1.14	0.59	0.50	3.45	0.88	5.60
26	0.84	0.40	1.39	3.13	1.28	5.40
27	1.15	0.82	2.48	3.89	1.32	6.68
28	0.98	0.49	1.19	3.17	1.37	5.29
D 29	0.88	0.78	1.29	3.77	2.12	6.60

*Yields on 5-tree plat basis, and expressed as mean per tree.
†Certain plats omitted due to damage from freezing of fruit.
‡Yields lowered by severe scale infestation.

Experimental Error. In carrying on experiments in orchard management, it is necessary to give due consideration to experimental error, which makes difficult the accurate interpretation of the results secured under any particular conditions of soil, climate, plant material, plant pests, and cultural practices (13, 8, 27, 23, 24, 25). The scientific method requires that all other conditions be held constant while one or a combination of two or more are varied. The practical orchardist knows only too well that this is not strictly possible under orchard conditions where such factors as bud-mutation* (26, 23, 24, 25) in trees, soil fertility, damage from plant pests, and low temperature may not affect all the trees uniformly. However, when the danger from these sources is fully realized, it is possible by the application of proper statistical methods to determine the approximate relative performance under the experimental conditions together with

*Possibly not of much importance from the standpoint of total yield.

some estimate of the accuracy of such approximations. Such values will serve for practical purposes.

Plat Variability. In order to secure a rational basis for interpreting the data secured it is desirable to determine the amount of variation over the entire orchard. Johnston (17) in 1849, from a theoretical viewpoint, emphasized the importance of determining "the limits of variation in natural productivity of the field," i. e., the comparative yields of all the plats of the experimental field without differential treatment, as a necessary step in field experimentation. It was not until the 90's, however, that extensive blank field experiments were carried out by Larsen (18). Anthony (1) in 1927 used the principle of performance records in apple fertilizer experiments, and Batchelor, Parker, and McBride (3) in 1928 reported on a blank experiment with citrus trees prior to their use in a nutrition experiment.

In order to secure an index of the amount of variation over the entire orchard, the grapefruit crop was harvested without differential treatments for the season 1924-25. These yields are shown in Table 8. As a continuous measure of variation for the duration of the experiment, the yields from a portion of the orchard, hereafter called "continuity plats" (Plats C-13 to 29,

Table 10. Analysis of blank experiments; plat variability as influenced by size of plats

Size of plat, feet	Number of trees per plat	Number of plats	Season	Mean yield per tree 100-lb. boxes	Standard deviation	Coefficient of variability
I. Entire orchard, 1924-25						
21 x 21	1	550	1924–25	1.1 ±.01	0.58	52.7
21 x 105	5	104		1.1 ±.02	0.37	33.6
21 x 210	10	52		1.1 ±.02	0.26	23.6
II. Continuity plats (C-13 to 29 and D-13-29), 1925-30						
21 x 21	1	70	1925–26	0.8 ±.03	0.47	58.7
21 x 105	5	12		0.8 ±.06	0.36	46.0
21 x 210	10	5		*	*	*
21 x 21	1	155	1926–27	1.5 ±.06	1.12	74.6
21 x 105	5	34		1.5 ±.06	0.59	39.3
21 x 210	10	18		1.5 ±.07	0.46	30.6
21 x 21	1	169	1927–28	3.1 ±.05	0.99	31.6
21 x 105	5	34		3.1 ±.07	0.69	22.2
21 x 210	10	18		3.1 ±.10	0.65	20.9
21 x 21	1	168	1928–29	1.8 ±.04	0.91	50.5
21 x 105	5	34		1.8 ±.05	0.53	29.4
21 x 210	10	18		1.8 ±.06	0.41	22.7
21 x 21	1	160	1929–30	5.1 ±.08	1.44	28.0
21 x 105	5	32		5.1 ±.10	0.83	16.2
21 x 210	10	16		5.1 ±.11	0.66	12.8

*Omitted on account of small number of plats.

and D-13 to 29), were harvested each year without differential treatments. These yields, from 1924-25 to 1929-30, are shown in Table 9. A general idea of the amount of variation over the parts of the orchard included in these blank experiments may be secured by inspecting the data in Tables 8 and 9. However, a more accurate and quantitative measure of the variability may be secured by calculating the coefficient of variability (C. V.), which indicates the amount of variation over the entire area considered in terms of percentage of the average yield per plat. In Table 10, the coefficient of variability has been worked out for the blank experiments on the basis of 1-tree, 5-tree, and 10-tree plats.

In general, when the size of plats is increased without increasing the total area, there is a decrease in the coefficient of variability. When the yield data for the entire orchard are expressed in terms of 1-tree plats, the variation ranges from 28 to 74 per cent of the mean or average plat yield over the period of 5 years. This extreme variation throughout the entire orchard is reduced to a range of 16 to 46 per cent when the same data are expressed as 5-tree plats. Expressing the data on a 10-tree plat basis gives in general a further reduction in variability, but the amount of reduction is not as consistently large as it is when 1-tree and 5-tree plats are compared.

The relatively large number of trees per plat required for experimental purposes to overcome the indicated variability would make orchard experiments of this kind prohibitive if the ordinary method were to be used of contrasting treatments with check plats distributed over the entire orchard (1, 19, 30, 33). An economical method of statistical analysis in harmony with the facts must therefore be adopted.

Methods of statistical analysis should of course be used only for valid biological reasons. It is imperative, on this account, to consider carefully not only the type of plant material studied under the particular conditions of growth as already indicated but also the stage or stages in the development of the plant organism in which the quantitative measurements (variates) were secured. The pomologist, with few exceptions, deals with perennial woody plants,—trees and shrubs. Such plant material is often studied in the developmental stage,—the grand period of growth, during which yields are subject to progressive increases over a period of years. From the standpoint of statistical analysis, when the grand period of growth is ended and the stage of so-called maturity is reached in trees, the conditions are probably somewhat comparable to those which obtain in the case of annual crops. When the stage of decline or senescence sets in the conditions are again altered.

In the present case, the grapefruit trees were 5 years old when the experiment was begun, and have developed over a 5-year period. The absolute yields have, in general, reached a higher level with increasing age of the trees. Since we are not dealing with an absolute yield level, it is erroneous to consider a fictitious mean yield for the period on the basis of the normal curve of distribution where fluctuations about a mean value are logically considered as due to errors of random sampling. Unless each season is considered separately, it is clear that the use of probability tables, based upon the normal curve of distribution, are not justified. It has been shown, however, that variation in plat yields over the entire orchard is too great to make feasible the interpretation of data for single seasons on the basis of the comparison of widely separated plats. The making of seasonal paired comparisons of adjacent plats on the basis of the consistency of differences would make it possible to escape from the difficulty presented in the case of plants studied as developing organisms.

Method of Interpreting Data. It follows from the preceding discussion of plat variability that even if adjacent orchard plats are given the same cultural treatments for the duration of the experiment they will vary to some degree one from the other. However, as a general rule, plats adjacent or near each other will have a tendency to vary less one from the other than plats distributed in distant parts of the orchard for environmental factors, such as soil fertility, drainage, etc., will tend to be similar for both. By considering plats adjacent or near each other some of the variable factors affecting the trees are eliminated (22).

Since 1908, there has been available a method, commonly known as "Student's" Method (28, 29, 30), which meets the requirements of our problem: (a) it makes possible the use of paired comparisons, and (b) it is applicable to small numbers.

By this method groups of contrasting pairs may be compared on the basis of the consistency of individual gains in estimating the significance of the average difference. When this method is employed, in the present instance, the yields of 5-tree plats of grapefruit trees adjacent or near each other and receiving different treatments may be compared, and the results interpreted on the basis of the consistency of the gain of one plat over the other.

The making of paired comparisons was not original with "Student," and his real contribution to methods of statistical analysis is due to the development of probability tables which are applicable to small numbers,—2 to 30 variates. When large numbers are available it is possible to calculate quite accurately the value of the standard deviation of a mean value. In such a case the calculated results for the purpose of determining the significance of a difference would naturally be referred to probability tables based upon the normal curve of distribution. When relatively small numbers are the only data available these tables would not give reliable indications of the significance of a difference since we have then only an estimate of the true standard deviation. In the development of "Student's" tables (28, 29, 30, 19) this fact was taken into consideration. It is not claimed that results from small samples are as reliable as those based upon large numbers of variates. It is true, however, that the use of "Student's" tables eliminates the mathematical error that would enter in if probability tables based on the normal curve were used when mean values and their standard deviations from the means have been calculated from relatively small samples. The worker in such a field of economic botany as horticulture must assume a practical attitude, and must expect to encounter the condition of small populations when dealing with plant materials such as grapefruit trees which are not as cheaply produced as annual crops. So long as the due caution is exercised in the interpretation of the results under the conditions there is little likelihood of going astray.

It has been pointed out above that probability tables have been developed by "Student" (29, 19) to which the calculated results, according to "Student's" formula, from any group of contrasting pairs may be referred for the purpose of securing an indication of the significance of the results. The probability tables give the odds that such differences as may be obtained are due to a cause or causes which affected one of the pairs and not the other and is not the result of chance variation.

When the experiment is so conducted that the factors which influence one side of the pairs and not the other is reduced to the minimum, except the differential treatment required by the experiment, then the odds indicated give a measure of the significance of the increases secured from the differential treatment.

It is the usual practice to conclude that a certain treatment is better than another, when the odds are 30 to 1 or higher that a given difference is the result of differential treatment and not of chance variation. When the odds are less than 30 to 1, further proof is required before we may conclude that the difference obtained is due to the differential treatment and not to chance. This condition applies especially when one is dealing with small numbers.

Utilization of Plats. Out of a total of 104 plats, containing 5 trees each, 20 were devoted to studies in cultivation, cover crops, and mulches; 48 were used for fertilizer work; and 38 were reserved for a continuous blank experiment as indicated in the preceding discussion.

CULTIVATION, COVER CROPS, AND MULCHES

Experiments concerning cultivation, cover cropping, and mulching in citrus orchards have been reported by workers in California (39, 40) and Florida (31, 41). The results in general show the necessity of maintaining the organic content of the soil at a productive maximum. This is borne out especially by the Rubidoux experiments with citrus in California (39, 40), and for crops in general by the classical experiments at the Rothamstead Experiment Station in England.

There is considerable variation in the season of the year when cover crops are chiefly grown in the important citrus-producing regions. In Florida cover crops are grown during the rainy season, May to October; in California they are produced from December to March, and in Texas, summer cover cropping, from May to August, is the general rule.

The present experiments will serve as a first step in determining, on an experimental basis, the most economical methods of cultivation, cover cropping or mulching under Valley conditions.

Plan of Experiment

The experimental work concerning cultivation, cover cropping, and mulching as factors in maintaining the Valley grapefruit orchard at maximum bearing capacity was planned to include ten contrasting treatments:

(a) **Modified clean culture.** This system of cultivation and cover cropping consists of disking under the weeds that appear after each irrigation. Whenever possible, weeds are not allowed to grow to a height of more than two feet before they are disked under. No effort is made to keep the ground entirely free of weed growth.

This is the method commonly followed by many Valley citrus growers on account of the fact that it becomes difficult to keep Valley citrus orchards free of weeds during certain periods of the year.

(b) **Modified clean culture with 6-inch plowing.** When this system is followed, a strip about 8 to 10 feet wide between the trees is plowed to a depth of 6 inches and then the method described under "modified clean culture" is followed.

(c) **Winter cover crops,—non-legume.** This method consists of growing a crop of oats or barley on the soil during the season from November to April and then incorporating it with the soil. Subsequent management is the same as that described under "modified clean culture."

(d) **Winter cover crop,—legume.** Crops of yellow annual Sweet Clover, *Melilotus indica,* are grown during the period from

November to March and then incorporated with the soil by disking. After this, "modified clean culture" is given.

(e) **Summer cover crops,—legume.** Crops of cowpeas are grown during the period from May to August, inclusive; followed by "modified clean culture."

(f) **Intermittent sod—legume and culture.** Alfalfa and sweet clover were allowed to grow undisturbed for a period of three years and were then incorporated into the soil. "Modified clean culture" was followed the fourth year.

(g) **Continuous sod,—legume.** The land is kept seeded to alfalfa for an indefinite period. No cultural tillage is given.

(h) **Mulched basin.** Natural grass and weeds are allowed to grow and are cut down with scythes several times each season and used to mulch around trees. No cultural tillage is given.

(i) **Continuous sod,—culture about trees.** Natural grass and weeds are allowed to grow undisturbed except that a small area around the trees is kept hoed free of vegetation. No other cultural tillage is given.

(j) **Continuous sod,—no culture about trees.** Natural grass and weeds are allowed to grow undisturbed. No cultural tillage is given.

Utilization of Plats. A total of twenty 5-tree plats were available for this work, which made it possible to replicate each of the above ten treatments twice. Practical limitations dependent on available irrigation laterals made it necessary to arrange the treatments in two parallel series, Plats C-30 to 39, and D-30 to 39; C-29 and C-40, D-29 and D-40 serving as border plats. The plat arrangement is shown in Figure 1. The treatments are indicated in Table 11.

Duration of Experiment. The experiment was conducted for a period of 4 years, 1925-26 to 1928-29. The work had to be discontinued after the season 1928-29 on account of the fact that by this time the branches of the 8-year-old trees touched in the middle of the rows. This condition made it impractical to grow cover crops as originally planned.

Interpretation of Results

The results have been analyzed by the application of "Student's" Method on the basis of comparing adjacent plats. This does not make it possible to compare "Modified Clean Culture," for instance, directly with other treatments not adjacent. However, the comparative value of any particular plat may be determined by comparison with adjacent plats on both sides, and these in turn may be compared with plats farther removed.

Table 11. Influence of cultivation, cover crops and mulches on yield of grapefruit trees, 1925-29

Treatment	Plat No.	Mean yield per tree*				4-yr. mean gain or loss over preceding plats 100-lb. boxes	Odds**
		1925-26† 100-lb. boxes	1926-27 100-lb. boxes	1927-28 100-lb. boxes	1928-29‡ 100-lb. boxes		
Modified clean culture	C 30	0.6	1.9	4.7	2.2		
	D 30	0.7	1.6	3.9	1.4		
Modified clean culture, 6-inch plowing	C 31	0.5	1.3	5.4	1.9	—0.03	1:1 Preceding better than this treatment
	D 31	0.7	1.2	4.5	1.5		
Winter cover crop, non-legume	C 32	0.4	2.9	4.4	2.1	+0.23	2:1 This treatment better than preceding
	D 32	0.6	2.3	3.7	1.9		
Winter cover crop, legume	C 33	0.7	3.2	5.9	2.5	+0.4	87:1 This treatment better than preceding
	D 33	0.4	2.3	4.7	2.3		
Summer cover crop, legume	C 34	0.6	3.2	5.3	2.3	—0.1	4:1 Preceding better than this treatment
	D 34	0.4	3.0	3.9	2.2		
Intermittent sod, legume and culture	C 35	0.3	3.0	5.0	2.6	—0.2	11:1 Preceding better than this treatment
	D 35	0.4	2.0	3.8	2.3		
Continuous sod, legume	C 36	0.6	2.7	4.7	2.7	+0.1	2:1 This treatment better than preceding
	D 36	0.2	1.8	4.2	3.4		
Mulched basin	C 37	0.5	3.1	5.2	2.3	+0.1	1:1 This treatment better than preceding
	D 37	0.4	2.7	4.4	2.2		
Continuous natural sod, culture about trees	C 38	0.3	2.5	3.8	0.4	—0.8	70:1 Preceding better than this treatment
	D 38	0.4	2.9	3.7	0.3		
Continuous natural sod, no culture around trees	C 39	0.6	1.6	4.8	0.7	+0.1	2:1 This treatment better than preceding
	D 39	0.6	1.8	4.0	0.7		

*Based on 5-tree plats; similar results are secured when 1-tree plats are utilized.
†Fruit damaged by low temperature.
‡Yields were reduced this season by excessive scale injury.
**Odds that the difference in yields of treated over untreated plats (checks) is not due to chance variation. Odds as high as 30 to 1 or higher are considered as an indication that the two differential treatments have given different yields as a result of the treatment and not as a result of chance variations.

It will be noted, by referring to Table 11, that on the basis of a 4-year-average loss of 0.03 box, or 3 pounds, per tree, the odds are 1:1 that "Modified Clean Culture with 6-inch Plowing" has caused a lesser yield than "Modified Clean Culture." Since odds of 30:1 are considered on the border line of significance, we conclude that there is no significant difference, and that nothing has been gained or lost by the additional 6-inch plowing.

Similarly, the 4-year-average gain of 0.2 box per tree in favor of "Winter Cover Crop,—Non-legume" as compared with "Modified Clean Culture with 6-inch Plowing" shows odds of only 2:1 that this gain is due to the treatment and not to chance variation. Clearly the gain is not significant.

When, however, "Winter Cover Crop,—Legume" is contrasted with "Winter Cover Crop,—Non-legume," the 4-year-average gain of 0.4 box per tree in favor of the first treatment is shown to be significant. The odds are 87:1 that this treatment has caused consistent gains over a 4-year period.

The 4-year-average differences, gains or losses as the case may be, between "Summer Cover Crop,—legume" and "Winter Cover Crop,—legume," between "Intermittent sod—legume and culture" and "Summer Cover Crop,—legume," between "Continuous sod, —legume" and "Intermittent sod—legume and culture," and between "Mulched Basin" and "Continuous sod,—legume" are apparently not significant, since on the basis of comparison of adjacent plats the odds that these differences were due to the treatments received and not to chance range from 1:1 to 11:1. We conclude therefore that these five types of treatment have given about the same responses as far as yields are concerned during the 4 years covered by the experiment. Further experiments are necessary over a longer period of years to determine the relative importance of the various treatments which have given the most favorable responses so far.

When the "Mulched basin" system is compared with "Continuous natural sod,—culture about trees," there is an apparent annual average loss of 0.8 box per tree as a result of the latter treatment. The odds are 70:1, and therefore significant that this system of sod culture was responsible for the loss.

No significant difference was revealed between the two methods of sod culture: the one with culture about trees, and the other without culture about trees. The odds are only 2:1 that the latter is better than the former.

Application of Results. The four years' results indicate that better yield responses, a gain of approximately 0.4 box per tree, were obtained in grapefruit culture by methods of seasonal or continuous cover cropping with legumes, or a system of mulching, than were secured by the commonly used method of "Modified clean culture," or systems of continuous sod culture. Although the results are quite conclusive as regards the two groups of cultural practices, the evidence is not conclusive with reference to the relative importance of the treatments which have given most favorable increases in yield. This may be due to the fact (a) that the experiment was conducted on relatively fertile virgin soil and covered a period of only 4 years, and (b) that the trees were only 9 years old at the end of the experiment. It is possible that the natural fertility of the soil made it impossible to reveal differences great enough to be measured under the conditions. With mature trees (10 to 20 years of age) over a similar or longer period of years, the relative values of these outstanding treatments may be obtained.

For the present, it will be safe to recommend a system of seasonal leguminous cover cropping with tillage rather than the customary method of clean cultivation with only sporadic natural cover crops. Deeper plowing, 6 inches once per season, does not seem to be of practical value, when added to the system of "Modified clean culture."

FERTILIZER APPLICATION

It is natural that where large crops are removed from the land annually, even in the case of virginally fertile soils, the plant food will ultimately become exhausted and must be replaced. The question of economical fertilizer application must therefore be considered sooner or later. Consequently, in other citrus-producing areas fertilizer experiments have been carried on for some time. Work carried on in California (39, 40) over a period of year points to the fact that nitrogen is a critical element in citrus-fruit production on the soils utilized. Similar experiments conducted in Florida (7, 31, 41) seem to indicate the advisability of using complete fertilizers.

Plan of Experiment

The present experiment concerning grapefruit fertilization was undertaken with the object of determining (a) the time required for exhausting the natural fertility of the soil to such a point, by cropping with grapefruit, where the application of commercial fertilizers will become profitable, and (b) the grade and amount of fertilizer mixture required to keep productivity at the most profitable point when the time arrives that fertilizer applications are profitable.

Plats Available. Exclusive of border plats, a total of forty 5-tree plats were available for these experiments: A-2 to 11; B-2 to 11; C-2 to 11; and D-2 to 11. The location of the plats with reference to the entire experimental orchard is shown in Figure 1.

Kind of Treatments. A total of 18 different treatments are included in the experiment. The fertilizer formula, 4-8-4 (4 per cent nitrogen; 8 per cent phosphoric acid; and 4 per cent potash), was adopted as the standard grade or formula for the treatments with inorganic fertilizers. Treatments were arranged to test the three fertilizer elements, nitrogen, phosphoric acid, and potash (a) in combination as a so-called complete fertilizer (N-P-K); (b) in pairs (two fertilizer elements, O-P-K N-O-K, and N-P-O); and (c) alone (one fertilizer element, N-O-O, O-P-O, and O-O-K). In addition to these treatments, phosphoric acid was used in one-half (4-4-4), and potash in double (4-8-8) amounts with full amounts of the other two as required by the standard formula. In one treatment, consisting of nitrogen alone, one-half of the amount was applied in the spring, and the other half in the summer. In one case cottonseed meal was added to the standard treatment (4-8-4) with inorganic chemicals. The following sources of the fertilizer elements were used: (a) nitrogen,—nitrate of soda; (b) phosphoric acid,—superphosphate; and (c) potash,—sulphate of potash, and muriate of potash.

Organic fertilizers (barnyard manure, bone meal, and cottonseed meal), hydrated lime, gypsum, flowers of sulphur, and iron sulphate were applied alone.

The amounts and kind of fertilizers constituting the various treatments are conveniently indicated in the first column of Table 12.

Replication. The relatively large number of treatments, 18 in all, precluded the possibility of much replication. As 11 plats were reserved as checks receiving no treatment, two replications were possible with 11 treatments; this left 7 treatments without replicates. The relatively small number of replications will necessitate carrying on the experiment over a long period of years to make up in part for this deficiency.

Application of Fertilizers. The various treatments have been indicated in actual weight of fertilizer material applied. In order to reduce the possibility of cross feeding to a minimum, the greater part of the amount was applied to the soil between trees in the same row, but small amounts were also applied on the other two sides. No fertilizer was placed on the soil comprising the irrigation borders between plats.

Table 12. Influence of fertilizers on yield of grapefruit trees, 1925-30

Amount and kind of fertilizer, etc., applied, per tree	Plat Nos.	Mean yield per tree* 1925-26† 100-lb. boxes	1926-27 100-lb. boxes	1927-28 100-lb. boxes	1928-29‡ 100-lb. boxes	1929-30 100-lb. boxes	5-yr mean Gain or loss over check; 100-lb. boxes per tree	Odds**
I. Application of complete fertilizers								
2 2/3 lbs. nitrate of soda	C-2..................	1.9	3.0	2.8	3.1	6.8	+0.6	8:1
5 lbs. acid phosphate	C-4 (check)..........	0.3	2.8	3.5	2.1	6.1		
8/10 lb. sulphate of potash	D-10................	0.4	3.3	2.8	3.3	5.0	+0.1	1:1
	D-7 and 11 (checks) ..	0.7	3.3	2.3	3.5	4.8		
2 2/3 lbs. nitrate of soda								
5 lbs. acid phosphate	A-10................	0.2	1.3	1.9	+	3.0	+0.1	1:1
8/10 lb. muriate of potash	A-9 (check)..........	0.3	1.2	1.9	+	2.9	(4-yr. mean)	
2 2/3 lbs. nitrate of soda								
2 1/2 lbs. acid phosphate	C-9..................	0.6	3.3	2.8	2.2	5.2	+0.3	12:1
8/10 lb. sulphate of potash	C-7 and 10 (checks) ..	0.6	2.6	2.8	1.9	2.0		
2 2/3 lbs. nitrate of soda								
5 lbs. acid phosphate	A-5..................	0.8	0.4	1.5	+	3.5	+0.3	4:1
1 6/10 lbs. sulphate of potash	A-4 and 9 (checks)....	0.5	0.9	1.5	+	2.2	(4-yr. mean)	
2 2/3 lbs. nitrate of soda	A-6..................	0.3	0.3	2.2	+	4.0	+0.5	2:1
5 lbs. acid phosphate	A-4 and 9 (checks)....	0.5	0.9	1.5	+	2.2	(4-yr. mean)	
8/10 lb. sulphate of potash	B-11................	0.3	1.4	2.3	0.4	5.7	—0.2	14:1
4 lbs. cottonseed meal	B-9 (check)..........	0.8	1.5	2.7	0.4	5.7		
II. Application of two fertilizer elements								
5 lbs. acid phosphate	C-5..................	0.2	3.6	3.2	3.5	5.4	+0.4	1:1
8/10 lb. sulphate of potash	C-4 and 7 (checks)...	0.4	2.5	3.2	2.1	5.3		
	D-8..................	0.4	2.6	1.6	3.5	3.7	—0.6	40:1
	D-7 and 11 (checks) ..	0.7	3.2	2.3	3.5	4.8		
2 2/3 lbs. nitrate of soda	C-3..................	0.6	2.6	3.0	2.8	5.6	—0.1	1:1
8/10 lb. sulphate of potash	C-4 (check)..........	0.3	2.8	3.5	2.1	6.1		
	D-9..................	0.4	3.4	2.6	4.5	3.7	—0.1	2:1
	D-7 and 11 (checks) ..	0.7	3.3	2.3	3.5	4.3		
2 2/3 lbs. nitrate of soda	D-6..................	1.1	3.5	2.2	3.8	4.9	+0.4	32:1
5 lbs. acid phosphate	D-4 and 7 (checks)...	0.7	2.8	2.3	3.2	4.6		
	C-11................	0.7	3.2	2.7	3.1	4.5	+0.2	3:1
	C-10 (check)..........	0.5	2.6	2.8	1.7	5.4		

III. Application of one fertilizer element

2 2/3 lbs. of nitrate of soda spring and summer	D-3	1.0	2.7	3.4	1.9	5.5	—0.1	1:1
	D-4 (check)	0.3	2.8	3.5	2.1	6.1		
2 2/3 lbs. nitrate of soda	C-8	0.5	3.2	2.6	2.6	4.3	+0.1	2:1
	C-7 and 10 (checks)	0.5	2.4	2.8	1.8	5.0		
5 lbs. acid phosphate	C-6	0.7	3.9	3.2	2.9	6.5	+0.7	35:1
	C-4 and 7 (checks)	0.4	2.5	3.2	2.1	5.3		
	D-2	0.9	3.1	3.2	3.1	5.0	+0.1	2:1
	D-4 (check)	0.3	2.8	3.5	2.1	6.1		
8/10 lb. sulphate of potash	D-5	0.6	4.2	2.5	3.8	4.3	+0.4	3:1
	D-4 (check)	0.8	2.4	2.5	2.9	4.8		
	B-3	0.9	1.7	2.1	1.6	4.8	+0.1	1:1
	B-2 and 5 (checks)	0.8	1.6	2.3	1.5	5.0		

IV. Application of various organic fertilizers

400 lbs. stable manure	A-2	0.5	1.1	1.1	+	3.0	+0.5	5:1
	A-4 (check)	0.7	0.6	1.1	+	1.5		
	B-10	0.4	1.4	2.4	1.0	5.3	—0.1	2:1
	B-9 (check)	0.8	1.5	2.7	0.4	5.7		
10 lbs. bone meal	A-11	1.0	1.2	1.9	+	3.0	—0.7	7:1
	A-9 (check)	0.8	1.5	2.7	0.4	5.7		
	B-4	0.5	1.9	2.5	1.3	4.9	+0.1	4:1
	B-2 and 5 (checks)	0.8	1.6	2.3	1.0	5.0		
7½ lbs. cottonseed meal	A-3	0.6	1.1	1.4	+	1.7	+0.3	11:1
	A-4 (check)	0.7	0.6	1.1	+	1.5		
	B-7	0.7	1.6	2.9	0.6	5.9	+0.1	5:1
		0.7	1.5	2.5	0.9	5.3		

V. Application of lime and other chemicals

12 lbs. hydrated lime	B-6	0.8	1.9	3.8	0.7	6.3	+0.5	20:1
	B-5 and 9 (checks)	0.7	1.5	2.5	0.7	5.3		
12 lbs. Gypsum	B-8	.06	1.3	2.8	0.6	5.7	+0.1	2:1
	B-5 and 9 (checks)	0.7	1.5	2.5	0.9	5.3		
1½ lbs. flowers of sulphur	A-7	0.7	0.9	2.0	+	3.5	+0.2	4:1
	A-9 (check)	0.3	1.2	1.9	+	2.9		
1½ lbs. iron sulphate	A-8	†	0.7	2.4	+	4.6	+0.5	3:1
	A-9 (check)	†	1.2	1.9	+	2.9		

*On basis of 5-tree plats; similar results are secured when 1-tree plats are utilized.
†Yields affected by low temperature.
‡Plats omitted due to excessive dust and scale injury.
**Odds that the difference in yield of treated over untreated plats (checks) is not due to chance variations. Odds as high as 30 to 1 or higher are considered as an indication that the two differential treatments have given different yields as a result of the treatments and not as a result of chance variations.

Method of Interpreting Results

It has been emphasized in the discussion of cultivation and cover cropping that in an experiment with relatively young trees (4 to 10 years old) grown on fertile virgin soil, it may be possible to show only the marked differences over such a comparatively short period of 5 years. The experiment must be continued long enough to include also the behavior of mature grapefruit trees (10 years or older). The analysis of the 5-year data, however, will shed some light on the degree of natural fertility of the soil, which is one of the purposes for conducting the experiment. The second enquiry regarding the grade and amount of fertilizers to apply will become of importance only when nutrient deficiencies become apparent. The interpretation of the results at the end of 5 years, in the case of young trees which were 4 years old at the beginning of the experiment and are now 10 years old, under the conditions of the experiment must be approached with due respect for these facts.

Yields without Fertilizer Application. Seasonal variations in yields are quite marked, as would be expected in the case of developing trees. The trees, four years of age, at the beginning of the continuity experiment as shown in Tables 9 and 10, averaged one 100-pound box of fruit per tree. During the following years seasonal mean yields per tree were: 1925-26, 0.8; 1926-27, 1.5; 1927-28, 3.1; 1928-29, 1.8; and 1929-30, 5.1 boxes. These yields were secured without the use of fertilizer. It will be noted that when the trees in this experiment had attained the age of 10 years the per tree yield was comparable to that secured from well-cared for commercial orchards of similar age, approximately 4.0 100-pound boxes.

Use of "Student's Method. The results have been interpreted according to "Student's" method, the contrasted pairs consisting of a treated plat and a mean or average value arrived at by considering the nearest check plats on both sides of the treated plat. Where this procedure was not possible, the nearest check plat alone was utilized as the other member of the pair. The complete results are presented in Table 12.

Application of Complete Fertilizers. As shown in Table 12, a complete fertilizer composed of 2.6 pounds of nitrate of soda, 5 pounds of acid phosphate, and 0.8 pound of sulphate of potash gave indicated increases of 0.6 and 0.1 box per tree over a 5-year period. On the basis of the consistency of these increases, the odds, according to "Student's" tables, range from 1:1 to 8:1 that these indicated differences are consistent and therefore significant. In the light of the results from the continuity experiment, where no fertilizer was applied, and the yields are apparently normal as judged by comparison with yields from commercial orchards of the same age, such results as secured by the application of a complete fertilizer would seem to indicate that soil fertility has not as yet become a limiting factor under the conditions of the experiment.

In the case of all the remaining treatments with complete fertilizers as shown in Table 12, similar results have been secured so far. The odds range from 1:1 to 14:1 that such treatments have caused increases or losses as the case may be, and are therefore, not significant.

Application of Two Fertilizer Elements. When two fertilizer elements are applied, as shown in Table 12, the indicated gains or losses due to the treatments, over a 5-year period, are apparently not significant. Two exceptions appear. A loss of 0.6 box per tree in the case of a treatment with 5 pounds of acid phosphate and 0.8 pound of sulphate of potash with odds of 40:1 is counterbalanced by an indicated gain of 0.4 box in another similar treatment with odds of 1:1 in another part of the orchard. Similar contradictory results were secured for the treatment of two plats with 2⅔ pounds of nitrate of soda and 5 pounds of acid phosphate.

Application of One Fertilizer Element. As would be expected from the results discussed thus far, the gains or losses indicated as associated with the treatment with one fertilizer element are apparent rather than real. The odds range from 1:1 to 3:1 that the differences indicated are due to the treatments, excepting in one instance. When 5 pounds of acid phosphate was applied in one case the indicated gain was 0.7 box, with odds of 35:1, but another identical treatment in another part of the orchard gave an indicated increase of 0.1 box per tree with odds of only 2:1 that the difference is due to the treatment and not to chance variation.

Organic Fertilizers, Lime and Other Chemicals. When different plats were treated at the rate of 400 pounds of stable manure, 10 pounds of bone meal, 7½ pounds of cottonseed meal, 12 pounds of hydrated lime, 12 pounds of gypsum, 1½ pounds of flowers of sulphur, and 1½ pounds of iron sulphate per tree in each case, the odds that increases or decreases indicated are significant range from 3:1 to 20:1. In all except one case, the odds are 11:1 or below that the differences are due to the treatments and not to chance variation. When hydrated lime was applied at the rate of 12 pounds per tree an indicated mean anuual increase of 0.5 box per tree is shown, and the odds are 20:1 that this difference is significant, but in the absence of a replicate, the results must be observed over a longer period before any reliance can be placed on the odds approaching 30:1.

Discussion of Results. The results secured over a five-year period with fertilizer treatments seem to show that on the basis of the application of "Student's" method, increases or decreases indicated are not significant. Several explanations are possible: (a) soil fertility may not as yet be a limiting factor in this orchard; (b) variation in yields due to differences in soil, plant materials, etc., may be important; (c) the differences caused by the treatments may not be great enough to be revealed by the technic of analysis used; or (d) cross feeding may occur.

In view of the fact that consistent results were secured by the application of "Student's" method in the interpretation of data secured with varying treatments in the cultivation, cover cropping, and mulching experiment, it would appear that the method of analysis used is adequate, and that cross feeding has not been an important factor up to the present.

Although there was a rather great variation in yields over the entire orchard at the beginning of the experiment as shown in Table 8, the yields of the continuity experiment, shown in Tables 9 and 10, indicate that this variation is becoming generally less and less as the orchard reaches maturity. The elimination of yields from abnormal trees, and the comparison of plats which are adjacent or in close proximity also has the tendency to reduce plat variation from such causes as differences in soil fertility, injury from pests, etc., to the minimum.

It appears, therefore, that the inconsistent results from the application of fertilizers under the conditions of the experiment, up to the present, are due to the favorable virginal fertility of the soil. That the fertilizer elements applied under the experimental conditions were apparently not limiting factors up to the present time is borne out by the yields indicated in the continuity experiment as pointed out above. Although these trees received no fertilizer applications, their development and yields appear normal.

Application of Results. The results from the fertilizer experiments thus far seem to indicate that the Valley citrus grower is favorably situated as regards natural soil fertility. These results are in essential harmony with the practice of not utilizing fertilizers until the trees reach bearing age.

The results, however, should not be interpreted as meaning that fertilizers should be withheld after the trees reach bearing age since moderate applications along with other orchard practices throughout the development and maintenance of the orchard will tend to keep the original fertility of the soil unimpaired.

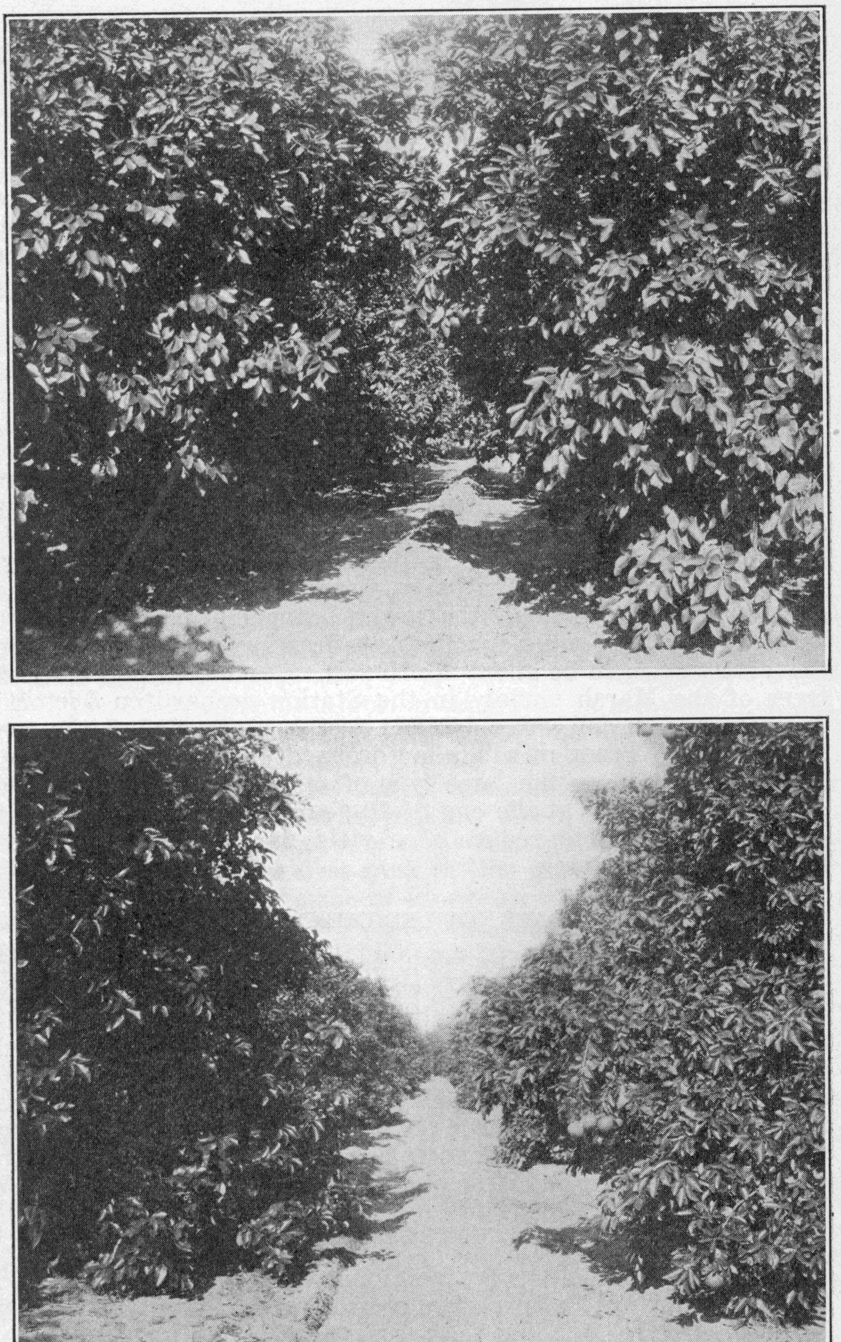

Figure 2. Spacing of grapefruit trees. Upper—10-year Marsh trees spaced 21x21 ft., Weslaco Station; lower—10-year Marsh trees spaced 30x30 ft., Donna, Texas.

SPACING GRAPEFRUIT TREES

In laying out the grapefruit orchard one should allow sufficient space between the trees to facilitate such necessary orchard practices as cultivation, cover cropping, orchard heating, pest control, fruit harvesting, and the maintenance of irrigation borders. Planting distances will depend in the main upon the growth habits of the variety and root-stock, the fertility of the soil, and the amount of irrigation water available, or the amount of rainfall. Although grapefruit trees planted relatively closer together are better protected from wind and frost, close spacing has the effect of crowding out the lower fruiting branches.

The spacing distances formerly used in the Valley, 21x21 feet, as used in California (42), are apparently not suited to local conditions of high soil fertility and favorable climatic factors for growth. As a general rule grapefruit trees grow vigorously in the Lower Rio Grande Valley, and after 8 years the branches of adjacent trees spaced 21x21 feet, usually touch. This interferes seriously with cultivation and other orchard practices, and as has been pointed out, the lower branches of the trees are unduly shaded. Proper spacing distances for grapefruit trees in the Valley seem to be about 25x25 feet. As shown in Figure 2, trees of the Marsh variety in the Station orchard on Victoria fine sandy loam soil, spaced 21x21 feet, are crowded at the end of 10 years. Trees in a similar orchard of the Marsh variety at Donna, Texas, on the same type of soil, spaced 30x30 feet, do not show crowding at the end of 10 years. However, this wide spacing will tend to reduce acre yield during the first six or eight years of bearing.

ACKNOWLEDGMENTS

The experiments dealing with the various factors that enter into citrus production in the Lower Rio Grande Valley, including standardization of varieties, citrus root-stocks, fertilizer application, use of tillage, cover crops and mulches, etc., were initiated by W. H. Friend and A. T. Potts in 1924. Experiments on quality in citrus were initiated by H. P. Traub and W. H. Friend in 1928. Thanks are due Dr. G. S. Fraps for advice in planning the fertilizer experiments and for assistance in connection with the analytical work on citrus quality.

CONCLUSIONS

1. The annual citrus-fruit shipments from the Lower Rio Grande Valley of Texas reached approximately 4000 carloads by 1929-30.

2. More than 5,000,000 citrus trees were growing in orchard

form in the Lower Rio Grande Valley as of July 1, 1929; of these, approximately 75 per cent were grapefruit, 13 per cent of which were 5 years of age or older.

3. On the basis of adaptability to local conditions, physical character of the whole fruit, and quality of juice, the relative merits of various types of citrus fruits have been studied during the period from 1924 to 1930.

4. The Marsh grapefruit and Thompson, a pink-fleshed bud-mutation of Marsh, are recommended for general planting in the Valley. These varieties are desirable because of their relative "seedlessness" and superior quality of juice.

5. The desired tartness in sweet oranges as grown under Valley conditions seems to be present in late varieties like Valencia; early varieties like Parson Brown are apparently lacking in this respect. Of the early varieties, Hamlin is recommended for general planting on account of its relative "seedlessness" and excellent quality. However, this variety lacks the qualities desirable in a good "shipping" orange. Of the late varieties, Valencia is recommended as the standard. This variety possesses excellent "shipping" quality and the desired tartness of juice.

6. The Clementine or Algerian tangerine is recommended as the most desirable variety in this group, because of its early maturity and superior quality.

7. Ordinary commercial forms of lemons are too tender to frost to be profitable in this region. From the standpoint of general adaptability, especially frost resistance, a special form, the Meyer lemon, takes first rank in this group of citrus fruits.

8. The commercial forms of limes are too tender to frost to be profitable in this region. A special form, Rangpur lime, although quite hardy to cold, is lacking in quality.

9. The kumquat is one of the hardiest forms of citrus grown in the Valley and is well adapted to local conditions.

10. The following citrus root-stocks are recommended for the various types: (a) grapefruit, sweet orange, tangerine, and lime on sour orange; (b) Satsuma orange on Rusk Citrange; (c) Meyer lemon on its own roots; (d) Kumquat on rough lemon or Rusk Citrange.

11. Four years' results with cultivation, cover crops, and mulches in grapefruit culture indicate that better yield responses, an annual gain of approximately 0.4 box per tree, were obtained by the use of leguminous cover crops and by a system of mulching than were secured by the commonly used method of "modified clean culture," or non-leguminous cover cropping.

12. Five years' results with differential fertilizer treatments in grapefruit culture indicate that the materials and amounts used have not produced significant increases in yield.

13. A spacing distance of 25x25 feet is apparently more desirable for grapefruit in the Lower Rio Grande Valley than a closer spacing. The 21x21-foot spacing used in the early days of the industry is too close for this region.

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