GROWTH AND MATURITY CHANGES IN ARIZONA LEMONS DURING THE HARVEST PERIOD

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Robert J. Barr

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SIGNED: Robert H. Baas

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Robert H. Hilgeman
ROBERT H. HILGEMAN
Horticulturist

May 14, 1965
Date

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ABSTRACT

Lemon growth and maturity changes were studied in two areas of Arizona at bimonthly intervals during the summer and fall of 1959. Fruit volume increased 66 percent between September 15 and December 15 in Yuma and the Salt River Valley. The percentage of juice by weight reached a maximum of 50 percent in December at Yuma and 51 percent in late October in the Salt River Valley. At Yuma the citric acid percentage of the juice increased to 5.25 percent on November 3. In the Salt River Valley a maximum of 6.19 percent occurred on October 27. To obtain the maximum amount of citric acid per acre, the fruit should be harvested in late November or early December at Yuma and during December in the Salt River Valley. However, since harvest costs increase as the fruit becomes larger, there is little change in income per acre after November 30 at Yuma and after October 31 in the Salt River Valley.

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INTRODUCTION

In Arizona the commercial growing of lemons, Citrus limon (Linn.) Burm. f., is limited principally to the warmer parts of the Salt River Valley near Phoenix and the mesa south of Yuma. The total lemon acreage for the state in 1960 was about 7,300 acres of which 5,800 acres were at Yuma where the acreage has expanded rapidly since 1951 when only about 200 acres were present.

An important factor contributing to this development is the expanding market for lemon fruit by-products such as lemonade, lemon oil, lemon concentrate, and citric acid. In 1959 sixty percent of the Arizona lemon crop was used for such products. Demand for fresh fruit has remained constant.

Under Arizona climatic conditions only one crop of fruit is set from the spring bloom which is harvested between September and December. The only legal requirement determining the time of harvest is that the fruit for the fresh fruit market must contain thirty percent juice by volume. For the fresh fruit market a high grade fruit of uniform size is desirable. The present method of harvesting for fresh fruit employs picking the larger fruit one or two times in September and October with a final harvest of all sizes in late November or December. The fruit is large enough to pick and easily meets the

legal requirement by mid-September in the Salt River Valley and two weeks earlier at Yuma. After the best fruit has been selected for sale as fresh fruit, the remainder is used for by-products. The value of fruit for by-products is based on the citric acid content. As existing trees become larger and production increases, a higher percentage of the crop will be used for by-products. This creates new harvest problems. The emphasis will change from growing high quality fruit to be sold as fresh fruit to production of the maximum amount of citric acid per acre.

The purpose of the present study is to determine a time to harvest for the maximum yield of citric acid.

LITERATURE REVIEW

Hilgeman and Pfenninger (1) showed that in 1957 five lemon groves in the Salt River Valley attained the legal harvest requirement prior to the third week in September. In late October the fruit developed the highest citric acid percentage and the greatest number of pounds of citric acid per ton of fruit. Hilgeman and Everling (2), using a different sampling method, found that similar changes occurred during the 1958 season with one major exception. The highest yield of citric acid per ton of fruit occurring late in October remained near this level until the middle of December. Since fruit growth continued into December, the maximum amount of citric acid per acre was not attained until December.

The rootstock influence on citric acid production is reported by Hodgson and Eggers (5). Fruit produced on lemon trees budded on sour orange rootstock contained about ten percent more acid than those budded on Rough lemon rootstock. Sinclair (8) reports an even greater difference in the acid of Valencia oranges between sour orange and Rough lemon rootstocks.

A study by Rygg and Harvey (7) shows the Eureka lemon to be higher in juice content and lower in acid percentage than the Lisbon variety.

Differences in the constituents of grapefruit from the Salt River Valley and Yuma were noted by Hilgeman (4). The percentage of acid in the juice of Yuma fruit was up to 15% less than in Salt River

Valley fruit. The percentage of soluble solids was also lower at Yuma, but the maximum difference between the two areas was about 5%.

Hilgeman and Everling (3) show that higher than average temperatures and precipitation during October and November are related to increases in the growth rate of lemon fruit.

METHODS AND MATERIALS

To study growth and maturity changes six groves on the Yuma Mesa and five groves in the Salt River Valley were selected during the summer of 1959. The six groves at Yuma were: (1) Citrus Experiment Station (Block 26), Lisbon variety; (2) Coastaluck (west of vineyard), Lisbon variety; (3) Evans (southeast block), Lisbon variety; (4) Harding, Eureka variety; (5) McMillan, Lisbon variety; (6) Waldrip (bordering Fourth Avenue), Villafranca variety. All trees were growing on Rough lemon rootstock and varied in age from five to eight years. The soil in this area is Superstition Sand which is very deep and has a low water holding capacity.

The five groves in the Salt River Valley were: (1) Arrowhead Ranch (two areas in the block north of the farm buildings), Villafranca variety, Rough lemon rootstock; (2) Burgher (south block of large trees), Eureka variety, sour orange rootstock; (3) Mehren (Block 23), Eureka variety, sour orange rootstock; (4) Tyler (south of the farm buildings), Eureka variety, sour orange rootstock; (5) Citrus Experiment Station (Block D, old trees), Eureka variety, sweet orange rootstock. Generally speaking, the soils in these groves are sandy loam types underlaid with caliche and have a moderately high water holding capacity.

In each grove five typical trees were selected. These were at least two rows from the edge of the field and in different irrigation rows. Usually, alternate trees were selected on a line from a corner to the center of the grove. The fruit used to measure growth were tagged, and measurements were begun in June at Yuma and in July or September in the Salt River Valley. Large, medium, and small size classifications were established in five Yuma groves and in one Salt River Valley grove. The large size was omitted in four Salt River Valley groves and in one Yuma grove because the fruit size was relatively small. Each tree had two tagged fruit of each size classification making a total of ten measured fruit of each size per grove. Size classifications were determined in most cases after measuring about 100 fruit selected at random from the five trees. The mean of these measurements was the size of the medium class and the large and small fruit represented the average size of the fruit approximately 35 percent larger and smaller than the mean. Fruits were selected at a height between three and six feet above the ground on all sides of the tree. Exposed fruits, particularly those on the south side of the trees, were excluded as were fruits on weak limbs.

Fruit growth measurements were taken before noon at two or three week intervals. A steel tape was wrapped around the fruit at its greatest circumference and read to the nearest one-half millimeter. This value was converted to volume using the table of Taylor and Furr (6).

Fruit samples were taken in September and every two or three weeks thereafter through December. Each sample consisted of 25 fruit

at different exposures around the five trees. The sampled fruit corresponded in size to the mean for the measured fruit in each size classification on the date sampled. Sunburned or otherwise damaged fruit were excluded.

The fruit was weighed and the volume obtained by displacement of water on the day of harvest. For verification this procedure was repeated for the Yuma samples after they were transported in moisture proof bags to the Salt River Valley Citrus Experiment Station at Tempe. Analyses for juice, acid, solids, specific gravity, and hydrogen ion concentration were completed in most cases within 48 hours after harvesting. The fruit was refrigerated in moisture tight bags at 45° F. during the interval between harvesting and analyzing.

After obtaining the sample weight and volume, the fruit was cut transversely at the widest diameter. Using a caliper, peel thickness was measured to the nearest one-tenth of a millimeter at an average point on the transverse section of each fruit. The juice and pulp were then removed using a Sunkist Senior Extractor equipped with a vibrating shaker. Enough pressure was applied to the fruit to remove the juice and pulp without damaging the rag or peel which were weighed together and recorded. Seeds were retained by the shaker and discarded. The juice was separated from the pulp by filtering through two thicknesses of standard mesh cheese cloth. The material remaining in the cloth was squeezed by hand to remove most of the juice. Juice volume and pulp weight were recorded. The volume measurement was made after the air, which was incorporated with the juice during the juicing

operation, had escaped. An Abbe refractometer was used to measure soluble solids in the juice sample. The solids were recorded as equivalent sucrose. No correction was made for the effect of citric acid or other constituents on the refractive index. A pH reading of this sample was taken with a Beckman meter. The amount of acid was determined by titrating a 0.159 Normal sodium hydroxide solution into a mixture of 10 cc. of juice and 25 cc. of distilled water until a pH of 8.5 was reached. This was recorded as the percent total titratable acid calculated as citric.

Experiment I: Arrowhead Ranch Study

In addition to providing information on seasonal variations in fruit, the Arrowhead Ranch grove was selected for a special study consisting of two parts: (1) To define the effect of a mid-season partial crop harvest on the growth and development of the remaining fruit and (2) to determine variations between two areas of a large grove, and between individual trees of each area.

The Arrowhead Ranch has a forty acre lemon grove of the Villafranca variety on Rough lemon rootstock. The trees were planted at the same time and subjected to the same cultural practices. The soil is a uniform silt loam throughout the grove.

One area on the east side and one on the west side of the grove were selected. In each area ten paired trees were chosen and three fruit of each of three sizes were tagged on each tree. The selection of tagged fruit sizes and the method of sampling and measurement was the same as described previously.

On October 13 approximately one-half of the fruit were harvested from one tree of each pair. Between November 16 and 25 a twenty or twenty-five fruit sample of each size was collected from each tree. This sample was used to provide information on variations between trees.

RESULTS AND DISCUSSION

Observations at the Yuma and Salt River Valley Areas

Growth of fruit: The growth of fruit is shown by Tables 1 and 2. Fruit increased in size uniformly at Yuma and the Salt River Valley during the harvest period.

Large, medium, and small Yuma fruit increased in volume 74, 75, and 80 percent respectively between September 11 and December 15. The Evans, Coastaluck, and Citrus Experiment Station groves had a greater average increase in the small fruit than in other sizes. The other groves had similar values for all fruit sizes. The range between groves was 78 to 82 percent with the exception of the Waldrip grove which had an average increase of 63 percent.

The average volume increase for medium and small Salt River Valley fruit was 70 and 68 percent respectively during the September 21 to December 21 period. There were no great differences in the growth rate between fruit sizes except in the Burgher grove where medium sized fruit increased 60 percent and small fruit increased 65 percent in volume between September 21 and December 21.

From the above growth data it is possible to predict the growth of the fruit during the season. If the September 15 volume is taken as 100 cubic centimeters, the predicted semi-monthly values for Yuma would be: September 15, 100; September 30, 113; October 15, 126; October 31, 138; November 15, 151; November 30, 164; and December 15, 169. In the Salt River Valley seasonal increases could be

TABLE 1

Yuma Mesa; Enlargement of Fruit Measured in Cubic Centimeters

Date	Size	Grove: Harding	Coastaluck	Evans	McMillan	Waldrip	Citrus Expt. Station	Mean
Sept. 9	Large	124	145	141		172	126	142
	Medium	89	106	108	116	126	92	106
	Small	67	73	78	85	77	76	76
	Mean	93	108	109	101	125	98	108
Sept. 29	Large	143	171	169		189	150	164
	Medium	103	120	129	136	140	108	123
	Small	78	88	95	101	85	91	90
	Mean	108	126	131	119	138	116	126
Oct. 20	Large	164	192	193		217	169	187
	Medium	119	136	148	156	160	123	140
	Small	91	101	109	117	98	103	103
	Mean	125	143	150	137	158	132	143
Nov. 3	Large	176	208	206		231	184	201
	Medium	128	148	157	169	171	135	151
	Small	97	109	117	127	106	114	112
	Mean	134	155	160	148	169	144	155
Dec. 1	Large	205	240	237		264	208	231
	Medium	150	171	180	196	195	151	174
	Small	113	127	135	147	120	131	129
	Mean	156	179	184	172	193	163	178
Dec. 15	Large	220	257	254		280	225	247
	Medium	158	181	195	208	206	161	185
	Small	119	135	145	155	126	141	137
	Mean	166	191	198	182	204	176	190
Seasonal increase	Large	78%	77%	80%		63%	79%	74%
	Medium	78%	71%	81%	80%	63%	75%	75%
	Small	78%	85%	86%	82%	64%	86%	80%
	Mean	78%	78%	82%	81%	63%	80%	76%

TABLE 2

Salt River Valley; Enlargement of Fruit Measured in Cubic Centimeters

Date	Size	Grove: Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher[1]	Mean[2]
Sept. 21	Medium	102	91	103	122	119	105
	Small	80	62	73	67	79	72
	Mean	91	77	88	95	99	89
Oct. 6	Medium	114	104	114	139	139	118
	Small	90	71	81	76	93	82
	Mean	102	88	98	108	116	100
Oct. 27	Medium	132	115	129	162	156	135
	Small	104	78	92	89	106	94
	Mean	118	97	111	126	131	115
Nov. 11	Medium	142	124	141	173	168	145
	Small	113	84	100	93	115	101
	Mean	128	104	121	133	142	123
Dec. 9	Medium	166	148	158	200	173	168
	Small	131	100	111	109	120	114
	Mean	149	124	135	155	147	141
Dec. 21	Medium	171	156	171	214	188	178
	Small	135	106	120	115	130	121
	Mean	153	131	146	165	159	150
Seasonal increase	Medium	69%	71%	66%	75%	58%	70%
	Small	68%	71%	64%	72%	65%	68%
	Mean	68%	71%	65%	74%	61%	69%

[1]Medium value is estimated by averaging large and small values.

[2]Burgher values excluded.

predicted as follows: September 15, 100; September 30, 112; October 15, 124; October 31, 136; November 15, 147; November 30, 158; and December 15, 169. Thus there was a 69 percent increase in both areas from September 15 to December 15.

The uniform summer and fall growth rate of each size category of fruit indicated that the growth rate is determined for an individual fruit early in the season. The combined factors affecting the rate of fruit growth exert an equal influence on all sizes of fruit during the August to December period. The effects of external injury to the fruit induced by sunburn, wind scar, or insect damage were not observed since fruits showing such injury were excluded from this study.

Fruit growth is stopped by periods of freezing temperatures which occur during November and December some years. In the Salt River Valley temperatures during the fall were slightly warmer than normal with only three days below 32 degrees. The fruit volume increase of 69 percent from September 15 to December 15 can be compared to the five year Salt River Valley average of 63 percent reported by Hilgeman and Everling (3). They report uniform growth except during periods of freezing temperatures.

At Yuma the months of November and December were warm with no freezing temperatures.

Percent juice by weight: The percent juice by weight increased during September and October at Yuma and the Salt River Valley as shown by Tables 3 and 4.

TABLE 3

Yuma Mesa; Percentage of Juice by Weight

Date	Size	Grove: Harding	Coastaluck	Evans	McMillan[1]	Waldrip	Citrus Expt. Station	Mean
Sept. 11	Large	38	43	43	43	44	46	43
	Medium	43	42	47	44	43	46	44
	Small	43	43	45	44	45	45	44
	Mean	41	43	45	44	44	46	44
Sept. 30	Large	47	45	48	46	44	48	46
	Medium	48	47	48	46	46	48	47
	Small	46	47	48	47	47	48	47
	Mean	47	46	48	46	46	48	47
Oct. 21	Large	48	46	47	48	46	53	48
	Medium	50	49	48	50	47	54	50
	Small	49	48	49	49	46	53	49
	Mean	49	48	48	49	46	53	49
Nov. 3	Large	48	48	47	47	42	52	47
	Medium	49	47	50	52	46	49	49
	Small	50	48	50	50	46	53	50
	Mean	49	48	49	50	45	51	49
Dec. 2	Large	48	50	47	49	49	52	49
	Medium	51	50	52	50	50	54	51
	Small	50	48	54	49	50	55	51
	Mean	50	49	51	49	50	54	50
Dec. 15	Large	49	47	53	50	47	53	50
	Medium	50	48	51	49	49	51	50
	Small	47	49	52	51	47	51	50
	Mean	49	48	52	50	48	52	50
Seasonal average	Large	46	47	48	47	45	51	47
	Medium	49	47	49	49	47	50	49
	Small	48	47	50	48	47	51	49
	Mean	48	47	49	48	46	51	48

[1]Large value estimated

TABLE 4

Salt River Valley; Percentage of Juice by Weight

Date	Size	Grove: Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher[1]	Mean[2]
Sept. 21	Medium	48	44	45	48	50	46
	Small	47	42	41	46	50	44
	Mean	48	43	43	47	50	45
Oct. 6	Medium	49	45	49	49	47	48
	Small	49	44	49	48	48	48
	Mean	49	45	49	49	48	48
Oct. 27	Medium	51	49	50	52	51	51
	Small	51	49	51	52	51	51
	Mean	51	49	51	52	51	51
Nov. 11	Medium	51	49	50	49	51	50
	Small	51	47	51	53	52	51
	Mean	51	48	51	51	52	51
Dec. 9	Medium	49	48	52	51	52	50
	Small	49	47	51	47	54	49
	Mean	49	48	52	49	53	50
Dec. 21	Medium	49	47	47	50	51	48
	Small	50	48	49	51	52	50
	Mean	50	48	48	51	52	49
Seasonal average	Medium	50	47	49	50	50	49
	Small	50	46	49	50	51	49
	Mean	50	47	49	50	51	49

[1]Medium value is estimated by averaging large and small values.

[2]Burgher values excluded.

Average values at Yuma increased rapidly from 44 percent on September 11 to 49 percent on October 21. During the next five weeks there was relatively little change to 50 percent on December 2. The Citrus Experiment Station grove was consistently higher than the average for each sampling date. The Waldrip grove was below average on October 21 and each date thereafter. There were no consistent differences between other groves sampled nor between sizes.

In the Salt River Valley juice increased from 45 percent on September 21 to 51 percent on October 27 with relatively small decreases during the remainder of the season. The December 21 average was 49 percent. The Mehren grove had consistently lower values than all other sampled groves in the Salt River Valley. The only consistent difference between sizes was at the Burgher grove where the medium sized fruit had less percent juice by weight than small fruit.

Percent juice by volume: Tables 5 and 6 show the changes in percent juice by volume which are similar to the data for percent juice by weight.

Yuma fruit increased from an average of 40 percent on September 11 to 47 percent on December 2. The values for small and medium fruit were similar and greater than for large fruit.

The average for the Salt River Valley fruit increased from 41 percent on September 21 to 47 percent on October 27. This was followed by a gradual decrease to 44 percent on December 21. After October 6 the large fruit in each grove usually had less percent juice than the small fruit.

TABLE 5

Yuma Mesa; Percentage of Juice by Volume

Date	Size	Grove: Harding	Coastaluck	Evans	McMillan[1]	Waldrip	Citrus Expt. Station	Mean
Sept. 11	Large	35	39	39	39	40	42	39
	Medium	40	38	43	40	40	43	41
	Small	40	40	42	41	42	42	41
	Mean	38	39	41	40	41	42	40
Sept. 30	Large	44	42	43	42	41	44	43
	Medium	45	43	44	42	43	45	44
	Small	43	43	45	43	43	46	44
	Mean	44	43	44	42	42	45	44
Oct. 21	Large	43	41	41	42	40	47	42
	Medium	45	43	43	44	42	49	44
	Small	44	43	44	45	42	48	44
	Mean	44	42	43	44	41	48	44
Nov. 3	Large	44	44	42	44	40	47	43
	Medium	46	43	46	45	43	48	45
	Small	48	44	46	47	43	50	46
	Mean	46	44	45	46	42	48	45
Dec. 2	Large	44	47	43	45	44	48	45
	Medium	47	46	48	46	46	50	47
	Small	46	45	50	44	46	51	47
	Mean	46	46	47	45	45	50	47
Dec. 15	Large	44	42	47	44	42	47	44
	Medium	45	43	47	45	45	47	45
	Small	43	45	47	47	43	46	45
	Mean	44	43	47	45	43	47	45
Seasonal average	Large	42	43	43	43	41	46	43
	Medium	45	43	45	44	43	47	44
	Small	44	43	46	45	43	47	45
	Mean	44	43	45	44	42	47	44

[1]Large value estimated.

TABLE 6

Salt River Valley; Percentage of Juice by Volume

Date	Size	Grove: Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher[1]	Mean[2]
Sept. 21	Medium	44	40	41	44	47	42
	Small	44	38	37	39	47	40
	Mean	44	39	39	42	47	41
Oct. 6	Medium	45	41	46	45	43	44
	Small	45	41	46	45	44	44
	Mean	45	41	46	45	44	44
Oct. 27	Medium	45	44	47	47	47	46
	Small	46	45	48	48	47	47
	Mean	46	45	48	48	47	47
Nov. 11	Medium	46	44	46	44	47	45
	Small	46	44	47	48	48	46
	Mean	46	44	47	46	48	46
Dec. 9	Medium	44	40	47	43	48	43
	Small	45	42	47	46	50	45
	Mean	45	41	47	45	49	44
Dec. 21	Medium	44	41	42	45	46	43
	Small	45	42	44	45	48	44
	Mean	45	42	43	45	47	44
Seasonal average	Medium	45	42	45	45	46	44
	Small	45	42	45	45	47	44
	Mean	45	42	45	45	47	44

[1]Medium value is estimated by averaging large and small values.

[2]Burgher values excluded.

Changes in the juice content of the fruit are related to the efficiency of by-product production. The lemon differs from other citrus fruits in that the juice percentage increases during storage. Rygg (7) reports an average juice content of at least 40 percent at the time of harvest for Eureka, Lisbon, and Villafranca varieties grown in desert areas of Arizona and California. He showed that during the first month in storage a 10 percent increase in juice content occurred in each variety. Rygg also relates the high juice content (and thin peel) of desert grown lemons to a short commercial storage life. The fruit in his study became soft and developed a bronze peel color after the third month in storage.

Specific gravity: Changes in specific gravity were small, and no consistent seasonal trends or growth differences appeared during the sampling period as shown by Tables 7 and 8. The relationship to fruit size is evident as the larger fruit usually possessed a very slightly lower specific gravity than the small fruit. The seasonal averages for large, medium, and small Yuma fruit were 0.93, 0,94, and 0.95. The Salt River Valley averages were 0.93 and 0.94 for medium and small fruit.

Peel thickness: Tables 9 and 10 show peel thickness relationships. A gradual average increase in peel thickness occurred throughout the sampling period with all fruit sizes increasing at about the same rate.

At Yuma the large fruit always had at least a 25 percent thicker peel than small fruit. Medium fruit were midway between large

TABLE 7

Yuma Mesa; Specific Gravity of Fruit

Date	Size	Grove: Harding	Coastaluck	Evans	McMillan[1]	Waldrip	Citrus Expt. Station	Mean
Sept. 9	Large	.95	.93	.93	.94	.94	.95	.94
	Medium	.96	.93	.94	.94	.95	.95	.95
	Small	.95	.95	.97	.96	.97	.96	.96
	Mean	.95	.94	.95	.95	.95	.95	.95
Sept. 29	Large	.96	.95	.93	.94	.94	.95	.95
	Medium	.96	.94	.95	.94	.95	.96	.95
	Small	.96	.95	.96	.95	.95	.98	.96
	Mean	.96	.95	.95	.94	.95	.96	.95
Nov. 3	Large	.95	.94	.93	.94	.96	.94	.94
	Medium	.96	.94	.95	.94	.95	.95	.95
	Small	.98	.95	.95	.96	.96	.96	.96
	Mean	.96	.94	.94	.95	.96	.95	.95
Dec. 1	Large	.94	.95	.93	.93	.93	.94	.94
	Medium	.95	.94	.94	.94	.95	.95	.95
	Small	.94	.96	.94	.94	.95	.95	.95
	Mean	.94	.95	.94	.94	.94	.95	.95
Dec. 15	Large	.93	.93	.93	.93	.92	.93	.93
	Medium	.94	.93	.94	.93	.94	.94	.94
	Small	.93	.94	.94	.94	.95	.94	.94
	Mean	.93	.93	.94	.93	.94	.94	.94
Seasonal average	Large	.94	.94	.92	.93	.93	.94	.93
	Medium	.95	.93	.94	.93	.94	.95	.94
	Small	.95	.95	.95	.95	.95	.96	.95
	Mean	.95	.94	.94	.94	.94	.95	.94

[1]Large value estimated.

TABLE 8

Salt River Valley; Specific Gravity of the Fruit

Date	Size	Grove: Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher[1]	Mean[2]
Sept. 21	Medium	.95	.93	.94	.94	.97	.94
	Small	.95	.94	.93		.97	.95
	Mean	.95	.94	.94	.94	.97	.95
Oct. 6	Medium	.93	.93	.96	.93	.95	.94
	Small	.95	.94	.97	.97	.95	.96
	Mean	.94	.94	.97	.95	.95	.95
Oct. 27	Medium	.92	.94	.96	.94	.96	.94
	Small	.94	.95	.96	.95	.97	.95
	Mean	.93	.95	.96	.95	.97	.95
Nov. 11	Medium	.93	.93	.95	.93	.95	.94
	Small	.95	.96	.95	.94	.96	.95
	Mean	.94	.95	.95	.94	.96	.95
Dec. 9	Medium	.92	.91	.94	.92	.94	.92
	Small	.93	.92	.95	.93	.95	.94
	Mean	.93	.92	.95	.93	.95	.93
Dec. 21	Medium	.93	.90	.92	.91	.93	.92
	Small	.93	.91	.93	.92	.94	.93
	Mean	.93	.91	.93	.92	.94	.92
Seasonal average	Medium	.93	.92	.95	.93	.95	.93
	Small	.94	.94	.95	.93	.96	.94
	Mean	.94	.93	.95	.93	.96	.94

[1]Medium value is estimated by averaging large and small values.

[2]Burgher values excluded.

TABLE 9

Yuma Mesa; Peel Thickness Measured in Millimeters

Date	Size	Grove						
		Harding	Coastaluck	Evans	McMillan[1]	Waldrip	Citrus Expt. Station	Mean
Sept. 11	Large	5.1	4.7	5.1	4.8	5.0	4.0	4.8
	Medium	4.1	4.2	4.2	4.2	4.1	3.7	4.1
	Small	3.6	3.7	3.8	3.6	3.7	3.3	3.6
	Mean	4.3	4.2	4.4	4.2	4.3	3.7	4.2
Sept. 30	Large	4.5	4.8	4.9	4.8	5.0	3.8	4.6
	Medium	3.8	4.2	4.5	4.3	4.7	3.4	4.2
	Small	3.5	4.0	3.8	3.2	3.8	3.1	3.6
	Mean	3.9	4.3	4.4	4.1	4.5	3.4	4.1
Oct. 21	Large	4.7	5.5	5.5	5.4	5.7	3.7	5.1
	Medium	4.5	4.6	4.5	4.7	5.1	3.4	4.5
	Small	3.9	4.3	4.2	4.0	4.3	3.2	4.0
	Mean	4.4	4.8	4.7	4.7	5.0	3.4	4.5
Nov. 3	Large	4.3	5.1	5.4	5.1	5.7	4.0	4.9
	Medium	3.8	4.5	4.5	4.5	4.9	3.5	4.3
	Small	3.4	4.0	4.0	3.9	4.0	3.2	3.8
	Mean	3.8	4.5	4.6	4.5	4.9	3.6	4.3
Dec. 2	Large	4.6	4.5	5.4	4.8	5.7	4.1	4.9
	Medium	4.2	4.6	4.6	4.5	4.9	3.6	4.4
	Small	3.9	3.9	3.6	4.2	4.0	3.3	3.8
	Mean	4.2	4.3	4.5	4.5	4.9	3.7	4.4
Dec. 15	Large	5.3	5.7	4.9	4.5	6.0	4.5	5.2
	Medium	4.6	4.9	4.7	4.2	4.7	3.8	4.5
	Small	4.3	4.5	4.0	3.9	4.6	3.6	4.2
	Mean	4.7	5.0	4.5	4.2	5.1	4.0	4.6
Seasonal average	Large	4.8	5.1	5.2	5.0	5.5	4.0	4.9
	Medium	4.2	4.5	4.5	4.4	4.7	3.6	4.3
	Small	3.8	4.1	3.9	3.8	4.1	3.3	3.8
	Mean	4.2	4.5	4.5	4.4	4.8	3.6	4.4

[1]Large value estimated.

TABLE 10

Salt River Valley; Peel Thickness Measured in Millimeters

Date	Size	Grove					
		Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher[1]	Mean[2]
Sept. 21	Medium	3.5	3.5	4.0	3.2	3.5	3.6
	Small	3.3	3.8	3.5	2.7	2.8	3.2
	Mean	3.4	3.7	3.8	3.0	3.2	3.5
Oct. 6	Medium	3.9	4.1	3.8	3.9	4.8	3.9
	Small	3.5	3.7	3.3	3.1	4.0	3.5
	Mean	3.7	3.9	3.6	3.5	4.4	3.7
Oct. 27	Medium	4.4	3.7	3.4	3.8	3.9	3.8
	Small	3.9	3.1	3.4	3.0	3.3	3.3
	Mean	4.2	3.4	3.4	3.4	3.6	3.6
Nov. 11	Medium	4.1	4.3	4.1	4.5	4.5	4.2
	Small	3.9	3.6	3.5	3.2	3.8	3.6
	Mean	4.0	4.0	3.8	3.9	4.2	3.9
Dec. 9	Medium	4.7	4.8	4.1	4.2	4.4	4.5
	Small	4.4	3.9	3.5	3.3	3.7	3.8
	Mean	4.6	4.4	3.8	3.8	4.1	4.2
Dec. 21	Medium	4.7	5.1	4.8	4.1	4.7	4.6
	Small	4.3	4.3	4.1	3.7	4.0	4.1
	Mean	4.5	4.7	4.5	3.9	4.4	4.4
Seasonal average	Medium	4.2	4.3	4.0	4.0	4.3	4.1
	Small	3.9	3.7	3.6	3.2	3.6	3.6
	Mean	4.1	4.0	3.8	3.6	4.0	3.9

[1]Medium value is estimated by averaging large and small values.

[2]Burgher values excluded.

and small values. The average for all Yuma sizes was 4.2 mm. on September 11 and 4.6 mm. on December 15. The Citrus Experiment Station had much thinner peeled fruit than the other Yuma groves and the Waldrip grove had thicker peeled fruit. The peel of the Evans fruit was thicker than average during the earlier part of the season.

The same relationship between fruit size and peel thickness that occurred at Yuma was present in the Salt River Valley. The averages on September 21 and December 21 were 3.5 mm. and 4.4 mm. respectively. The Tyler grove contained thinner peeled fruit than the other Salt River Valley groves while relatively small differences separated the other groves.

In the development of the lemon fruit the peel develops early. The young fruit consists largely of peel but as it grows the percentage of peel decreases during the early part of its development. During the harvest period the peel thickness is increasing but the percentage of peel per volume of fruit is unchanged.

It is desirable to limit the development of peel thickness of fruit grown for juice by-products since the weight contributed by the peel increases the harvest and transportation cost without increasing the value of the fruit. The physical protection given by a thick peel is not so important for by-product fruit and the presence of processing plants close to the growing areas prevents most of the transportation and storage losses associated with thin peeled fruit.

Percent soluble solids: Tables 11 and 12 show that no marked differences in solids existed with respect to fruit size. There was no seasonal change between September and November. In both areas there was

TABLE 11

Yuma Mesa; Percentage of Solids in Extracted Juice

Date	Size	Grove: Harding	Coastaluck	Evans	McMillan[1]	Waldrip	Citrus Expt. Station	Mean
Sept. 11	Large	7.6	7.3	7.7	7.9	7.7	7.8	7.7
	Medium	7.4	7.3	7.9	7.9	7.7	7.9	7.7
	Small	7.4	7.4	8.0	8.1	7.7	7.8	7.7
	Mean	7.5	7.3	7.9	8.0	7.7	7.8	7.7
Sept. 30	Large	7.5	7.5	7.8	7.6	7.6	7.8	7.6
	Medium	7.5	7.5	7.9	7.6	7.5	8.1	7.7
	Small	7.4	7.5	7.9	7.8	7.6	7.8	7.7
	Mean	7.5	7.5	7.9	7.7	7.6	7.9	7.7
Oct. 21	Large	7.3	7.5	8.0	7.7	7.6	7.7	7.6
	Medium	7.3	7.4	8.0	7.8	7.8	7.8	7.7
	Small	7.3	7.3	8.5	7.8	7.8	7.3	7.7
	Mean	7.3	7.4	8.2	7.8	7.8	7.6	7.7
Nov. 3	Large			7.8	7.8	7.8	7.8	7.8
	Medium	7.5	7.4	8.0	7.8	7.6	7.9	7.7
	Small	7.4	7.4	8.0	7.8	7.7	7.9	7.7
	Mean	7.5	7.4	7.9	7.8	7.7	7.9	7.7
Dec. 2	Large	7.1	7.3	7.8	7.8	7.4	7.7	7.5
	Medium	7.3	7.4	7.7	7.8	7.5	7.8	7.6
	Small	7.2	7.4	7.9	7.9	7.5	7.7	7.6
	Mean	7.2	7.4	7.8	7.8	7.5	7.7	7.6
Dec. 15	Large	7.2	7.4	7.6	7.6	7.6	7.7	7.5
	Medium	7.2	7.3	7.7	7.6	7.4	7.7	7.5
	Small	7.1	7.2	7.6	7.6	7.4	7.6	7.4
	Mean	7.2	7.3	7.6	7.6	7.5	7.7	7.5
Seasonal average	Large	7.3	7.4	7.8	7.8	7.6	7.8	7.6
	Medium	7.4	7.4	7.9	7.8	7.6	7.9	7.7
	Small	7.3	7.4	8.0	7.8	7.6	7.7	7.6
	Mean	7.4	7.4	7.9	7.8	7.6	7.8	7.6

[1]Large value estimated.

TABLE 12

Salt River Valley; Percentage of Solids in Extracted Juice

Date	Size	Grove: Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher[1]	Mean[2]
Sept. 21	Medium	8.3	8.4	8.4	8.4	8.6	8.4
	Small	8.4	8.5	8.5	8.7	8.8	8.5
	Mean	8.4	8.5	8.5	8.6	8.7	8.5
Oct. 6	Medium	8.2	8.4	8.3	8.8	9.1	8.4
	Small	8.1	8.5	8.4	8.7	9.1	8.4
	Mean	8.2	8.5	8.4	8.8	9.1	8.4
Oct. 27	Medium	8.3	8.4	8.8	8.6	9.1	8.5
	Small	8.3	8.4	8.6	8.7	9.1	8.5
	Mean	8.3	8.4	8.7	8.7	9.1	8.5
Nov. 11	Medium	8.0	8.3	8.4	8.5	9.1	8.3
	Small	8.2	8.4	8.5	8.6	9.1	8.4
	Mean	8.1	8.4	8.5	8.6	9.1	8.4
Dec. 9	Medium	8.4	8.3	8.7	8.4	9.3	8.5
	Small	8.4	7.9	8.5	8.6	9.3	8.3
	Mean	8.4	8.1	8.6	8.5	9.3	8.4
Dec. 21	Medium	8.1	8.1	8.5	8.4	9.0	8.3
	Small	8.3	7.9	8.3	8.4	9.1	8.2
	Mean	8.2	8.0	8.4	8.4	9.1	8.3
Seasonal average	Medium	8.2	8.3	8.5	8.5	9.1	8.4
	Small	8.3	8.3	8.5	8.6	9.1	8.4
	Mean	8.3	8.3	8.5	8.6	9.1	8.4

[1]Medium value is estimated by averaging large and small values.

[2]Burgher values excluded.

a slight decline in solids in December. There were marked differences in the values between Yuma and the Salt River Valley groves as a whole as well as between groves within each area.

The Yuma seasonal average was 7.6 percent. The Citrus Experiment Station and Evans groves were 0.2 and 0.3 higher than the average and the Harding and Coastaluck groves were 0.2 below the average.

The Salt River Valley samples with an average of 8.4 percent contained about 10 percent more solids than Yuma samples. The Burgher grove was 0.7 higher than the average.

The differences in solids between the Yuma and the Salt River Valley fruit appear to be related to environmental and rootstock factors. The Harding grove, although of the Eureka variety, was actually the lowest in solids of the Yuma groves. It does not appear that the higher values encountered in the Salt River Valley were due to the varietal difference between the two areas.

Hydrogen ion concentration (pH): Data on the hydrogen ion concentration is shown in Tables 13 and 14. The average value for all groves throughout the season was 2.66 at Yuma and 2.63 in the Salt River Valley. During the entire season values ranged from 2.57 to 2.74 in individual tests in all groves. No evidence of seasonal changes nor differences between sizes existed.

TABLE 13

Yuma Mesa; pH of Extracted Juice

Date	Grove						
	Harding	Coastaluck	Evans	McMillan	Waldrip	Citrus Expt. Station	Mean
Sept. 11	2.62	2.68	2.63	2.69	2.74	2.68	2.67
Sept. 30	2.70	2.70	2.67	2.72	2.72	2.71	2.70
Oct. 21	2.65	2.65	2.62	2.64	2.65	2.66	2.65
Nov. 3	2.62	2.63	2.60	2.60	2.63	2.62	2.62
Dec. 2	2.63	2.64	2.60	2.67	2.65	2.62	2.64
Dec. 15	2.69	2.69	2.63	2.62	2.69	2.64	2.66
Seasonal average	2.65	2.67	2.63	2.66	2.68	2.66	2.66

TABLE 14

Salt River Valley; pH of Extracted Juice

Date	Grove					
	Arrowhead	Mehren	Citrus Expt. Station	Tyler	Burgher	Mean
Sept. 21	2.62	2.68	2.70	2.60	2.60	2.64
Oct. 27	2.56	2.66	2.65		2.62	2.63
Nov. 11	2.58	2.62	2.61	2.57	2.60	2.60
Dec. 9	2.62	2.62	2.62	2.60	2.60	2.61
Dec. 21	2.62	2.75	2.64	2.61	2.61	2.65
Seasonal average	2.60	2.67	2.64	2.60	2.61	2.63

Percent acid: Tables 15 and 17 show percent acid relationships at Yuma and in the Salt River Valley. Tables 16 and 18 present the analyses of variance for each area.

Percent acid at Yuma remained at the same level during late September and most of October. Between October 21 and November 3 a significant increase in acid occurred which remained at the same level until December 2. It then decreased rapidly during the first two weeks of December. For at least four weeks the acid remained at the top level of 5.24 percent, considerably less than the maximum Salt River Valley level of 6.19 percent. The small Yuma fruit contained significantly less acid throughout the season except in the Coastaluck grove where no large or consistent differences occurred between fruit sizes. The Evans fruit contained a maximum of 5.72 percent on November 3. Its seasonal average of 5.58 percent was 9 to 15 percent higher than the seasonal average for the other Yuma groves. The Harding grove was low in acid throughout the season. For the Yuma area as a whole, significant differences at the one percent level occurred between sizes, between locations, and between dates of harvest.

In the Salt River Valley the percent acid in the juice increased during September and October. An average peak of 6.19 percent was reached near the end of October followed by a gradual decrease. The only consistent acid differences between fruit size occurred in the Tyler grove where medium fruit had more acid than small fruit, and in the Burgher grove where the reverse was true. For the area as a whole, the acid differences between fruit sizes were not significant. The Burgher grove was much higher, and the Mehren grove much lower in

TABLE 15

Yuma Mesa; Percentage of Acid in Extracted Juice

Date	Size	Grove: Harding	Coastaluck	Evans	McMillan[1]	Waldrip	Citrus Expt. Station	Mean[2]
Sept. 11	Large	5.07	5.13	5.58		4.95	5.08	5.16
	Medium	4.78	4.95	5.60	5.08	4.78	4.78	4.98
	Small	4.67	5.00	5.50	5.03	4.55	4.63	4.87
	Mean	4.84	5.03	5.56	5.06	4.76	4.83	5.00
Sept. 30	Large	5.03	5.10	5.70		5.00	5.03	5.17
	Medium	4.93	5.05	5.68	5.30	5.03	4.93	5.12
	Small	4.90	5.10	5.50	4.98	4.90	4.83	5.05
	Mean	4.95	5.08	5.63	5.14	4.98	4.93	5.11
Oct. 21	Large	5.00	4.98	5.55		5.05	5.23	5.16
	Medium	4.75	5.00	5.48	5.28	4.95	4.95	5.03
	Small	4.75	4.95	5.35	4.95	4.93	4.85	4.97
	Mean	4.83	4.98	5.46	5.12	4.98	5.01	5.05
Nov. 3	Large	4.94	5.06	5.73		5.40	5.40	5.31
	Medium	5.15	5.00	5.70	5.40	5.05	5.35	5.25
	Small	4.83	5.10	5.73	5.35	4.95	5.20	5.16
	Mean	4.97	5.05	5.72	5.38	5.13	5.32	5.24
Dec. 2	Large	4.78	5.23	5.65		5.28	5.50	5.29
	Medium	4.98	5.18	5.70	5.13	5.45	5.29	
	Small	4.78	5.15	5.70	5.13	5.00	5.23	5.17
	Mean	4.85	5.19	5.68	5.13	5.14	5.39	5.25
Dec. 15	Large	4.78	4.83	5.38		4.75	5.20	4.99
	Medium	4.60	4.85	5.48	5.20	4.70	5.03	4.93
	Small	4.45	4.98	5.45	4.90	4.38	4.53	4.76
	Mean	4.61	4.89	5.44	5.05	4.61	4.92	4.89
Seasonal average	Large	4.93	5.06	5.60		5.07	5.24	5.18
	Medium	4.87	5.01	5.61	5.23	4.94	5.08	5.10
	Small	4.73	5.05	5.54	5.06	4.79	4.88	5.00
	Mean	4.84	5.04	5.58	5.15	4.93	5.07	5.09

[1]Large fruit harvested by error.

[2]McMillan values excluded.

TABLE 16

Yuma Mesa; Analysis of Variance of Acid

	Item	Degrees of Freedom	Mean Square	L.S.D.
Main effects	Dates	5	0.3197*	0.11
	Sizes	2	0.3319*	0.27
	Locations	5	1.2192*	0.11
First-order interactions	Dates-Sizes	10	0.0074	
	Dates-Locations	25	0.0275*	0.11
	Sizes-Locations	10	0.0297*	0.11
Second-order	Dates-Sizes	50	0.0085	
Total		107	0.0920	

*Significant at the 0.01 level.

TABLE 17

Salt River Valley; Percentage of Acid in Extracted Juice

Date	Size	Grove: Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher[1]	Mean[2]
Sept. 21	Medium	6.02	5.50	5.75	5.93	6.28	5.80
	Small	6.04	5.15	5.80	5.78	6.63	5.88
	Mean	6.03	5.33	5.78	5.86	6.46	5.89
Oct. 6	Medium	6.10	5.50	5.93	6.13	6.60	6.05
	Small	6.12	5.45	6.05	5.80	6.83	6.05
	Mean	6.11	5.48	5.99	5.97	6.72	6.05
Oct. 27	Medium	6.04	5.88	6.18	6.33	6.53	6.19
	Small	6.13	5.78	6.15	6.28	6.63	6.19
	Mean	6.09	5.83	6.17	6.31	6.58	6.19
Nov. 11	Medium	6.07	5.70	5.90	6.15	6.23	6.01
	Small	6.04	5.70	6.18	6.03	6.58	6.11
	Mean	6.06	5.70	6.04	6.09	6.41	6.06
Dec. 9	Medium	5.60	5.38	5.90	6.08	6.50	5.89
	Small	5.65	5.15	5.80	5.75	6.63	5.80
	Mean	5.63	5.27	5.85	5.92	6.57	5.85
Dec. 21	Medium	5.55	5.13	5.75	5.93	6.30	5.73
	Small	5.57	5.23	5.65	5.65	6.43	5.71
	Mean	5.56	5.18	5.70	5.79	6.37	5.72
Seasonal average	Medium	5.89	5.52	5.90	6.09	6.41	5.96
	Small	5.93	5.41	5.94	5.88	6.62	5.96
	Mean	5.91	5.47	5.92	5.99	6.52	5.96

[1]Burgher medium value is estimated by averaging large and small values.

[2]Burgher values omitted from mean.

TABLE 18

Salt River Valley; Analysis of Variance of Acid

	Item	Degrees of Freedom	Mean Square	L.S.D.
Main effects	Dates	5	0.29768*	0.16
	Sizes	1	0.00076	
	Locations	4	1.67799*	0.15
	Dates-Sizes	5	0.00963	
First-order interactions	Dates-Locations	20	0.03071*	0.18
	Sizes-Locations	4	0.07743*	0.10
Second-order interaction	Dates-Sizes Locations (Error)	20	0.00717	
Total		59		

*Significant at the 0.01 level.

percent acid than the other Salt River Valley groves. Differences between locations and between dates of harvest were significant at the one percent level.

The higher values for citric acid which developed in the Salt River Valley can be considered to be related to some consistent environmental or rootstock difference between the areas.

Salt River Valley trees were of a different variety than those at Yuma with the exception of the Harding Eureka grove at Yuma. If the varietal difference contributed greatly to the acid difference between areas, the Harding Eureka fruit would be expected to yield a higher percent of acid than the Yuma average. In fact the reverse was true.

Hilgeman (4) reported higher acid for Salt River Valley grown grapefruit than for Yuma fruit. He also showed that trees fertilized with commercial nitrogen produced fruit with less acid than did trees which were unfertilized. This effect, if present in lemons, could be partially responsible for acid differences between groves.

The Yuma trees were all on Rough lemon roots while most of the Salt River Valley trees were on sour orange rootstock. The one Salt River Valley grove consisting of Rough lemon rootstocks was at the Arrowhead Ranch, but this grove differed little from the Salt River Valley average for acid percentage. In this grove it appears that the effect of the silt loam soil and non tillage with extensive cover crops throughout the year possibly offset the acid reducing effect of the Rough lemon rootstock.

The most consistent known differences between the Yuma and Salt River Valley areas are the rootstock, soil type, and climate. It is not possible to evaluate these factors separately.

Percentage of citric acid was more affected by seasonal changes than by fruit size. The fruit that were large in the early part of the season developed less citric acid than the fruit which reached a large size later in the season. This means that when fruit are harvested with a sizing ring, the first harvest yields fruit with less acid than succeeding ones, even though the same sized fruit are harvested each time. Also suggesting the importance of the seasonal effect is the fact that citric acid decreases occurred in all fruit sizes at about the same time.

Changes in citric acid per ton of fruit: Tables 19 and 20 present the changes in citric acid per ton of fruit at Yuma and the Salt River Valley. These values reflect the increase in juice content and the change in the citric acid during the season.

At Yuma the amount of citric acid per ton of fresh fruit increased rapidly during September and at a slower rate during October and November to an average maximum of 53.4 pounds per ton on December 2. During the next two weeks a large decrease occurred to a value of 49.4 pounds per ton on December 15. The Yuma groves had similar yields of citric acid per ton of fruit with the exception of the Evans grove. This grove had a higher yield because of its higher citric acid content.

In the Salt River Valley the average amount of citric acid per ton of fruit increased between September 22 and October 26 to a maximum of 62.6 pounds. After the second week in November the number of pounds

TABLE 19

Yuma Mesa; Pounds of Citric Acid per Ton of Fruit

Date	Size	Grove: Harding	Coastaluck	Evans	McMillan	Waldrip	Citrus Expt. Station	Mean
Sept. 11	Large	38.8	43.8	48.4		43.1	46.4	44.1
	Medium	48.2	41.7	53.0	45.1	41.1	44.1	45.5
	Small	40.4	43.4	54.8	43.8	41.2	41.3	44.2
	Mean	42.5	43.0	52.1	44.5	41.8	43.9	44.6
Sept. 30	Large	47.1	46.3	54.6		44.3	47.8	48.0
	Medium	55.6	47.7	54.0	48.5	46.4	47.3	49.9
	Small	45.3	47.7	53.2	46.3	46.1	46.3	47.5
	Mean	49.3	47.2	53.9	47.4	45.6	47.0	48.5
Oct. 21	Large	48.2	45.7	52.1		46.1	55.0	49.4
	Medium	55.1	48.7	52.6	52.7	46.9	53.0	51.5
	Small	46.4	47.1	52.6	48.7	45.8	51.3	48.7
	Mean	49.9	47.1	52.4	50.7	46.3	53.1	49.9
Nov. 3	Large	47.4	48.6	53.9		45.4	56.2	50.3
	Medium	58.8	47.0	57.0	56.2	46.5	52.4	53.0
	Small	48.3	49.0	57.3	53.5	45.5	55.1	51.5
	Mean	51.5	48.2	56.1	54.9	45.8	54.6	51.6
Dec. 2	Large	45.9	52.3	53.1		51.7	57.2	52.0
	Medium	59.2	51.8	59.3	51.3	51.3	58.9	55.3
	Small	47.8	49.4	61.6	50.3	50.0	57.5	52.8
	Mean	51.0	51.2	58.0	50.8	51.0	57.9	53.4
Dec. 15	Large	46.8	45.4	57.0		44.7	55.1	49.8
	Medium	53.6	46.6	55.9	51.0	46.1	51.3	50.8
	Small	41.8	48.8	56.7	50.0	41.2	46.2	47.5
	Mean	47.4	46.9	56.5	50.5	44.0	50.9	49.4
Seasonal average	Large	45.7	47.0	53.2		45.9	53.0	48.9
	Medium	55.1	47.3	55.3	50.8	46.4	51.2	51.0
	Small	45.0	47.6	56.0	48.8	45.0	49.6	48.7
	Mean	48.6	47.3	54.8	49.8	45.8	51.3	49.5

TABLE 20

Salt River Valley; Pounds of Citric Acid Per Ton of Fruit

Date	Size	Grove: Arrow-head	Mehren	Citrus Expt. Station	Tyler	Burgher	Mean
Sept. 21	Medium	57.3	48.1	51.8	57.3	61.8	55.3
	Small	57.2	43.4	47.6	53.2	66.2	53.5
	Mean	57.3	45.8	49.7	55.1	64.0	54.4
Oct. 6	Medium	61.4	49.2	58.2	60.3	59.3	57.7
	Small	59.8	48.3	59.4	55.2	65.6	57.7
	Mean	60.6	48.8	58.8	57.8	62.5	57.7
Oct. 27	Medium	60.9	57.6	61.8	65.8	65.3	62.3
	Small	62.2	56.6	62.7	65.3	67.6	62.9
	Mean	61.6	57.1	62.3	65.6	66.5	62.6
Nov. 11	Medium	61.8	55.9	59.0	60.3	62.3	59.9
	Small	61.1	53.6	63.0	63.9	68.4	62.0
	Mean	61.5	54.8	61.0	62.1	65.4	61.0
Dec. 9	Medium	54.1	48.4	61.4	62.0	63.7	57.9
	Small	55.7	48.4	59.2	54.1	71.6	57.8
	Mean	54.9	48.4	60.3	58.0	67.7	57.9
Dec. 21	Medium	54.8	48.2	54.1	59.3	63.0	55.8
	Small	55.4	50.2	55.4	57.6	66.9	57.1
	Mean	55.1	49.2	54.8	58.5	65.0	56.5
Seasonal average	Medium	58.4	51.2	57.7	60.8	62.6	58.1
	Small	58.6	50.1	57.9	58.2	67.7	58.5
	Mean	58.5	50.7	57.8	59.5	65.2	58.4

of citric acid per ton of fruit decreased significantly to 56.5 pounds by December 21. A wider range existed between the Salt River Valley groves than between the Yuma groves. The Burgher grove was the highest with an average value of 65.2 pounds and the Mehren grove was the lowest with only 50.7 pounds. There were no consistent differences between medium and small fruit except in the Burgher grove where small fruit had consistently higher values.

During the late October to early December period of maximum yield, the Salt River Valley groves had an average of 60.5 pounds per ton and the Yuma groves had an average of 51.6 pounds of citric acid per ton of fruit.

The range between the high and low yielding groves in the two areas showed that the highest yielding Evans grove in the Yuma area produced about the same as the lowest yielding Mehren grove in the Salt River Valley during the high yield interval.

Changes in citric acid per ton of fruit are determined by combining the effects of two variables, percent acid of the juice and percent juice of the fruit. As the fruit grows in size the juice assumes a greater proportion of the weight. Percent acid of the juice is also increasing during the period when juice is increasing. The period of greatest acid yield per ton is reached when the product of percent acid and percent juice is highest. This value represents total quantity of acid in the fruit which is a measure of efficiency of the fruit to produce citric acid. Since both the juice and acid factors are subject to normal sample variation the random combination of two high

values or two low values produces greater differences between samples than may actually exist. Thus the differences between samples are more variable and large values must be obtained for statistical significance.

Seasonal changes in citric acid per production unit: Table 21 gives an estimated citric acid value for a lemon crop harvested at different dates during the harvest period. The yield column is based on the product of the average fruit volume and the average specific gravity on each date. These values were plotted on graph paper and a trend was established. The harvest and delivery costs were considered to be directly proportional to the tonnage. The pounds acid per ton values were converted to bi-monthly values by the plotting method used for the yield values using the average values set forth in Tables 19 and 20. The acid yield is based on the product of pounds acid per ton and the yield. These values were multiplied by $0.80, an estimated value for one pound of citric acid. Subtracting these values from the harvest costs gives the net return on each date.

In both the Salt River Valley and at Yuma the weight of citric acid per acre increased into December. However, in the Salt River Valley there was little change in net dollar return after October. The maximum value of citric acid occurred in late October and November. At Yuma the maximum value of citric acid occurred near the end of November. The net return dropped rapidly in early December when a large decrease in pounds acid per ton occurred.

TABLE 21

Relationship Between Time of Harvest and Net Value of the Crop

Yuma Mesa

Date	Yield (tons) (a)	Harvest cost (b)	Acid per ton (pounds)	Acid yield (pounds)	Acid value (c)	Net value (d)
Sept. 15	1.00	$30.00	45.3	45.3	$36.24	$6.24
Sept. 30	1.12	33.60	48.5	54.3	43.44	9.84
Oct. 15	1.22	36.60	49.5	60.4	48.32	11.72
Oct. 31	1.34	40.20	51.2	68.6	54.80	14.60
Nov. 15	1.44	43.20	52.3	75.3	60.24	17.04
Nov. 30	1.56	46.80	53.2	83.0	66.40	19.60
Dec. 15	1.66	49.80	49.5	82.2	65.76	15.96
Salt River Valley						
Sept. 15	1.00	30.00	53.0	53.0	42.40	12.40
Sept. 30	1.12	33.60	56.3	63.0	50.40	16.80
Oct. 15	1.25	37.50	59.8	74.8	59.84	22.34
Oct. 31	1.37	41.10	62.2	85.2	68.16	27.06
Nov. 15	1.47	44.10	60.6	89.1	71.28	27.18
Nov. 30	1.56	46.80	58.9	92.0	73.60	26.80
Dec. 15	1.66	49.50	57.2	94.4	75.52	26.02

(a) Increase in weight of fruit during the season. (Fruit volume times specific gravity)

(b) Harvest and delivery to juice plant estimated at $30.00 per ton.

(c) Value of citric acid estimated at $0.80 per pound.

(d) Citric acid value less the cost of harvest and delivery.

If lemons should become more valuable as by-product fruit rather than fresh fruit, the yields would be computed on the basis of citric acid per production unit such as per acre or per tree.

The total weight of citric acid per production unit is affected by the percent acid in the juice, the juice content of the fruit and the weight of the fruit on the tree. A decrease in acid content of the fruit does not preclude an increase in the total acid per production unit if the fruit is increasing in weight at a greater rate than the acid is decreasing. This was the case in the Salt River Valley where the total acid per production unit continued to increase more than a month beyond the time the pounds acid per ton started to decrease. At Yuma the weight of the fruit was not increasing at a fast enough rate to offset a decrease in the percent acid of the fruit during December. This resulted in a slight decrease in the citric acid per production unit on December 15.

As the weight of the fruit on the tree increases, the cost of harvesting and transporting the fruit increases. Consideration of this weight factor may require harvesting prior to the time of maximum production of citric acid per acre. Citric acid increases may be too slow to pay for increased harvest costs which accompany an increase in the weight of the crop.

The figures used for citric acid value and harvest and transportation cost could change, although a considerable change would be necessary even with an increase in one and decrease in the other to effect the optimum harvest period. It is more likely that greater differences in acid or juice of the fruit would occur between years.

Experiment Number 1: Arrowhead Ranch Study

Growth of fruit: Tables 22 and 23 show conflicting results between two areas of the Arrowhead Ranch grove. Approximately equal growth of fruit occurred in all treatments between August 5 and October 7.

In the west area the same rate of fruit growth occurred in both treatments and in all fruit sizes between October 28 and December 21. During this period there was a 29 percent gain in fruit volume.

In the east area a more rapid growth occurred in the partially harvested trees which had an increase of 35 percent from October 28 to December 21. The average fruit growth for the unharvested trees of the east area was 28 percent.

There was no marked difference in the growth rate between fruit sizes within each treatment.

Percentage of juice by weight: Percentage of juice ranged from 45 percent to 53 percent between September 22 and December 21 as shown by Table 24. The highest values occurred in late October and November after which time a decrease occurred. Large fruit had seven to ten percent more juice than small fruit on September 22. However, the small fruit increased at a faster rate until late October or November when nearly equal percentages of juice occurred in fruit of all sizes.

More information is required to interpret these variable results as they cannot be explained by any known difference between the areas or treatments.

TABLE 22

Arrowhead Ranch; Enlargement of Fruit Measured in Cubic Centimeters

East block; unharvested

Date	Large	Medium	Small	Average
Aug. 5	65.5	50.8	40.2	52.2
Sept. 2	87.6	68.1	54.9	70.2
Sept. 23	103.8	81.3	65.6	83.6
Oct. 7	115.0	90.0	73.2	92.7
Oct. 27	133.2	103.8	83.7	106.9
Nov. 13	143.1	112.1	90.8	115.3
Nov. 25	154.7	120.8	96.3	123.9
Dec. 11	166.8	129.0	104.7	133.5
Dec. 21	170.6	132.1	107.5	136.7

East block; partially harvested

Large	Medium	Small	Average
65.0	50.2	40.0	51.7
85.7	66.2	54.6	68.8
100.3	78.2	65.6	81.4
110.3	86.8	73.2	90.1
127.9	100.3	85.3	104.5
139.8	110.3	93.3	114.5
153.6	118.9	101.1	124.5
168.1	131.1	111.2	136.8
173.1	135.4	115.0	141.2

West block; unharvested

Date	Large	Medium	Small	Average
Aug. 3	64.8	49.6	39.3	51.2
Sept. 2	88.4	69.4	54.1	70.6
Sept. 22	100.3	80.6	61.8	80.9
Oct. 7	114.0	91.6	69.7	91.8
Oct. 28	133.3	106.5	80.6	106.8
Nov. 13	142.3	114.0	87.6	114.6
Nov. 25	152.4	122.8	94.1	123.1
Dec. 10	164.3	132.1	102.0	132.8
Dec. 21	170.6	136.4	105.6	137.5

West block; partially harvested

Large	Medium	Small	Average
64.6	49.8	38.2	50.9
88.7	69.6	53.5	70.6
102.9	80.6	62.7	82.1
115.9	90.8	72.5	93.1
133.2	105.6	83.7	107.5
143.1	114.0	90.0	115.7
153.6	122.8	97.6	124.7
165.6	133.2	104.7	134.5
170.6	137.5	108.4	138.8

TABLE 23

Arrowhead Ranch; Gain in Fruit Volume from October 27 to December 21

	East block		West block	
Size	Unharvested	Partially Harvested	Unharvested	Partially Harvested
Large	28.1	35.3	28.0	28.1
Medium	27.3	35.0	28.1	30.2
Small	28.4	34.8	31.0	29.5
Average	28.0	35.0	29.0	29.0

TABLE 24

Arrowhead Ranch; Percentage of Juice by Weight

Date	East block; unharvested				East block; partially harvested			
	Large	Medium	Small	Average	Large	Medium	Small	Average
Sept. 22	46.6	48.5	43.8	46.3	47.9	48.0	44.5	46.8
Oct. 7	49.0	49.6	47.0	48.5	50.4	47.5	46.1	48.0
Oct. 28	49.0	49.0	47.0	48.3	50.0	51.0	50.0	50.3
Nov. 23	52.0	52.0	53.0	52.3	51.0	50.0	49.0	50.0
Dec. 10	48.0	49.0	50.0	49.0	--	50.0	48.0	49.0
Dec. 21	50.0	51.0	49.0	50.0	50.0	49.0	49.0	49.3
Average for Oct. 28 to Dec. 21	49.8	50.3	49.8	49.9	50.3	50.0	49.0	49.2
	West block; unharvested				West block; partially harvested			
Sept. 22	47.5	44.9	43.0	45.1	48.2	47.8	43.0	46.3
Oct. 7	49.2	48.6	46.3	47.7	49.1	49.7	48.1	49.0
Oct. 28	50.0	51.0	50.0	50.3	--	52.0	52.0	52.0
Nov. 25	50.0	50.	51.	50.3	50.0	50.0	50.0	50.0
Dec. 10	50.0	48.0	49.0	49.0	48.0	50.0	48.0	48.7
Dec. 21	47.0	50.0	49.0	48.7	50.0	49.0	50.0	49.7
Average Oct. 28 to Dec. 21	49.3	49.8	49.8	49.6	49.3	50.3	50.0	50.1

Only slight differences occurred between the west and east blocks. The combinations of east block unharvested and west block partially harvested fruit developed the highest average maximums of about 52 percent on November 23 and October 28 respectively. The east block partially harvested and west block unharvested fruit maintained an average maximum of 50 percent on those dates.

Peel thickness: Table 25 shows peel thickness relationships at the Arrowhead Ranch. Maximum values, occurring about December 10, were higher in the east block at 0.47 mm. than in the west block at 0.43 mm.

The increase in peel thickness from October 7 through December 10 varied from 17 to 20 percent in the west block treatments and from 30 to 35 percent in the east block treatments.

The large fruit were always thicker peeled than the small fruit and medium sized fruit were usually intermediate.

Percentage of acid: The seasonal acid data is presented in Table 26. From September 23 through November 25 the acid changes were similar in both treatments of the east block and in the west unharvested block. The west partially harvested block had higher values during most of this period. The December 10 and 21 samplings contained similar amounts of acid in all treatments except in the east unharvested block which had a much larger decrease from the November value. This drop reflected the very low acid values occurring in the small fruit during December. The percent of acid in the small fruit in the other three treatments usually was about the same as in large or medium sized fruit.

TABLE 25

Arrowhead Ranch; Peel Thickness in Millimeters

Date	East block; unharvested				East block; partially harvested			
	Large	Medium	Small	Average	Large	Medium	Small	Average
Sept. 23	.37	.34	.33	.35	.36	.33	.30	.33
Oct. 7	.38	.34	.31	.34	.39	.34	.33	.35
Oct. 27	.42	.39	.34	.38	.43	.39	.35	.39
Nov. 23	.43	.39	.36	.39	.43	.40	.37	.40
Dec. 10	.53	.44	.40	.46	.56	.45	.39	.47
Dec. 21	.47	.43	.38	.43	.49	.43	.40	.44
	West block; unharvested				West block; partially harvested			
Sept. 22	.35	.34	.30	.33	.33	.32	.31	.32
Oct. 7	.40	.36	.33	.36	.40	.35	.34	.36
Oct. 28	.42	.39	.37	.39	.47	.40	.37	.41
Nov. 25	.39	.38	.34	.37	.39	.37	.31	.36
Dec. 10	.46	.45	.37	.43	.47	.42	.38	.42
Dec. 21	.46	.43	.36	.42	.44	.41	.36	.40

TABLE 26

Arrowhead Ranch; Percentage of Acid in Extracted Juice

Date	East block; unharvested				East block; partially harvested			
	Large	Medium	Small	Average	Large	Medium	Small	Average
Sept. 23	6.03	5.98	5.83	5.95	5.93	5.98	6.08	6.00
Oct. 7	5.95	6.00	5.83	5.93	5.98	6.00	6.25	6.08
Oct. 27	6.08	6.13	6.03	6.08	6.00	6.18	6.20	6.13
Nov. 23	5.98	5.97	5.86	5.94	6.00	6.00	5.91	5.97
Dec. 10	5.50	5.55	5.13	5.39	5.38	5.63	5.50	5.50
Dec. 21	5.33	5.45	5.18	5.32	5.43	5.60	5.65	5.56
	West block; unharvested				West block; partially harvested			
Sept.22	5.93	6.03	6.15	6.04	6.20	6.18	6.30	6.23
Oct. 7	6.18	6.08	5.98	6.08	6.30	6.38	6.08	6.25
Oct. 28	6.08	6.13	6.13	6.11	5.98	6.08	6.03	6.03
Nov. 25	6.06	5.95	5.97	5.99	6.22	6.25	6.28	6.25
Dec. 10	5.87	5.73	5.60	5.70	5.75	5.70	5.75	5.73
Dec. 21	5.73	5.65	5.35	5.58	5.70	5.58	5.60	5.63

More information is required to interpret these variable results as they cannot be explained by any known difference between the areas or treatments.

The results of the percent acid determination for the November sampling of individual trees are presented in Tables 27 and 28.

The most striking feature of this data is the large variation in the percent acid between trees. The high and low values were 6.40 and 5.73. Such a large variation suggests the need for data from a greater number of trees in order to insure the selection of a random sample. This experiment might have provided more conclusive data if a greater number of trees had been sampled.

TABLE 27

Arrowhead Ranch; Percentage of Acid in Extracted Juice in Late November

		Replication				
West Block	Size	1	2	3	4	Mean
Partial Harvest	Small	6.07	6.28	6.13	6.43	6.28
	Medium	6.05	6.38	6.20	6.48	6.25
	Large	6.03	6.28	6.28	6.30	6.22
	Mean	6.05	6.31	6.20	6.40	6.25
Unharvested	Small	5.98	6.18	6.03	5.68	5.97
	Medium	5.98	6.30	5.98	5.70	5.95
	Large	5.95	6.45	6.05	5.80	6.06
	Mean	5.97	6.31	6.02	5.73	5.99
East Block						
Partial Harvest	Small	5.83	5.88	6.28	6.33	6.08
	Medium	5.93	6.00	6.30	6.23	6.12
	Large	5.85	6.05	6.23	6.28	6.10
	Mean	5.87	5.98	6.27	6.28	6.10
Unharvested	Small	5.65	6.23	5.90	6.28	6.02
	Medium	5.85	6.35	6.05	6.40	6.16
	Large	5.98	6.13	6.10	6.35	6.14
	Mean	5.83	6.24	6.02	6.34	6.11

		Partial Harvest	Unharvested	Mean
Means by size and harvest	Small	6.18	6.00	6.09
	Medium	6.18	6.06	6.12
	Large	6.16	6.10	6.13
	Mean	6.17	6.05	6.11

TABLE 28

Arrowhead Ranch; Analysis of Variance of Acid in Late November

	Item	Degrees of Freedom	Mean Square	Least Significant Difference
	Locations	1	0.0058	
	Location X Replication	6	0.1629	
Main plots	Harvest	1	0.1576	
	Harvest X Location	1	0.3398	
	Error	6	0.1032	
	Size	2	0.0203**	0.06
	Size X Harvest	2	0.1094*	0.11
Sub-plots	Size X Location	2	0.0263**	0.08
	Harvest X Location X Size	2	0.2100*	0.15
	Error	24	0.0059	

* Significant at the .01 level.

** Significant at the .05 level.

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