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STUDIES OF THE RIPENING OF MARSH GRAPEFRUIT IN ARIZONA

WITH ESPECIAL REFERENCE TO THE IMPROVEMENT OF MATURITY MEASUREMENTS

BY

R. H. HILGEMAN

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STUDIES OF THE RIPENING OF MARSH GRAPEFRUIT IN ARIZONA WITH ESPECIAL REFERENCE TO THE IMPROVEMENT OF MATURITY MEASUREMENTS[1]

BY R H HILGEMAN

INTRODUCTION

THE PROBLEM

The rapid increase in the production of Arizona grapefruit has been reflected in a tendency to ship fruit early in the season. In 1933 legal grapefruit maturity standards designed to prevent the shipment of inedible fruit were enacted. However, it soon became evident that the requirements set forth in this law did not prevent the shipment of relatively unpalatable fruit. Many growers feel that the marketing of low quality fruit in the early season has resulted in an unfavorable reaction to Arizona grapefruit which extends to the more palatable fruit shipped later in the season.

The objects of the investigations reported in this bulletin have been fourfold:

1. To evaluate the factors influencing the accuracy of the methods of measurement of physical and chemical values.
2. To acquire data pertaining to changes in the physical and chemical characteristics of Arizona grapefruit during ripening.
3. To interpret the data with respect to improving existing maturity standards.
4. To evaluate the influence of cultural and environmental factors upon maturity.

Studies by Collison (8); Wood and Reed (21); Traub, Fraps, and Friend (20); Chase and Church (6); Baier (2); in

[1]These studies were initiated in October, 1934, by the Arizona Citrus Standardization Service under the direction of J. M. Foote, Supervisor of Inspection. In December, 1936, the investigations were taken over by the University of Arizona Agricultural Experiment Station. The writer became associated with the project in September, 1935, while in the employment of the Standardization Service.

Florida, Texas', and California; and the writer (14) in Arizona, all indicate that the ripening of grapefruit is a gradual process accompanied by a progressive improvement in flavor, juiciness, aroma, tenderness, and flesh quality. The ideal standard of maturity would determine the exact point at which these changes have sufficiently progressed to render the fruit palatable to the consumer. Determining such a point by taste tests is not practical for obvious reasons. This was recognized by early workers, and efforts were made to find measurable physical and chemical features which might provide an index of palatability.

The ratio of total soluble solids (Brix) to acid has been reported by Chase and Church (6) and others (2, 21) to be a measure of edibility and has therefore been incorporated into various maturity standards. Practical experience with this requirement in Arizona has shown that relatively high ratios may occur when the fruit contains but little juice and is not palatable. Juiciness of the fruit has been reported in Florida (16), in Texas (21), and in Arizona (14) to be associated with edibility. Also, Baier and Higby (3) have indicated that color is related to fitness for consumption. It would appear then that maturity may be correlated to some extent with total soluble solids to acid ratio, the quantity of juice, and the color of the fruit.

LEGAL MATURITY REQUIREMENTS

Arizona and California

The Arizona citrus maturity law (1) was enacted in 1933. Since a considerable quantity of Arizona grapefruit is marketed in California, the Arizona law contains the same provisions as the California law (5) pertaining to desert grapefruit. According to these laws, grapefruit is deemed mature when it has attained 25 per cent characteristic yellow color and contains six parts or more total soluble solids to each part of acid calculated as anhydrous citric. It also provides that after December 15 of each year all grapefruit are deemed mature. These requirements apply to the fruit at the time it is shipped, so the grower or shipper must make tests to satisfy himself that the fruit will pass. If the fruit, at the time of packing, does not meet the 6:1 ratio, it is condemned.

Texas

The Texas legal standards have been changed several times since the first law was enacted in 1927. The law enacted in 1935 (19) provided for a varying total soluble solids to acid ratio dependent upon the total soluble solids as shown in Table 1.

TABLE 1.—TEXAS, BRIX AND BRIX:ACID RATIO REQUIREMENTS.

Minimum total soluble solids (degrees Brix)	Minimum ratio (Brix to acid)
9.0	7.2:1
10.0	7.0:1
11.0	6.8:1
11.5 and above	6.5:1

In addition, "the Commissioner of Agriculture may prescribe additional seasonal requirements from time to time to the end that citrus fruit shall at all times be fit for human consumption before being offered for sale." Acting under this authority, juice requirements were established as shown in Table 2 during the 1938 and 1939 seasons.

TABLE 2.—TEXAS JUICE REQUIREMENTS, 1938 AND 1939.

Commercial size[a]	Diameter of fruit (inches)	Juice required per fruit (cc.)	Percentage juice[b]
126	3.5	150	40.9
96	3.75	180	39.9
80	4.00	195	35.5
70	4.12	200	33.4
64	4.25	205	31.2

[a]This refers to the Texas standard container which has two compartments each 12 inches by 12 inches by 12 inches.

typhe percentage of juice is not listed as such in the Texas law. It has been calculated and included so that comparison could be made with data in this bulletin. Using the diameters listed, calculations were based on the volume of a sphere which is not exactly comparable.

In the operation of the Texas law, the inspector visits the grove to be tested and picks fifteen to twenty representative fruit. These are sized, the juice extracted on a hand reamer, and the required determinations made, If the fruit passes the requirements, a certificate of maturity is

issued to the grower which allows him to harvest and ship without further tests.

Florida

The Florida grapefruit maturity law has been frequently changed. The legal requirements enacted in 1939 (11) provide for "a break in color caused solely by nature," 7,0 per cent minimum total soluble solids (Brix), and the total soluble solids to Brix:acid ratio requirements as shown in Table 3,

TABLE 3.—FLORIDA, BRIX AND BRIX:ACID RATIO REQUIREMENTS.

Minimum Brix	Ratio required	Minimum Brix	Ratio required
7.0	7.00	9.4	6.75
9.0	6.95	9.5	6.70
9.1	6.90	9.6	6.65
9.2	6.85	9.7	6.60
9.3	6.80	9.8	6.55
		9.9 and up	6.50

In addition, a minimum juice requirement is included in the Florida law. This requirement, however, is subject to change by the Florida Citrus Commission which is "vested with the power to raise or lower the requirements fixed by statute ... provided that in no case shall such increase or decrease exceed 10 per cent of the amount fixed by statute," This may be done after public hearings establish that seasonal conditions have influenced the amount of juice in the fruit. The juice requirement as set forth in the Florida law is shown in Table 4,

In Florida, tests are made at the packing houses on fruit which has been prepared for shipment. Not less than three

TABLE 4.—FLORIDA JUICE REQUIREMENTS.

Commercial size[a]	Juice required per fruit (cc.)	Percentage juice[b]
126	176	47.9
96	209	46.2
80	236	43.0
70	247	41.2
64	269	40.9

[a]Florida standard container—two compartment box each 12 inches by 12 inches by 12 inches.

[b]Computed for comparison, see footnote b, Table 2.

fruits of any given size are used to make a test. These are peeled and the juice extracted by pressing in a fruit press. If satisfactory juice, Brix, and acid values are found, a certificate is issued covering the particular shipment.

DEFINITION OF MATURITY

Maturity in grapefruit as used in this bulletin implies the attainment of sufficient quality to render the fruit palatable to the consumer. A mature grapefruit is characterized by tender, juicy, well-developed juice sacs, and a pleasing flavor.

EXPERIMENTAL PROCEDURE

SAMPLING

Field Samples

About 4,000 samples were tested between September, 1934, and June, 1940. Fruit maturity was studied from groves carefully selected so that many conditions would be represented. Differences in fruit maturity were known to occur between the Phoenix and the Yuma areas, districts within these areas, and even between adjacent groves in the same district.

Ten to twenty-five groves in the Salt River Valley were sampled each year. Fruit from the same four groves on the Yuma Mesa and one in the Yuma Yalley were tested each year beginning in the 1936-37 season. A limited number of tests were made on fruit from the Imperial Yalley in the 1937-38 season and from the Coachella Yalley in 1937-38 and 1939-40.

In studying the influence of such factors as size of fruit and location on the tree upon maturity, samples were collected in a way that would best measure the particular factor in question.

In studying seasonal changes in the fruit, samples were obtained at 1-week intervals from the same trees. In some instances the fruit was obtained from the same trees throughout the 5-year period. Four fruits were selected from each of three trees, making a total of twelve fruits per sample. During 1935 and 1936, one fruit was picked from the inside, one from the outside, and two from just inside the drip of each tree. In 1937, 1938, and 1939 one fruit was ob-

tained from the north, east, south, and west sides of each tree at a point where the maximum amount of fruit was found. This latter method was less arbitrary and represented more nearly a representative sample of the fruit on the tree. Each sample contained fruit of approximately the same size which represented the average size of the fruit on the tree at the time. The size of the fruit sampled, therefore, increased during the season. Records were made of cultural practices with particular reference to irrigation.

Packing-House Samples

Salt River Valley samples were obtained from four major packing houses after the fruit had been colored and graded. During 1934 and up to November, 1935, these samples were simply segregated into sizes, larger and smaller than size 80. Beginning in November, 1935, and throughout 1936 and 1937 samples of definite sizes and grades were selected. No samples were obtained from the packing houses in 1938 and 1939, although the data obtained by the houses themselves were studied.

Yuma district samples of definite sizes and grades were tested by the local packing house in 1936, 1937, and 1938 and the data given to the writer.

METHODS AND MATERIALS

In studies of seasonal changes all fruit was tested within 24 hours after picking except that from Yuma, which was usually tested within 24 hours, but on some occasions 36 to 48 hours elapsed. The volume of this fruit was obtained within a few hours after picking.

The percentage of color break in each fruit was estimated by comparison with a color plate. After weighing, the volume of the entire sample was obtained by water displacement.

In studying seasonal changes, the juice was removed with a power reamer-type extractor after the fruit was halved. The extracted juice was strained through an 18-mesh strainer and double thickness medium weight cheesecloth. The free juice thus obtained was measured and used for Brix and acid determinations. The pulp remaining within the strainer was stirred vigorously for several minutes. After weighing, this pulp was squeezed to remove all juice. This juice was added to the free juice in calculating percentage of juice.

During 1937, 1938, and 1939 the weight of rag adhering to the peel and the weight of the peel without rag were obtained.

Changes in the location of laboratories necessitated changing from 60- to 25-cycle extractors. The same reamer head was used on all extractors, but the rated speed was 1,725 r.p.m. in some cases and 770 r.p.m. in other cases. The differences in reamer speeds incorporated different amounts of air in the juice which affected Brix readings when made at once (p. 117). To eliminate errors due to aeration, the Brix hydrometer was not read until the sample had deaerated and no further rise in the spindle occurred.

Percentage acid was determined by titrating 25 cc. of juice with N/6.4 sodium hydroxide to a light pink color. Five drops of phenolphthalein were used as an indicator. The results are expressed as percentage of anhydrous citric acid.

In studies to evaluate errors arising from variations in time between picking and analyses, and from variations in extracting technique, the above standard procedure was varied as needed to evaluate the particular variable involved.

The degree of palatability was evaluated for each sample on the basis of quality, as indicated by the development and condition of the juice sacs, and flavor. The fruit was rated as follows: poor (inedible); fair (edible); good (sufficiently palatable to be satisfactory to the average consumer); very good (highly palatable); excellent (maximum of palatability). The writer was assisted in these ratings by laboratory technicians. Frequently, fruit inspectors, visitors, and disinterested persons were present, and their reactions to the fruit were noted.

PRESENTATION AND DISCUSSION OF DATA

PART I.—EVALUATION OF FACTORS INFLUENCING THE ACCURACY OF MEASUREMENTS OF MATURITY

Variations in Samples

Size of Fruit

Percentage of Juice.—A higher percentage of juice was found in small than in large Florida grapefruit by L. Longfield-Smith (16) and others'. Both the Florida and Texas

legal requirements for juice provide for this difference. The determination of the percentage of juice in different sizes of Arizona grapefruit has been an important part of this investigation each year.

In 1934 and 1935 preliminary tests were made on large and small Salt River Valley grapefruit obtained from the local packing houses after it had been colored with ethylene. The data indicated that small fruit contained approximately 3.5 per cent more juice than large fruit. This difference was maintained throughout the fall test period.

During 1936, Salt River Valley packing-house fruits of definite sizes, from the fancy and choice grades, were tested. Similar data were obtained by the Yuma Mesa Fruit Growers' Association. The percentage of juice in different commercial sizes during the fall of 1936 is presented for Salt River Valley fruit in Figure 1 and for Yuma fruit in Figure 2, as typical of all seasons studied. The trends for seasonal changes were determined by the formula $Y = a+bx+cx^2$.

From the data it is clearly evident that a difference in the percentage of juice exists between sizes during the entire fall testing period. All of the trends are similar, with the values for percentage of juice at successively higher levels as smaller fruit is considered.

These data, however, do not indicate a definite relationship between size and percentage of juice. Figure 1 and Table 26 show that no significant change in the percentage of juice occurs after early December. Therefore, the data from seventy-one Salt River Valley packing-house tests and forty-four Yuma packing-house tests made between December 1 and January 20 were plotted ignoring the time factor. These data are graphically presented in Figure 3 in which the percentage of juice is plotted against the volume of the fruit. The straight line trend was calculated from the formula $Y = a+bx$. This trend shows that small fruit has a higher percentage of juice than large fruit. Inasmuch as this fruit was mature, it may be considered as representative of normal relationships between size and percentage of juice. Similar trends were developed from comparable data in 1935 and 1937.

It is clear from the preceding data that the percentage of juice by volume is less in large than in small fruit. In order to determine the factors causing this relationship, data on percentage of juice by volume and weight, percentage peel by weight, and percentage of juice in the peeled fruit were obtained during December and January in 1938-39 and

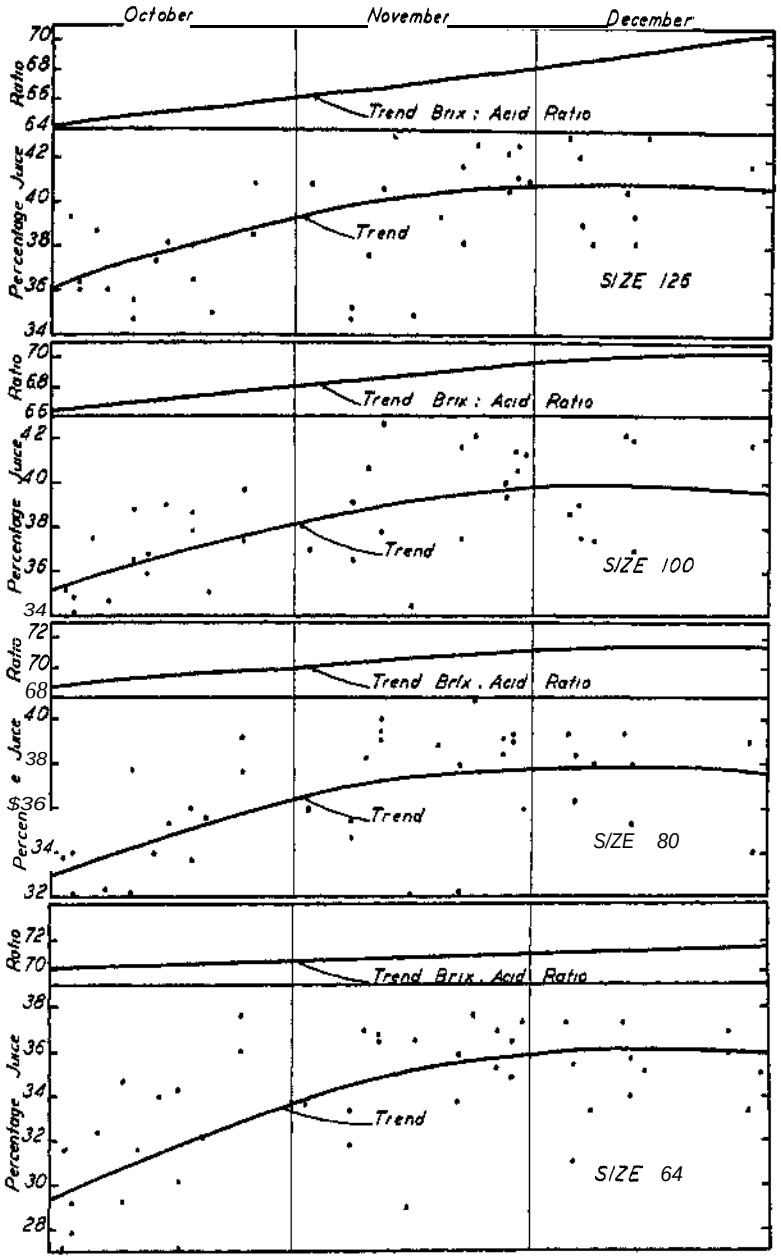

Figure 1.—Graphs showing differences in percentage of juice and Brix:acid ratio in Salt River Valley grapefruit of four commercial sizes. October, November, and December, 1956.

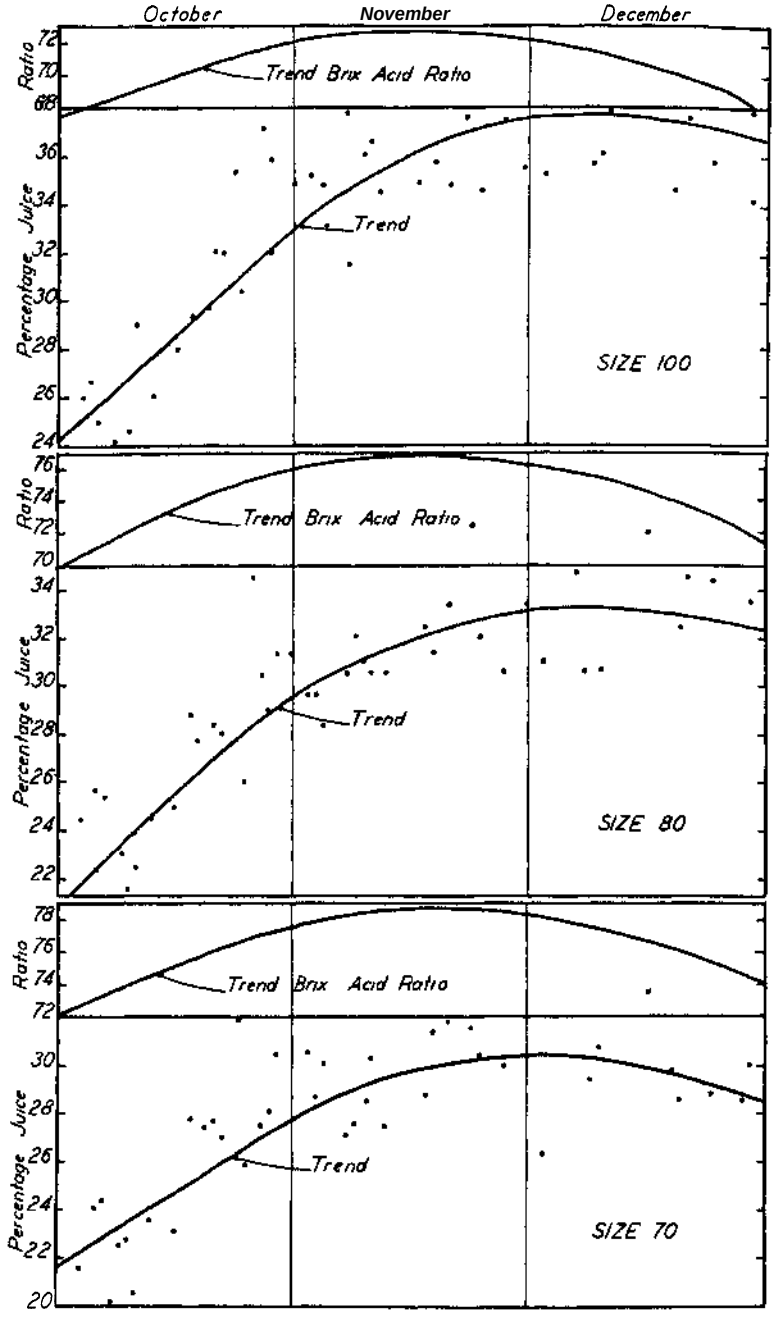

Figure 2.—Graphs showing differences in percentage of juice and Brix:acid ratio in Yuma grapefruit of three commercial sizes. October, November, and December, 1936. Data courtesy Yuma Mesa Fruit Growers' Association.

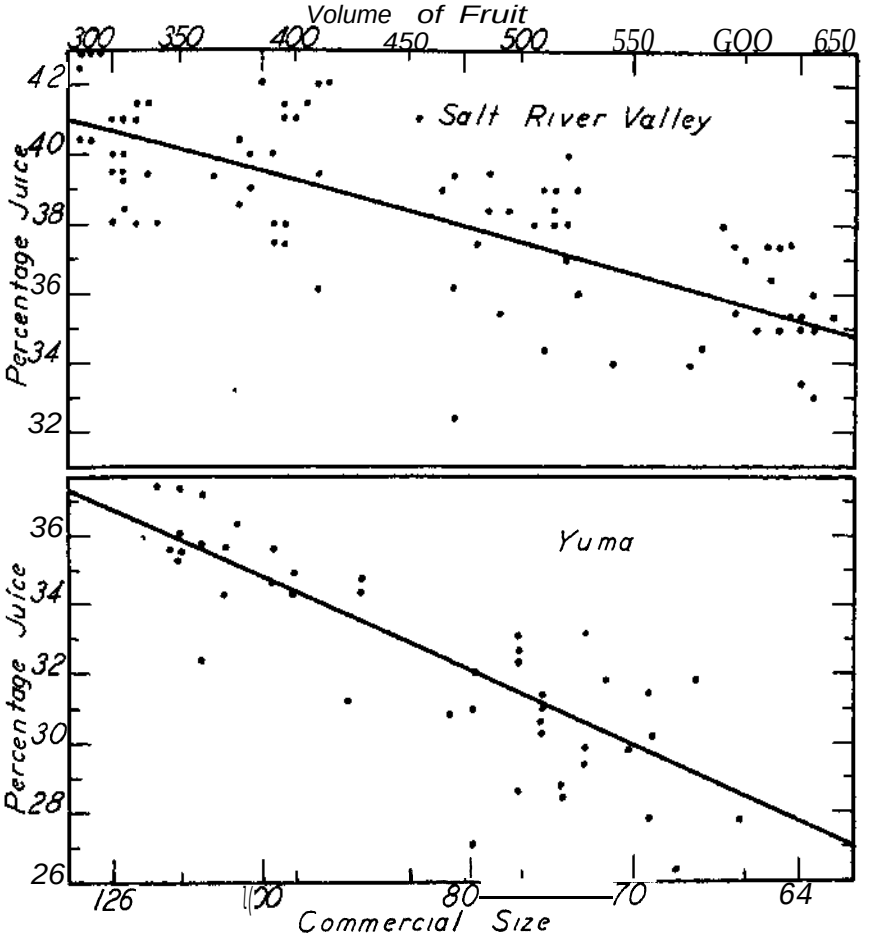

Figure 3.—Scatter diagrams showing linear relationships between size and percentage of juice in fruit from Salt River Valley and Yuma packing houses. (Yuma data obtained by Yuma Mesa Fruit Growers' Association.)

1939-40. Comparable field samples of commercial sizes were obtained from twenty-eight groves each year. The 1939-40 data presented in Figures 4 and 5 are typical.

The percentage of juice regression trend in Figure 4 derived from these data is similar to the trends obtained from packing-house samples. The factors affecting this inverse relation between size of fruit and percentage of juice are presented in Figure 5. The percentage of juice by weight is higher in small fruit than in large fruit. The difference by weight is less than the difference by volume because the

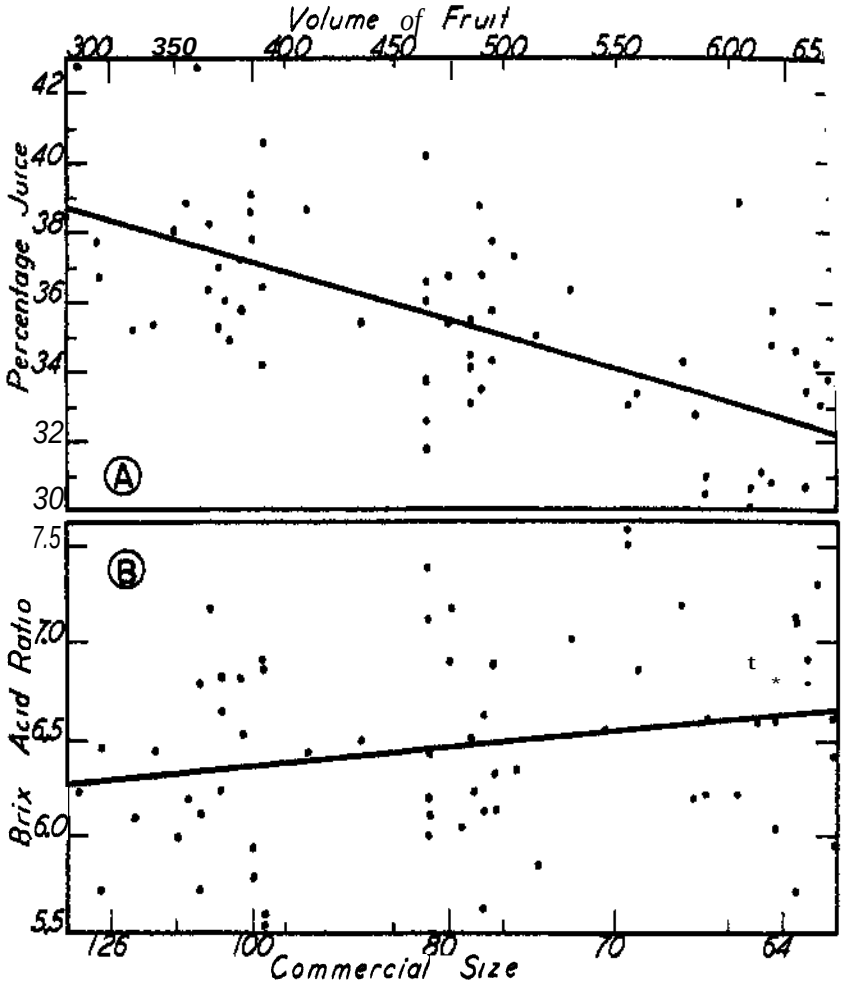

Figure 4.—Scatter diagrams showing linear relationships of size (A) to percentage of juice by volume and (B) to Brix:acid ratio. Salt River Valley, 1959-40.

peel has a lower specific gravity than the edible portion. The trend of the percentage of peel by weight shows that it is higher in large than in small fruit.

A comparison of the trends of percentage of juice and percentage of peel (Fig. 5) indicates that an inverse relationship exists between these values. Thus, the difference in percentage of juice in large and small peeled fruit after December 1 is less than 1 per cent. The wide scatter of the values indicates that this difference is not significant,

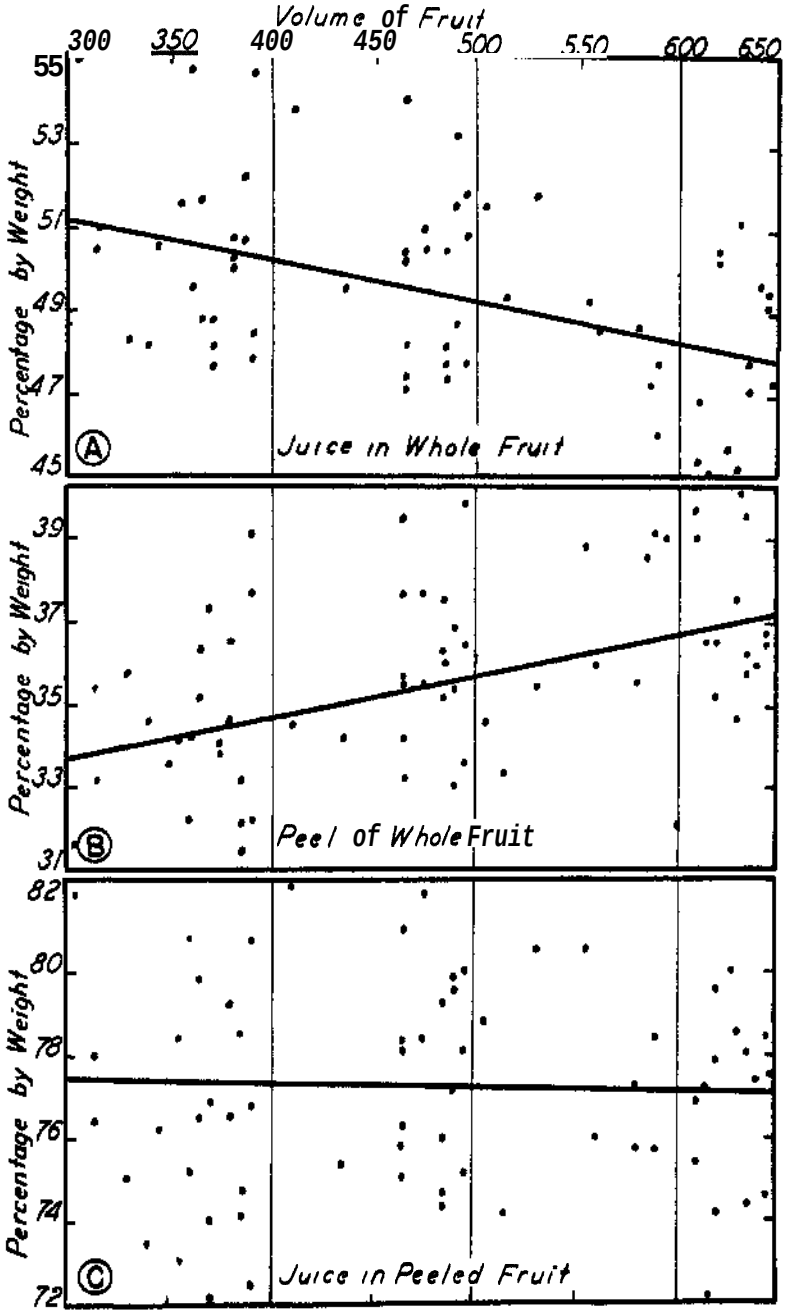

Figure 5.—Scatter diagrams showing linear relationships between volume of fruit and percentage by weight of: (A) Juice in whole fruit, (B) peel of whole fruit, (C) juice in peeled fruit. Salt River Valley, 1939-40, Data from the same series of tests as Figure 4.

Therefore, it may be stated that the percentage of juice in the edible portion of mature, large grapefruit is equal to that in mature small grapefruit. The differences found between sizes in the percentage of juice by volume and percentage of juice by weight are due to the effect of the peel.

A summary of the relationship between size of the mature fruit and percentage of juice as indicated by the regression trends for each year is set forth in Table 5.

TABLE 5.—SUMMARY OF DATA ON RELATIONSHIP BETWEEN SIZE OF MATURE FRUIT AND PERCENTAGE OF JUICE BY VOLUME.

Fruit volume (cc.)	Salt River Valley						Yuma			
	1935[a]	1936[a]	1937[a]	1938[b]	1939[b]	AT.	1936°	1937[c]	1938°	AT.
300	39.8	41.0	40.7	39.5	38.7	39.9	37.3	35.1	39.8	37.4
350	38.7	40.1	39.7	38.5	37.7	38.9	35.9	34.1	38.7	36.2
400	37.6	39.2	38.6	37.5	36.8	37.9	34.5	33.1	37.6	35.0
450	36.5	38.3	37.5	36.4	35.9	36.9	33.1	32.2	36.6	33.9
500	35.4	37.5	36.5	35.4	35.0	35.9	31.5	31.2	35.5	32.7
550	34.3	36.6	35.4	34.3	34.1	34.9	30.1	30.3	34.4	31.5
600	33.2	35.7	34.3	33.3	33.2	33.9	28.7	29.3	33.3	30.4
650	32.1	34.8	33.3	32.3	32.2	32.9	27.2	28.3	32.2	29.2

[a] Packing house samples.

[b] Field samples.

[c] Packing house samples; data obtained by Yuma Mesa Citrus Growers' Association,

The values of these trends show a considerable variation during the several years and between the Salt River Valley and Yuma districts. The yearly variations found for Salt River Valley fruit are probably greater than those which actually occurred, since packing-house samples were used for 3 years and field samples for 2. However, the same sampling method was used throughout each individual year, so each year's data are unaffected. The range in values between years, therefore, should not be accepted as representative of field conditions except in 1938 and 1939.

Within each year the relationship between size and percentage of juice by volume has been relatively uniform. Since the 5-year Salt River Valley average represents 328 tests, these relationships should closely approach average conditions.

Brix:Acid Ratio.—The differences in Brix:acid ratio between large and small fruit are generally known to the

grapefruit industry. Large fruit usually has a higher ratio than small fruit.

In Figure 4 the relationship between size and Brix:acid ratio, obtained from the field samples tested during December and January in 1939-40, is presented. These data are typical of each year studied because a wide scattering of points is evident. The 1935 and 1938 data were so variable that no trend occurred. A summary of maximum and minimum values of the trends established each year is presented in Table 6. From the average it appears that the Brix:acid ratio in large fruit is normally slightly higher than in small fruit.

TABLE 6.—RELATIONSHIP BETWEEN SIZE OF FRUIT AND BRIX:ACID RATIO, SALT RIVER VALLEY.

Fruit volume (cc.)	1935	1936	1937	1938	1939	Av.
300	6.52	6.76	6.84	6.72	6.26	6.62
650	6.52	7.16	7.10	6.77	6.66	6.84
Difference	0.00	0.40	0.26	0.05	0.40	0.22

Location of Fruit on the Tree

The effect of the location of the fruit on the tree was first investigated during December and January of 1935-36. During this period comparisons were made of comparable sized fruit from the extreme inside and the extreme outside of individual trees in twenty-three groves. The data obtained were averaged and are shown in Table 7.

TABLE 7.—COMPARISONS OF PHYSICAL AND CHEMICAL CHARACTERS OF MATURE INSIDE AND OUTSIDE GRAPEFRUIT (DEC. AND JAN., 1935-36).

	Inside fruit	Outside fruit	Difference	Maximum variation	Minimum variation
Brix	10.95	11.63	0.68	1.24	0.30
Acid (%)	1.82	1.75	0.07	0.21	- 0.03
Brix:acid ratio	6.02	6.64	0.62	1.26	0.10
Juice volume (%)	36.6	33.9	2.7	5.4	- 1.2
Juice weight (%)	49.0	46.0	3.0	6.2	- 0.1
Peel weight (%)	34.6	37.3	2.7	----	----
Juice in edible portion (% by weight)	74.6	73.3	0,3	3.9	- 3.4
Juice per fruit (cc.)	165.5	150.5	15	29	3
Vol. per fruit (cc.)	452	444	8	39	-42

These data indicated that mature inside and outside fruit differ widely in physical and chemical characters.

To determine if such differences existed at all times of the year, eight comparisons were made in April, 1936, followed by seven comparisons on the 1936-37 crop in September and four in December. These data, presented in Table 8, indicate that similar differences exist throughout the year, but that the difference in the percentage of juice by volume is less in the spring.

From these data it appears that the location of the fruit on the tree had a marked effect upon the percentage of peel, percentage of juice by weight and volume, percentage acid, Brix value, and the Brix:acid ratio. In every instance the ratio was higher in the outside fruit than in the inside fruit. About two thirds of this difference appeared to be due to a higher Brix value and the remainder to the lower percentage of acid. The percentage of juice by volume, however, was lower in the outside fruit in thirty-eight of the forty-two comparisons. This was accompanied by a correspond-

TABLE 8.—COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERS OF INSIDE AND OUTSIDE GRAPEFRUIT (1936).

	April, 1936		September, 1936		December, 1936	
	Inside	Outside	Inside	Outside	Inside	Outside
Brix (degrees).....	10.41	11.60	10.13	10.85	10.76	11.41
Acid (%).....	1.54	1.52	1.75	1.71	1.62	1.57
Brix:acid ratio....	6.84	7.67	5.78	6.34	6.74	7.34
Juice volume (%)...	35.3	34.5	28.8	26.0	37.8	36.3
Juice weight (%)...	48.1	45.7	40.5	37.5	-----	-----
Peel weight (%)___	37.1	40.2	37.6	40.4	-----	-----
Juice in edible portion (% by wt.)	76.6	76.4	64.8	62,8	-----	-----

ingly higher percentage of peel. If the percentage of juice is calculated excluding the peel, lesser differences between inside and outside fruit are evident.

In October, 1939, samples of ten fruit each were selected from the center, north, east, south, and west sides of a tree in each of two groves. The fruit was of uniform size and, except for the center samples, was picked in an area 3 to 6 feet above the ground within 15 inches of the outside of the tree. Data obtained are shown in Table 9. In addition to these samples, three fruits from each of these locations

TABLE 9.—ANALYSIS OF SAMPLES (TEN FRUIT EACH) FROM FIVE LOCATIONS ON INDIVIDUAL TREES (OCT. 21, 1939).

	Brix	Acid (%)	Brix: acid ratio	Juice volume (%)	Juice weight (%)	Vol. of fruit (cc.)	Color (%)
Grove A—Tree 1. ...							
North	11.46	1.85	6.19	28 2	40.6	416	36
East	11.64	1.89	6.16	29.2	41.8	408	35
South	11.67	1.72	6.80	31 3	43.0	383	30
West	11.46	1.69	6.79	28 4	41.7	425	3ft
Inside	10.88	1.77	6.14	31.0	42.7	433	25
Average	11.42	1.78	6.42	29.6	41.9	413	33
Grove B—Tree 1							
North	10,98	1.82	6.03	33.2	47.7	534	29
East	11.28	2.00	5.64	30.9	44.8	559	35
South	11.80	1.85	6.11	31.1	45.1	563	35
West	11.38	1.85	f.12	33 3	46.8	515	24
Inside	10.55	1.90	5.56	30.5	43.7	553	21
Average	11.10	1.88	5.89	31.8	45.6	545	29

on the same trees but representing a range of sizes were analyzed individually. The data obtained from these tests are tabulated in Table 10.

TABLE 10.—ANALYSIS OF INDIVIDUAL FRUIT FROM SINGLE TREES (OCT. 21, 1939).

Location	Approx. com'l size	Brix	Acid (50	Brix: acid ratio	Juice volume (70	Juice weight (%)	Vol. of fruit (cc.)	Color
Grove A—Tree 1								
North	70	11.40	1.86	6.12	26.6	38.7	510	55
North	80	11.33	1.80	6.28	32.2	37.1	435	35
North	126	11.50	2.04	5.63	30.8	44.9	305	40
East	70	11.19	1.93	6.49	29.2	45.4	510	40
East	100	11.25	1.97	5.71	31.7	47.2	375	45
East	126	11.35	1.97	5.78	30.3	45.2	340	30
South	64	11.47	1.63	7.04	28.9	44.7	615	30
South	80	11.67	1.72	6.79	32.6	48.6	466	30
South	100	11.37	1.90	5.99	36.2	49.8	370	35
West	70	11.49	1.66	6.92	32.2	47.7	550	30
West	100	11.59	1.83	6.34	28.1	43.3	395	30
West	126	11.19	1.93	5.79	30.8	45.3	295	30
Inside	80	11.05	1.78	6.21	32.1	47.0	470	30
Inside	100	10.63	1.88	5.65	34.6	47.8	335	40
Inside	126	10.49	2.09	5.01	34.6	48.7	315	35

TABLE 10.—ANALYSIS OF INDIVIDUAL FRUIT FROM SINGLE TREES (OCT. 21, 1939)—Continued.

Grove B—Tree 1								
North	.54	11.25	1.99	5.65	29.5	45.8	675	35
North	.80	11.00	1.93	5.70	33.2	49.5	470	35
North	1.00	11.00	2.08	5.28	38.2	50.7	340	40
East	.64	11.08	1.82	6.08	33.2	48.2	645	35
East	.80	11.38	2.04	5.58	32.7	47.7	490	40
East	1.00	11.88	2.26	5.26	31.7	45.7	370	45
South	.54	11.37	1.85	6.16	28.2	43.5	680	30
South	.80	11.35	2.03	5.59	30.2	46.0	520	25
South	1.00	11.48	2.12	5.41	32.5	41.8	335	30
West	.64	11.35	1.93	5.88	32.9	48.7	610	25
West	.80	11.61	1.87	6.20	36.8	50.4	465	35
West	1.00	11.65	1.88	6.20	37.1	49.0	380	25
Inside	.54	10.48	1.80	5.92	29.1	43.8	678	25
Inside	.80	10.65	2.11	5.05	31.7	44.5	485	35
Inside	1.00	11.11	2.17	5.12	38.4	49.3	360	40

The data in Tables 9 and 10 are presented to show the wide variations in Brix:acid ratio, and the percentage of juice of fruit which occurs on the same tree. Fruit from the inside, north, and east sides tends to have a lower Brix: acid ratio than fruit on the south and west sides. A study of these data indicates that errors in sampling may be reduced by selecting fruit of comparable sizes from the several parts of the tree in the proportion in which it occurs on those parts.

Summarizing the influence of size of fruit and location on the tree, it appears that a lower percentage of juice by volume and a higher Brix:acid ratio may be expected in large outside fruit on the south and west sides of the tree than in small fruit inside the tree*

Unit Functioning of Tree and Grove

One of the most interesting features arising from these studies is the relationship between Brix:acid ratio and the percentage of juice by volume which occurred in the fruit on each tree. This relationship is illustrated in the comparison of fruit from the two trees in Table 9. Despite its larger size, fruit from the tree in Grove B contained a higher percentage of juice than the fruit from the tree in Grove A, whereas the Brix:acid ratio was lower in fruit from Grove B than in fruit from Grove A.

Numerous tests made throughout the year on fruit from many groves have shown that when a relatively high percentage of juice and low Brix:acid ratio occur in the early season, the same relationship will continue as the fruit becomes mature. Similarly, in cases where high ratio and low juice are found early in the season, fruit of relatively high ratio and low juice will be found later in the season.

Commercial Grading

Ten-fruit samples of Fancy (No. 1 grade) and Choice (No. 2 grade) fruit were tested between December 1, 1935, and January 13, 1936. The data are averaged and compared in Table 11.

TABLE 11.—COMPARISON OF PERCENTAGE OF JUICE BY VOLUME AND BRIX:ACID RATIO IN FANCY AND CHOICE GRADES OF GRAPEFRUIT.

Com'l size	No. tests	Percentage juice		Brix:acid ratio	
		Fancy	Choice	Fancy	Choice
70	12	34.8	32.7	6.56	6.43
80	11	36.9	36.1	6.58	6.70
100	13	37.9	36.8	6.46	6.68

These studies indicate that Fancy fruit tends to have a higher percentage of juice by volume and a lower Brix:acid ratio than Choice fruit. The larger sizes in both grades contained a lower percentage of juice than the smaller sizes. Differences in Brix:acid ratio between sizes were not consistent. It is possible that the differences between grades reflect the effect of location of the fruit on the tree. Fancy fruit usually is found in the inside of the tree while Choice fruit frequently occurs nearer the outside.

Time Interval between Picking and Analysis

The percentage of juice by volume is markedly influenced by the interval between picking and analysis. A preliminary study to evaluate this source of error was made in November, 1936. Samples were carefully selected for uniformity of size and texture from a lot of colored, Fancy grade, unwaxed

fruit. They were stored at room conditions (temperature 68 to 74 degrees F., relative humidity 40 to 60 per cent) without wraps in an open box* A considerable loss in volume took place which was not paralleled by a loss of juice from the edible portion of the fruit. Thus an increase in the percentage of juice by volume was noted. No significant changes in the Brix:acid ratio occurred.

TABLE 12.—CEANGES IN GRAPEFRUIT DURING COLORING AND TEMPORARY STORAGE (SALT RIVER VALLEY, OCT. 25, 1939).

Time interval	Orig.[a]	Sweatroom 72 hrs.; storage 40 hrs.[a]	Room storage 5 days[b]	Room storage 6 days[b]	Room storage 10 days[b]
Volume measurements					
Original (cc. per fruit)	500	517	503	520	493
When analyzed (cc. per fruit)	500	494	455	458	431
Loss (%)	0	4.5	9.5	11.9	12.6
Juice (cc. per fruit)	162	167	168	167	165
When analyzed (%)	32.4	33.9	36.9	36.5	38.3
Weight measurements					
Original (gm. per fruit)	381	389	386	390	376
Loss (% of orig.)	0	3.3	6.7	8.2	10.5
Juice (% of orig.)	45.0	45.5	46.0	45.4	46.5
Peel (% of orig.)	34.7	32,8	28.7	28.2	25.9
Rag (% of orig.)	19.0	17.7	18.1	17.7	17.1
Total	98.7	99.3	99.5	99.5	100.0
Juice in peeled fruit (% when analyzed)	70.4	72.0	71.8	72.0	73.1
Brix	11.66	11.67	12.08	12.16	12.55
Acid (%)	1.74	1.73	1.82	1.82	1.89
Brix:acid ratio	6.70	6.75	6.62	6.68	6.64

[a] Average of three samples, ten fruit each.

[b] Average of two samples, ten fruit each.

To further evaluate these changes, a more complete study was initiated October 25, 1939. Recently picked fruit which had attained about 45 per cent color was carefully selected for uniformity of size and texture. Twelve samples, each containing ten fruit, were weighed and the volume deter-

mined. Three samples were tested immediately; the remaining nine were colored with ethylene gas in a commercial coloring room at 72 degrees F., with an average humidity of 92 per cent. After coloring, the unwrapped fruit was loosely placed in packing boxes and stored at room conditions. The data obtained in this experiment were averaged and set forth in Table 12.

These data after calculating deviations of individual samples did not indicate a significant change in the actual amount of juice during storage. The peel, however, became thinner and decreased in actual weight. This shrinkage of the peel caused an increase in the percentage of juice by volume during the interval of the experiment. Losses in volume during coloring averaged 4.5 per cent which produced an average increase of 1.5 per cent juice. An increase in the Brix and acid was recorded, but no significant change in the ratio took place.

It is evident that to determine accurately the percentage of juice by volume, analyses must be made soon after the fruit is removed from the tree.

Variations Related to Extraction

Composition of the Juice

Portion of Fruit Extracted.—Various workers (4, 21) have found that the juice from the stylar end of citrus fruit is lower in acid and higher in Brix:acid ratio than that from the stem end. Tests in the Salt River Valley (Table 13) indicate that the same situation exists in Arizona grapefruit during the fall. It also appears that the stylar end of the fruit contains slightly more juice and less peel.

Baier and Higby (3) and others have found that complete extraction of the edible juice is necessary for accurate determinations of the Brix:acid ratio because larger amounts of acid occur at the center of the fruit than near the peel. Many tests to further evaluate this factor were made in the present study. Typical data substantiating those of Baier and Higby are shown in Table 14.

From these data it is clear that juice in different parts of the fruit varies in composition, particularly with respect to the percentage of acid. The juice near the outside is low in acid, as is also that at the stylar end. Thus, the juice adjacent to the peel toward the stylar end con-

TABLE 13.—VARIATION IN COMPOSITION OF JUICE IN STEM AND STYLAR ENDS OF FRUIT.

	Brix		Acid (%)		Brix:acid ratio		Percentage by weight			
							Juice		Peel	
	Stem	Stylar	Stem	Stylar	Stem	Stylar	Stem	Stylar	Stem	Stylar
1935										
Oct. 20	10.96	11.04	1.78	1.61	6.16	6.76	----	----	----	----
Nov. 1	11.82	11.85	2.00	1.84	5.92	6.44	----	----	----	----
6	11.77	11.97	1.99	1.80	5.92	6.65	----	----	----	----
1938										
Oct. 14	11.12	11.23	1.90	1.69	5.86	6.62	45.8	48.8	37.8	36.4
14	10.63	10.71	1.74	1.56	6.11	6.86	49.5	50.1	33.4	33.6
25	12.17	12.07	2.04	1.81	5.96	6.67	48.4	51.0	33.2	31.5
1939										
Oct. 14	11.67	11.70	1.92	1.75	6.08	6.70	38.7	39.1	42.0	40.8
14	11.88	11.90	1.74	1.57	6.73	7.58	38.5	40.2	41.0	41.1

TABLE 14.—VARIATION IN COMPOSITION OF JUICE BETWEEN INNER AND OUTER PORTION OF FRUIT.

	October SO, 1938				April 18, 1939			
Fraction of juice	Brix	Acid (%)	Brix: acid ratio	Fraction of juice	Brix	Acid[a] (%)	Brix: acid ratio
Inside 32%..	11.38	2.19	5.20	Inside 41%..	10.15	1.59	6.38
Middle 28%..	11.87	1.82	6.52	Middle 23%..	9.85	1.25	7.88
Outside 40%.	11.95	1.48	8.07	Outside 36$.	9.63	1.12	8.60
Press extraction[a]..	12.93	1.20	10.78	Press extraction[a]..	10.03	0.98	10.20

[a]Juice extracted from juice-pulp mass remaining in strainer, using a Schriver fruit press. This fraction was rejected in routine operations.

tains the lowest percentage of acid and that nearest the center, toward the stem end, the highest percentage of acid. In extracting with a reamer-type extractor, the juice at the center is removed first; any unextracted juice is likely to he near the peel. Acidity of the juice and therefore the Brix:acid ratio can be markedly affected by the degree of extraction. Incomplete extraction produces a low Brix:acid ratio.

Type of Extractor.—The influence of different types of extractors upon the total soluble solids to acid ratio was reported by Baier and Higby (3) in 1931. Their tests indicated that extractors which permit oil and other liquids

from the peel to be incorporated with the juice give higher ratios than are obtained from juice which has been removed with a reamer-type extractor. Similar results obtained by the writer in tests upon uniform fruit samples are shown in Table 15. These data illustrate the differences which may be obtained by using different types of extractors.

TABLE 15.—EFFECT OF DIFFERENT TYPES OF EXTRACTORS UPON THE COMPOSITION OF JUICE.

Sunkist jr. extractor[a]			Gilchrist extractor[b]			Hand reamer[c]		
Brix	Acid (JO	Brix: acid ratio	Brix	Acid (JO	Brix: acid ratio	Brix	Acid (JO	Brix: acid ratio
10.84	1.96	5.54	11.01	1.90	5.79	10.83	1.94	5.59
10.75	1.92	5.60	10.71	1.86	5.75	10.69	1.98	5.40
10.62	2.05	5.18	10.74	1.93	5.57	10.68	2.03	5.26
-----	----	----	11.41	2.00	5.71	11.52	2.11	5.46
11.63	2.01	5.79	-----	----	----	11.71	2.08	5.63

[a]Mechanical reamer.

[b]Pressure extractor.

[c]Glass stationary hand reamer.

The glass reamer was found to produce juice having the widest variations. The Gilchrist extractor produced juice which was lower in acid than that obtained by the other extractors. This extractor exerts a high pressure and macerates the peel during extraction. The power reamer-type extractor removed all of the edible juice without extensively incorporating liquids from the peel where reasonable care in operation was used. This type of extractor is efficient, rapid, and the most practical for general use.

Air Incorporated during Extraction.—Studies by Wood and Reed (21) indicated that hand-powered reamer-type extractors did not add sufficient air to affect the readings of the Brix hydrometer. In the present studies motor-driven reamer-type extractors rated at 1,725 r.p.m. and 770 r.p.m. were employed. At such high speeds large amounts of air were incorporated into the juice, inviting errors in Brix determinations. The effect of this air upon the specific gravity of the solution as determined by a Brix hydrometer was tested frequently by permitting the juice to stand for varying periods exposed to atmospheric pressure and by deaerating under vacuum. The results of typical tests are presented in Table 16. These tests were conducted upon juice after it

TABLE 16.—EFFECT OF DEAERATION UPON THE BRIX VALUE.

Interval between extracting[a] and reading	Sample 1	Sample 2	Sample 3	Sample 4
1 minute	10.78	10.11	9.74	11.15
5 minutes	10.98	10.21	9.87	11.27
10 minutes	11.05	10.25	9.89	11.30
15 minutes	11.07	10.25	9.85	11.35
20 minutes	11.10	10.39	9.90	11.35
Check deaerated by vacuum	11.15	10.30	9.93	11.35

[a]Rated reamer speed 770 r.p.m.

had been strained through cheesecloth, an operation which removes part of the air.

It is evident that aeration during extraction may cause inaccuracies in Brix determinations. To obtain readings which are accurate to 0.1 per cent it is necessary to allow the juice to deaerate for 10 to 20 minutes.

Quantity of the Juice

Removal of Juice from Fruit.—The determination of the point at which all the juice has been removed from the fruit constitutes a problem in juice measurements. Florida workers (16) recommended the squeezing of individual peeled fruit in a fruit press under high pressure.

As an illustration of the differences in percentage of juice by volume which may be obtained by different operators, the results of a test made in 1935 on carefully selected samples are presented in Table 17.

TABLE 17.—VARIATIONS IN JUICE CONTENT MEN DETERMINED BY DIFFERENT PERSONS (SALT RIVER VALLEY, NOV. 19, 1935).

Operator	Vol. per fruit (cc.)	Juice per fruit (cc.)	Juice (%)
A	503	171	34.0
B	491	163	33.2
C	498	176	35.4

Assuming the samples were comparable, this test showed that considerable variations in the percentage of juice may be obtained by different operators. Fourteen duplicate tests made by the same operator showed an average difference be-

tween tests of 0,7 per cent juice. It appears that different percentages of juice may be obtained by different operators and even by the same operator. The variation in samples already discussed shows the impossibility of accurately checking these differences.

Removal of Juice from Juice-Pulp Mass.—While incomplete extraction of the juice from the fruit may occur, the major error appeared to be in the removal of the juice from the juice-pulp mass remaining in the strainer after the free juice had been stirred therefrom. To evaluate this source of error, the juice-pulp mass obtained from 100 fruits was placed in a container and thoroughly mixed. Samples containing 350 grams of this pulp were taken, and three operators using both hand squeezing and the Schriver fruit press extracted the juice. In order to translate the data to an effect on percentage of juice, it was assumed that the pulp had been obtained from a sample which contained 1,550 cc. of free juice and had a volume of 4,800 cc. The results are presented in Table 18.

TABLE 18.—INFLUENCE OF INDIVIDUAL OPERATOR AND METHOD UPON AMOUNT OF JUICE RECOVERED FROM JUICE-PULP MASS.

Operator	Hand squeezing			Schriver fruit press		
	Juice removed (cc.)	Juice removed (%)[a]	Total juice (%)[b]	Juice removed (cc.)	Juice removed (%)[a]	Total juice (%)[b]
A	130	37.1	35.0	110	31.5	34.6
	145	41.4	35.3	140	40.0	35.2
B	155	44.4	35.5	155	44.4	35.5
	165	47.2	35.7	150	42.8	35.4
C	120	34.3	34.8	140	40.0	35.2
	115	32.9	34.7	160	45.7	35.6

[a]Percentage of juice in 350 gm. of mass.

[b]Percentage of juice in theoretical sample having 1,550 cc. free juice and a fruit volume of 4,800 cc. The juice removed from the juice-pulp mass is added to 1,550 cc. free juice and percentages calculated

These data suggest that it is not possible to determine total percentage of juice by volume nearer than 1 per cent.

Since this source of error in juice determinations is present and since considerable labor is involved in removal of juice from the mass, the possibility that a method could be established which would eliminate the necessity for removing the juice from the juice-pulp mass was considered.

During October and November, 1938, records were made of the free juice, the juice extracted from the juice-pulp mass, and the weight of the juice-pulp mass in 100 samples.

These data presented three possible relationships:

1. A relationship between the free juice and the juice contained in the mass. The juice extracted from the juice-pulp mass averaged 8.96 per cent of the free juice, but was found to vary widely. When the percentage of juice was calculated on this basis, 20 per cent of the tests were in error in excess of 1 per cent juice.

2. A relationship between percentage of free juice and the percentage obtained by including the juice squeezed from the juice-pulp mass. The correct percentage of juice was found to average 2.8 per cent higher than the percentage obtained by ignoring the juice in the mass. Thirteen per cent of the tests so calculated were in error in excess of 1 per cent.

3. A relationship between the weight of the juice-pulp mass and the juice contained therein. Tests indicated that this relationship might be usable in determining the actual per cent juice of the fruit.

The latter relationship revealed that the juice-pulp mass contained an average of 41.87 per cent juice with an average deviation from this value of ±4.16 per cent. The practicability of substituting 42 per cent of the weight of the juice-pulp mass in place of the actual juice extracted in determining juice percentages was evaluated by calculating 100 tests. The calculated percentage of juice had an average deviation from the measured percentage of ±0.4 and a maximum deviation of 1.8. Only seven of the 100 tests varied more than 1 per cent from the actual percentage of juice, and fifty-one of the 100 tests had a deviation of less than 0.3 per cent.

An advantage of this calculation method is that allowance is made for unequal stirring of the juice-pulp mass in the strainer. For example, operator A may stir the pulp so that 350 grams of material remain to be weighed. Operator B may stir a similar sample so that only 300 grams remain. Multiplying the weight of the remaining pulp by 42 per cent, operator A has 147 cc. of juice to add. Similarly, operator B has 126 cc. of juice. However, he has removed 50 cc. more in stirring than A, so his total equals 176 cc. Thus, in-

stead of 50 cc. difference between operators, the variation is only 29 cc. Calculations show the resulting percentage of juice in the samples to be:

Operator A

Weight of juice-pulp mass	350
42 per cent of weight	147
Free juice	1,500 cc.
Total juice calculated	1,647

Percentage of juice in sample $\frac{1,647}{4,800} \times 100 = 34.3$

Operator B

Weight of juice-pulp mass	300
42 per cent of weight	126
Free juice	1,550 cc.
Total juice calculated	1,676

Percentage of juice in sample $\frac{1,676}{4,800} \times 100 = 34.9$

Summary of Part I

The physical and chemical characteristics of grapefruit vary with the size of the fruit at all seasons of the year. Large fruit tend to have a higher Brix:acid ratio and percentage of peel than small fruit. The average percentage of juice by volume was 7 per cent higher in small fruit (vol. 300 cc.) than in large fruit (vol. 650 cc.). This is due to the percentage of peel, as the percentage of juice in the edible portion is approximately the same in all sizes.

Fruit from the outside of the tree is typically higher in Brix:acid ratio and lower in percentage of juice by volume than fruit from the inside. Fruit on the south and west sides of the tree usually have a higher Brix:acid ratio than fruit on the east, north, or inside.

Inaccuracies in field sampling may be minimized by selecting fruit of uniform size and by including in the sample, fruit from the various parts of the tree in the numerical proportion in which it is borne by each part.

The percentage of juice by volume and weight based upon the whole fruit is higher after the fruit is commercially colored with ethylene. This is caused by the shrinkage of the peel during coloring. If values for juice percentages are to be representative, analysis should be made soon after removal of fruit from the tree.

Incomplete extraction of the juice or the incorporation of liquid from the peel affects the Brix:acid ratio. A power reamer is the most satisfactory method of extraction if care is taken to allow the juice to deaerate.

Juice values vary, depending upon the removal of the final fraction of juice from the pulp. There is evidence that percentage of juice by volume may be determined within an accuracy of 1 per cent by adding 42 per cent of the weight of the juice-pulp mass to the free juice.

PART II.—SEASONAL CHANGES IN THE RIPENING OF ARIZONA GRAPEFRUIT AND THEIR RELATION TO MATURITY

External Fruit Color

Seasonal Changes

Data on seasonal changes in external color of the fruit are set forth in Table 19. The change from green to the typical yellow of grapefruit is a gradual process taking place from September to December, the most rapid changes occurring during October and November. Comparing the Salt River Valley with the Yuma district, it is evident that the rate of coloration is about the same in the early season, but that full coloration occurs slightly earlier in the Yuma area. Marked seasonal differences in the rate of coloration occurred during the period studied.

TABLE 19.—AVERAGE SEASONAL CHANGES IN PERCENTAGE OF EXTERNAL COLOR.

	Salt River Valley (12 groves)							Yuma (5 groves)					
	1935	1936	1937	1938	1939	1939 High[a]	1939 Low[a]	1936	1937	1938	1939	1939 High[a]	1939 Low[a]
Sept. 8	8	—	11	16	12	17	10	—	17	11	11	12	11
16	8	20	18	20	16	19	13	—	19	18	14	15	12
23	9	—	18	18	18	28	12	—	21	22	16	17	16
30	14	27	21	23	23	32	13	29	23	24	17	18	17
Oct. 7	22	30	24	30	24	37	15	31	31	29	25	30	23
14	31	31	25	42	35	46	18	—	33	37	35	38	35
21	44	34	32	48	37	50	21	—	34	43	37	42	34
28	61	—	31	49	39	50	22	61	39	55	39	45	32
Nov. 3	75	57	39	58	42	58	20	80	52	58	49	60	42
11	82	71	43	61	44	74	21	88	55	67	50	55	45
18	86	82	68	72	53	92	23	93	72	90	69	80	65
25	93	87	84	90	80	92	35	91	79	96	86	94	78
Dec. 2	97	84	95	93	92	100	51	91	96	98	97	100	95
9	98	91	100	100	92	100	65	95	100	100	99	100	98
16	100	95	100	100	98	100	79	—	100	100	100	100	100
23	100	100	100	100	100	100	91	100	100	100	100	100	100
30	100	100	100	100	100	100	100	100	100	100	100	100	100

[a]Highest and lowest Talues found on the day tested.

The rate of coloration varies widely between groves* An example of the variation encountered is presented in the

high and low percentages of color which were found in 1939, Differences in rate of coloration are most marked during October and November. The date at which full coloration occurred varied as much as 35 days.

Relation to Maturity

In general, seasonal coloration of the fruit is associated with improvement in palatability. However, sufficient exceptions have been observed so that color alone cannot be used as a measure of maturity. This is illustrated in the high and low values recorded during November, 1939, in which fruit having 22 and 70 per cent color were deemed equally palatable. Fruit having less than 35 per cent color was seldom sufficiently palatable to be consumed. Except in a few instances, fruit which had attained 100 per cent color was mature.

Relation to Percentage of Juice and to Brix:Acid Ratio

Seasonal changes in color (Fig. 6) in general are associated with increases in percentage of juice and increases in Brix:acid ratio. However, wide differences have occurred in the relation of these features. Thus fruit may be fully colored and contain a low Brix:acid ratio or it may be only 35 per cent colored and contain almost a maximum amount of juice. Usually, fruit having less than 35 per cent color has a low Brix:acid ratio or a low juice content.

Color of the Juice

Seasonal Changes

Changes in color of the juice were estimated in 1939-40 by comparing with the color standards of Maerz and Paul (17). The data presented in Table 20 indicate a gradual

TABLE 20.—SEASONAL CHANGES IN COLOR[a] OF JUICES DURING 1939-40.

	Sept. 8	Oct. 5	Nov. 2	Deo* 1	Jan. 11	Feb. 21	Mar. 21	Apr. 18	May 15
Salt River Valley	1-c	1-c	1-c	1-d	1-d	1-C	1-C	1-f	1-g
Yuma	1-c	1-c	1-c	1-d	1-d	---	---	---	---

[a] Maerz and Paul, Dictionary of Color, Plate 10.

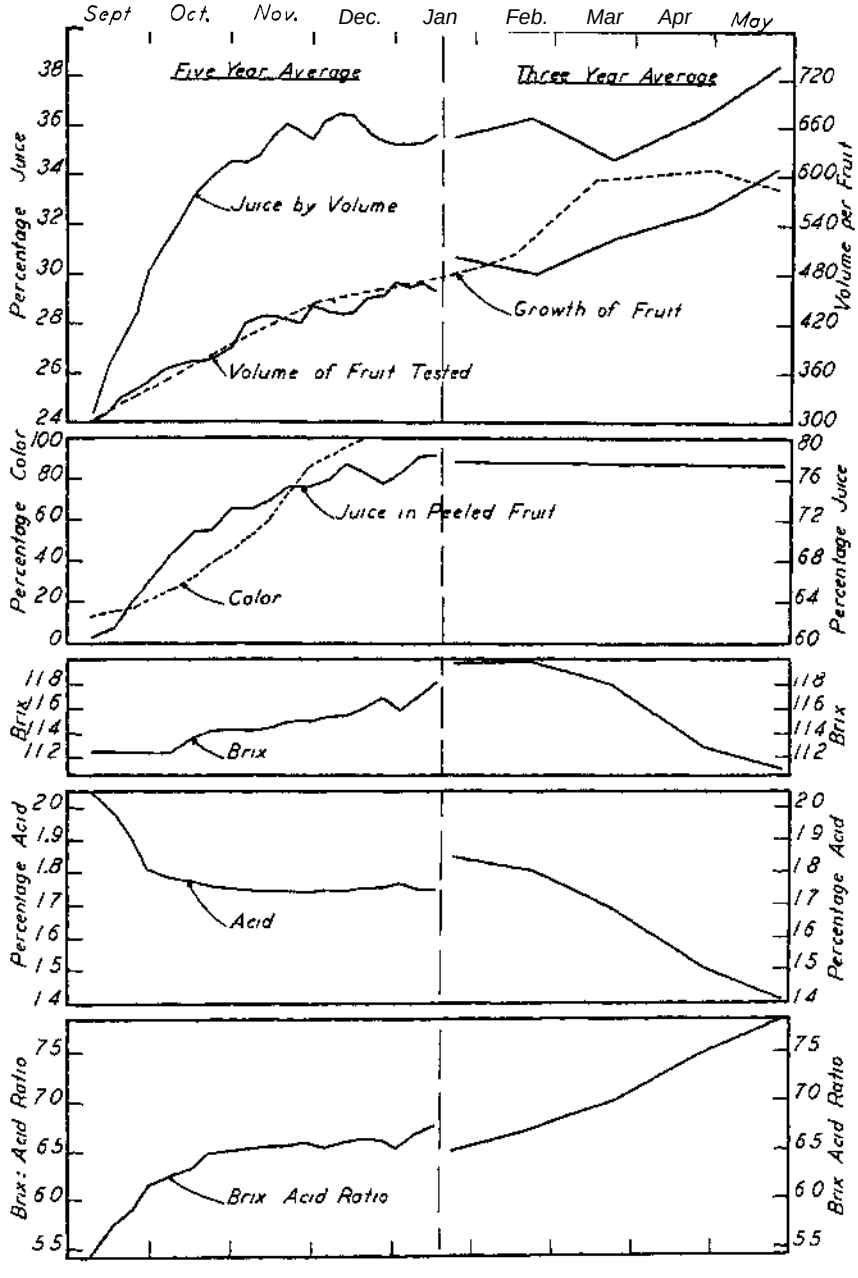

Figure 6.—Average seasonal changes in certain physical and chemical characteristics of Salt River Valley Marsh grapefruit, together with average growth curve as determined by Harris.

darkening from oyster white toward the sulphur yellow as the season advanced. No marked differences were found in the juice of fruit from different groves until the May 15 sample when a range from 1-f to 1-h on Plate 10 of the above standards was noted. The color of the juice did not appear to be closely related to edibility of the fruit.

Percentage of Total Soluble Solids (Brix)

Seasonal Changes

The seasonal changes in the percentage of total soluble solids (degrees Brix) are comparatively slight. The average trend for the Salt River Yalley (Fig. 6) indicates that an increase of 0.65 per cent occurs between September and mid-winter when the maximum amount is attained. Beginning in February a decrease occurs which accelerates as the season advances. Table 21 shows that this is frequently modified by seasonal conditions. In 1936 an increase of about 0.25 per cent took place, while in 1938 this increase amounted to about 1.00 per cent. It is also evident that slight variations in the magnitude of the Brix readings occur in different years.

The data for the Yuma area indicate that lesser increases occur through the season and that more uniform conditions exist between years. However, 1938 Brix readings were consistently higher than other years in all tests.

The range in Brix readings which may occur between groves is indicated in the high and low readings attained in each series of tests made in 1939. A difference of as much as 3.1 per cent in the Salt River Yalley and 1.7 per cent in the Yuma area was found. In each instance fruit from the same grove was respectively high and low in Brix values throughout the year. In the Salt River Yalley fruit from certain groves showed consistently low Brix values throughout the 5 years of the test period. The differences in Brix between groves have been considerably greater than yearly variations in the same grove.

Relation to Maturity

It is apparent that changes in Brix are relatively unimportant in determining those qualities which are associated with mature grapefruit. The absolute values are mean-

TABLE 21.—AVERAGE SEASONAL CHANGES IN PERCENTAGE OF TOTAL SOLUBLE SOLIDS (BRIX).

Date	Salt River Valley (12 groves)						
	1935	1936	1937	1938	1939	1939	
						High[a]	Low[a]
Sept. 8	11.38	-----	11.08	11.23	11.51	12.89	10.36
16	11.46	11.06	11.20	11.30	11.26	12.43	10.07
23	11.34	-----	11.13	11.45	11.22	12.46	9.91
30	11.39	10.91	11.17	11.44	11.11	12.48	9.91
Oct. 7	11.52	11.00	11.19	11.48	11.21	12.58	10.12
14	11.53	10.97	11.33	11.58	11.42	13.13	10.40
21	11.81	11.00	11.20	11.77	11.42	13.43	10.31
28	11.57	-----	11.56	11.69	11.51	13.68	10.25
Nov. 3	11.53	10.95	11.23	11.71	11.50	13.65	10.35
11	11.67	10.99	11.15	11.65	11.63	13.52	10.40
18	11.40	11.19	11.39	11.70	11.59	13.43	10.35
25	11.42	11.22	11.45	11.85	11.78	13.39	10.77
Dec. 2	11.44	11.16	11.15	12.00	11.62	13.20	10.17
9	11.52	11.25	11.40	11.85	11.94	13.75	10.59
16	11.56	11.21	11.52	12.13	11.84	13.65	10.65
23	11.75	11.24	11.76	11.88	11.69	13.43	10.38
30	11.75	11.28	11.21	11.83	11.95	13.38	10.65
Jan. 6	11.67	11.21	11.70	12.04	11.89	13.38	10.50
13	11.95	11.23	11.81	12.26	11.89	13.38	10.25
20	12.08	11.29	-----	12.52	11.97	13.28	10.73
28	12.40	11.22		12.08	-----	-----	-----
Feb. 21	12.22	-----	-----	12.30	11.82	13.03	10.89
Mar. 7	11.94	-----	-----	-----	-----	-----	-----
21	11.95	-----	-----	11.85	11.72	12.95	10.47
Apr. 20	11.35	-----	-----	11.24	11.34	12.50	10.48
May 22	-----	-----	-----	10.81	11.52	12.25	10.10

Date	Yuma (5 groves)					
	1936	1937	1938	1939	1939	
					High[a]	Low[a]
Sept. 8	-----	10.41	10.93	10.81	11.19	10.39
16	-----	10.74	10.98	10.65	11.04	10.22
23	-----	10.66	10.97	10.70	11.15	10.16
30	10.64	10.61	10.85	10.71	11.13	10.12
Oct. 7	10.77	10.73	10.87	10.75	11.17	10.35
14	-----	10.64	11.22	10.70	11.19	10.23
21	10.75	10.73	11.03	10.89	11.48	10.38
28	10.75	10.68	11.03	10.90	11.25	10.19

[a]Highest and lowest values found on the day tested.

TABLE 21.—AVERAGE SEASONAL CHANGES IN PERCENTAGE OF TOTAL SOLUBLE SOLIDS (BRIX)— Continued.

Nov.	3	10.76	10.62	11.09	10.83	11.33	9.92
	11	11.36	10.68	11.06	10.87	11.27	9.99
	18	11.07	10.61	11.09	10.64	10.93	9.98
	25	10.88	10.60	11.17	10.85	11.11	9.88
Dec.	2	10.73	10.69	11.19	10.87	11.37	9.92
	9	10.81	10.66	11.24	10.78	11.25	9.85
	16	-----	10.70	11.38	10.95	11.55	9.95
	23	11.03	10.73	11.39	10.87	11.35	9.81
	30	-----	10.77	11.27	10.88	11.45	9.75
Jan.	6	10.66	10.83	11.32	11.11	11.70	10.05
	13	-----	10.74	11.29	10.98	11.48	9.70
	20	10.65	-----	11.26	11.07	11.43	9.85
	28	10.74	-----	-----	-----	-----	-----

ingless as an indication of maturity. This is evident from the high and low values occurring during 1939. Immature fruit from one grove contained 12.89 per cent total soluble solids in September, whereas mature fruit from another grove contained only 10.17 per cent in December.

Percentage of Acid

Seasonal Changes

Marked changes occur in the percentage of acid in grapefruit juice during the season (Table 22, Fig. 6). In early September the acid is typically high. It decreases rather rapidly and more or less uniformly until late October or early November. During November, December, and January only slight changes occur. Beginning in February a decrease takes place which continues throughout the remainder of the season, the rate of decrease accelerating during April and May. These average changes have been found to be subject to considerable variation in several of the years studied.

In the Salt River Yalley in all years except 1936 the acid appeared to attain a low point during late October or early November and increase slightly during late November and December. In the Yuma district this condition occurred in 1937 when the acid increased from 1.51 per cent in October to 1.65 in late December and early January. The tests in the 3 other years indicate that this fall increase in acid is not as pronounced in the Yuma area as in the Salt River Valley district.

TABLE [illegible].—AVERAGE SEAS[illegible] CHANGE[illegible] IN PERCENTAGE OF ACID.

Date	Salt River Valley (12 groves)							Yuma (6 groves)					
	1935	1936	1937	1938	1939	1939 High*	1939 Low[a]	1936	1937	1938	1939	1939 High[a]	1939 Low[a]
Sept. 8	2.12	----	1.97	2.10	2.19	2.39	1.94	----	1.01	2.01	1.88	1.99	1.80
10	2.07	1.92	1.88	1.89	2.07	2.27	1.85	----	1.85	1.91	1.80	1.95	1.81
20	2.00	----	1.85	1.91	2.00	2.20	1.86	----	1.51	1.78	1.77	1.88	1.71
30	1.98	1.80	1.75	1.81	1.80	2.04	1.87	1.44	1.51	1.89	1.80	1.73	1.60
Oct. 7	1.88	1.74	1.77	1.88	1.88	2.05	1.72	1.07	1.64	1.88	1.80	1.70	1.60
14	1.80	1.98	1.72	1.82	1.88	2.14	1.78	----	1.58	1.88	1.71	1.77	1.68
21	1.80	1.98	1.71	1.82	1.84	2.10	1.78	1.42	1.50	1.82	1.84	1.78	1.55
28	1.89	----	1.64	1.77	1.82	2.10	1.82	1.41	1.44	1.59	1.81	1.71	1.53
Nov. 8	1.84	1.70	1.68	1.78	1.83	2.13	1.88	1.41	1.63	1.64	1.84	1.74	1.58
11	1.86	1.87	1.70	1.72	1.79	2.10	1.80	1.40	1.61	1.59	1.84	1.82	1.58
18	1.80	1.90	1.86	1.78	1.81	2.12	1.71	1.48	1.64	1.59	1.67	1.68	1.48
25	1.81	1.80	1.86	1.78	1.87	2.00	1.86	1.89	1.67	1.57	1.80	1.77	1.61
Dec. 2	1.78	1.68	1.98	1.79	1.83	2.21	1.84	1.39	1.69	1.80	1.81	1.87	1.52
9	1.80	1.63	1.89	1.74	1.85	2.15	1.57	1.41	1.81	1.56	1.82	1.89	1.53
16	1.84	1.82	1.90	1.76	1.89	2.32	1.73	----	1.83	1.55	1.65	1.74	1.52
23	1.80	1.90	1.90	1.78	1.81	2.21	1.86	1.49	1.86	1.60	1.65	1.72	1.55
30	1.80	1.82	1.98	1.81	1.86	2.24	1.70	----	1.84	1.81	1.82	1.86	1.67
Jan. 6	1.81	1.80	1.69	1.80	1.84	2.00	1.88	1.44	1.86	1.59	1.88	1.95	1.64
13	1.80	1.80	1.71	1.78	1.80	2.10	1.86	----	1.84	1.61	1.80	1.89	1.53
20	1.80	1.80	----	1.77	1.80	2.10	1.86	1.42	----	1.90	1.88	1.90	1.47
28	1.88	1.80	----	1.81	----	----	----	1.84	----	----	----	----	----
Feb. 1	1.88	----	----	1.90	1.80	2.00	1.82	----	----	----	----	----	----
Mar. 7	1.79	----	--	-	-	-	-	----	----	----	----	----	----
14	1.68	----	--	1.85	1.86	2.22	1.81	----	----	----	----	----	----
Apr. 20	1.48	----	----	1.48	1.80	2.02	1.42	----	----	----	----	----	----
May 22	----	1.80	----	1.81	1.81	1.84	1.84	----	----	----	----	----	----

[a]Highest and lowest values found on the day tested.

The data of Table 22 reveal that rather wide differences in the amount of acid have occurred between years and districts. The lowest acid during the period of the investigation occurred in 1936 in both districts. In the Salt River Valley the fruit contained very high amounts of acid in 1935 and 1939. Comparing the two areas, it is evident that the acid in the fruit from the Yuma district is 0.1 to 0.2 per cent lower than that in Salt River Valley fruit. However, the range between the high and low amounts is considerably greater in the latter area. Thus, the groves producing fruit with the lowest amounts of acid in the Salt River Valley approach the average for the Tuma district.

Relation to Maturity

The percentage of acid in the fruit is related to the total soluble solids. A high percentage of total soluble solids is usually accompanied by a high percentage of acid, while fruit with a low Brix value usually has a low per cent acid. Since this occurs, no definite relationship can be established between numerical percentages of acid and palatability. Thus, because of the values of the accompanying Brix, color, and juice, fruit containing 1.75 per cent acid may be equally as palatable as fruit containing 1*5 per cent acid.

Total Soluble Solids (Brix):Acid Ratio

Seasonal Changes

A decrease of 0.1 per cent in acid affects the ratio of total soluble solids to acid approximately as much as an increase of 0.65 per cent in the total soluble solids. Table 21 indicates that the average increase in Brix amounts to approximately 0.65 per cent between September and midwinter. Since the acid decreases approximately 0.30 per cent during this period, it is evident that the major changes in the ratio of Brix to acid are due to the changes in the acid.

In September this ratio is typically low (Table 23 and Fig. 6). It increases rapidly and more or less uniformly until late October or early November. From late November through January only- slight changes take place. In the spring an increase again occurs which continues at an accelerated rate as the season advances.

TABLE 88.—AVERAGE SEASONAL CHANGES IN TOTAL SOLUBLE SOLIDS (S S X) TO ACID RATIO

Date	Salt River Valley (12 groves)							Yuma (5 groves)					
	1985	1986	1987	1988	1989	1989 High[a]	1989 Low[a]	1988	1987	1988	1989	1989 High[a]	1989 Low[a]
Sept. 8	5.80	----	5.88	5.30	5.80	5.81	4.90	----	8.10	5.45	5.75	8.02	5.88
10	5.54	5.08	8.08	5.60	5.44	5.84	4.81	----	8.58	5.74	5.78	8.49	5.48
12	5.88	----	6.00	8.80	5.81	8.80	4.88	----	7.08	8.18	8.06	8.3	5.88
30	5.81	8.05	6.80	8.83	8.80	8.84	5.19	7.85	8.04	8.48	8.41	8.5	5.88
Oct. 7	8.18	8.83	8.81	6.28	8.14	8.70	5.57	7.88	7.88	8.45	8.48	8.69	8.12
14	8.41	8.81	8.81	8.37	8.00	6.70	5.81	----	6.88	8.73	8.24	8.64	5.88
21	8.57	8.89	8.81	8.48	8.30	6.97	5.47	7.88	7.14	8.81	8.68	8.71	8.5
28	8.12	----	7.88	8.61	8.88	7.44	5.45	7.68	7.42	8.91	8.78	7.17	8.38
Nov. 3	8.86	8.48	8.78	8.88	8.88	8.88	5.75	7.68	6.86	6.74	8.80	7.18	8.88
11	8.27	8.58	8.58	8.78	8.80	7.88	5.84	8.14	7.07	6.98	8.85	7.08	8.18
18	6.27	8.80	8.88	8.86	8.42	7.07	5.68	7.74	8.88	6.90	8.79	7.14	8.45
25	6.32	8.81	8.88	8.85	8.84	7.02	5.88	7.83	8.78	7.08	8.57	6.86	8.14
Dec. 2	6.43	8.88	8.44	8.88	8.38	7.10	5.45	7.88	8.03	6.93	8.77	7.21	8.52
9	8.41	8.88	8.64	8.82	6.34	7.29	5.58	7.88	8.88	7.20	8.65	8.98	8.44
16	8.28	8.88	6.73	8.89	6.27	6.73	5.38	----	8.88	7.29	8.85	8.98	8.48
23	8.48	8.88	6.95	8.87	8.47	7.19	5.64	7.54	8.45	7.09	8.59	8.78	6.83
30	8.48	8.88	8.88	8.88	8.44	7.10	5.58	----	8.56	7.00	8.69	8.98	6.81
Jan. 6	6.45	6.28	6.94	8.78	8.52	7.58	5.48	8.40	8.88	7.11	8.81	7.18	6.88
13	6.64	7.01	6.94	8.88	8.53	7.48	5.68	8.88	8.88	6.98	8.87	7.18	8.84
20	8.48	7.18	----	8.88	8.38	7.88	5.58	8.88	----	6.93	8.88	7.84	8.78
27	8.81	7.18	----	8.88	----	----	----	8.81	----	----	----	----	----
Feb. 24	6.71	----	----	8.85	8.88	8.88	5.62	----	----	----	----	----	----
Mar. 8	6.84	----	---	- -	-	7	- -	----	----	----	----	----	----
21	7.80	----	---	8.16	8.71	7.88	5.81	----	----	----	----	----	----
Apr. 8	7.47	----	----	7.82	8.17	8.88	6.18	----	----	----	----	----	----
May 8	----	----	----	8.81	7.88	8.84	8.87	----	----	----	----	----	----

[a]Highest and lowest values on the day tested.

Seasonal differences occurred between districts. In fruit of the Yuma area the high point attained in the fall was frequently recorded earlier; the period of slight change was less marked; and the ratio began to increase slightly earlier in the spring than in Salt River Valley fruit.

The increase in the acid previously noted in November and December was reflected in a decrease in the ratio in some seasons during the investigation. In the Salt River Yalley decreases were noted in late October, 1935; early December, 1937; late December, 1938; and in October and December, 1939. The most marked instance of a decrease occurred in the Yuma district in 1937 when the ratio decreased from 7.06:1 in October to 6.51:1 in late December. Variations in samples have undoubtedly influenced the results to a certain extent; however, in the cases pointed out it appeared that actual decreases in ratio had occurred.

Yearly variations in ratio are closely related to the acid variations. In seasons when the acid tends to be high the Brix:acid ratio tends to be low. In the Salt River Valley the ratio was high in 1936 and 1937 and low in 1935 and 1939.

Yuma fruit was 7 to 20 days earlier in attaining a 6.0:1 Brix:acid ratio and from 0.3 to 0.8 higher ratio in December than the Salt River Valley. However, individual groves in the latter area attained a ratio as high as found in the Yuma area.

Relation to Maturity

In general, a relationship exists between Brix:acid ratio and palatability of the fruit, since the ratio tends to increase throughout the season. However, high ratios may be attained early in the season when the fruit is still not palatable. Similarly, fruit may be palatable and have a rather low ratio. Furthermore, there is no definite and fixed numerical ratio at which all fruit becomes palatable, nor is ratio in itself an indication of palatability. These points are clearly indicated by comparing the maturity of the fruit having the high and low ratios during 1939. One grove (Table 23) produced fruit having a ratio of 6.3:1 on September 23, while fruit from another grove did not attain this ratio until late April. There was a marked difference in palatability of the fruit from these two groves, but not as great as is indicated by the wide difference in time at

which the same ratio was attained. In January, 1940, mature Salt River Valley grapefruit varied from 7.53:1 to 5.49:1 in Brix:acid ratio.

Relation to Color and Percentage Juice

A close relationship does not exist between any numerical ratio and color. Fruit may be fully colored and have a relatively low ratio, or may be 25 per cent colored and have a relatively high ratio. Seasonal changes during September and October indicate that increases in ratio are paralleled by increases in juice. After November 1 this correlation becomes less. However, palatability studies indicate that a high Brix:acid ratio and a low percentage of juice or a low Brix:acid ratio and a high percentage of juice may frequently be found in equally palatable fruit.

Juiciness of the Fruit

Estimation of Juiciness

In these studies juiciness has been measured as percentage by volume of the whole fruit, as percentage by weight of the whole fruit, and as percentage by weight of the peeled fruit. Percentages based on the whole fruit are affected by the amount of peel and are not an entirely satisfactory measure of juiciness. Since the amount of peel influences the percentages of juice found in different sizes of fruit, corrections must be made for fruit size. The peel affects the percentages by volume more than the percentage by weight because the specific gravity of the peel is less than that of the edible portion. Thus a higher portion of the fruit is peel when determined on a volume basis. However, a greater relative increase takes place in percentage of juice by volume than by weight, so more significance may be attached to small differences.

The most accurate determination of juice is obtained if the percentage is calculated upon the basis of the peeled fruit. This necessitates either removing the peel and pressing the juice, or determining the amount of peel after extracting the juice. Either method entails additional labor, is slower, and is not particularly well adapted to commercial or standardization service practice.

Seasonal Changes *in* Percentages of Juice by Volume

The percentage of juice based on the volume of the fruit increases rapidly and uniformly during September, October, and early November (Table 24 and Fig. 6). After mid-November the rate of increase gradually diminishes. Sometime between December 1 and 20 the maximum percentage of juice is attained. The decrease recorded during late January, February, and March and the slight increase in late April and May are not due to actual changes in the juiciness of the fruit but to changes in the size of the fruit and thickness of the peel.

The data presented in Tables 24 and 25 show respectively the average of percentage of juice obtained each week and the average volume of the fruit tested* Since the samples represented average-sized fruit, the size of the fruit tested gradually increased. Table 25 shows that the fruit increased in size approximately 100 per cent between September and May. This corresponds closely to the average increases in growth of fruit recorded by Harris (12) and shown in Figure 6.

In evaluating these seasonal changes in percentage juice, the size of the fruit tested must be considered. Since the fruit increased in size, the actual seasonal increases in percentage of juice are even greater than indicated in Table 24. Similarly, the variations in fruit size between years and between the districts make comparisons of juice percentage by volume inaccurate unless calculated to a common size. In order to make direct comparisons of percentage juice the data were calculated on a basis of size 80 fruit (volume 475 cc.)[2]

The data thus converted are set forth in Table 26. In the Salt River Valley the maximum amount of juice obtained

[2]It has been shown in Table 12 that the average change in percentage of juice due to fruit size is 1 per cent for each 50 cc. change in volume. Using this as a basis, the percentage of juice was either raised or lowered 1 per cent for each 50 cc. difference in volume either above or below 475 cc. An example of this calculation is as follows: The January 20, 1935, samples averaged 54.9 per cent juice and 400 cc. in volume. Subtracting 400 from 475 results in a difference of 75 cc. in volume. Dividing 75 by 50 equals 1.5, the percentage of juice to be used for correction. Since the fruit is smaller and therefore normally contains more juice than size 80, 1.5 per cent is subtracted from 54.9 to equal 33.4, the percentage of juice found in an average sample equivalent

varied from 34 per cent in 1935 to 37 per cent in 1936. The date at which 32 per cent was attained varied from October 10 to November 8. In 1935, 1937, and 1939 lesser percentages of juice were found in the fruit than in 1936 and 1938.

The maximum percentage of juice in fruit from the Yuma area varied from 33 to 36 per cent during the 4 years studied. In general, this fruit was from 7 to 15 days later in attaining 32 per cent juice than that from the Salt River Valley and contained from 1 to 3 per cent less juice when the maximum was reached.

Relation of Percentage of Juice by Volume to Maturity

The percentage of juice by volume may be correlated with palatability in that rapid increases in juice occur during the early fall when the fruit is becoming palatable. However, a rather wide range in the percentage of juice exists between palatable fruit as shown by the high and low values during January. This is partially due to the effect of varying peel thicknesses. Palatability during October and November is also related to the accompanying Brix:acid ratio.

Relation of Percentage of Juice by Volume to Color and Brix:Acid Ratio

The percentage of juice by volume tends to increase more rapidly during September and October than does fruit color. The percentage of juice and the Brix:acid ratio increase during September and October. However, fruit of equal palatability was found which had either a high percentage of juice and a low Brix:acid ratio or a low percentage of juice and a high Brix:acid ratio.

Seasonal Changes in Percentage of Juice by Weight

The seasonal changes in percentage of juice by weight was studied in 1937, 1938, and 1939. The data presented in Table 27 indicate that these changes closely parallel the changes in percentage of juice by volume. A rapid increase in the

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to size 80 fruit. This correction applied to an individual sample may vary somewhat from the actual amount of juice found in size 80 fruit on the same trees. However, by applying this average difference to average data, only minor variations have been found.

TABLE 24.—AVERAGE SEASONAL CHANGES IN PERCENTAGE OF JUICE BY VOLUME.

Date	Salt River Valley (12 groves)							Yuma (5 groves)					
	1936	1936	1937	1938	1939	1939		1938	1937	1938	1939	1939	
						High[a]	Low[a]					High[a]	Low[a]
Sept. 8	34.4	----	25.6	25.8	20.8	24.3	16.9	----	27.5	23.4	22.5	25.9	20.3
15	35.8	34.9	28.9	28.9	28.3	28.7	21.1	----	29.8	25.7	24.0	27.7	24.5
23	37.5	----	30.2	27.8	24.9	29.7	20.0	----	29.7	27.0	24.5	26.5	20.8
30	39.8	31.1	31.9	31.8	28.0	31.9	28.1	28.8	32.8	28.7	27.7	31.7	25.0
Oct. 7	31.2	32.1	32.[illegible]	31.2	29.2	32.3	26.0	29.0	30.7	29.1	29.0	34.3	29.7
14	38.1	38.9	34.3	38.8	30.3	34.3	27.7	----	30.2	29.6	30.2	34.1	27.9
21	38.8	34.6	35.0	38.8	31.6	35.4	28.8	31.4	33.4	31.1	31.2	36.0	28.8
28	34.7	----	35.9	35.0	38.6	36.8	30.0	38.0	36.5	32.7	32.0	38.0	29.9
Nov. 4	34.8	35.8	36.0	38.8	38.8	35.8	38.4	32.2	35.6	38.1	31.6	38.[illegible]	31.4
11	34.2	35.8	38.1	34.7	38.6	36.5	31.9	32.0	36.8	33.5	33.8	38.3	31.7
18	35.8	38.8	38.7	36.7	35.4	40.2	34.3	32.9	36.9	32.9	33.8	38.7	31.7
25	34.8	35.8	38.0	36.2	38.2	41.4	38.0	31.6	38.8	38.5	38.8	38.0	30.5
Dec. 2	35.4	36.8	38.9	35.0	34.1	37.4	38.3	38.2	38.0	38.0	38.4	39.1	31.0
9	34.9	38.4	37.1	37.3	38.8	41.4	34.5	30.0	38.9	34.4	33.1	37.6	31.8
16	34.9	38.6	38.1	30.4	38.8	38.4	38.7	-x--	35.8	33.9	31.8	30.1	29.4
23	35.1	38.1	35.7	34.0	34.7	40.1	31.7	31.8	38.1	38.7	38.8	30.0	31.1
30	34.5	38.4	34.3	35.4	34.4	39.4	31.4	----	38.2	32.4	38.0	38.0	31.5
Jan. 6	34.4	35.[illegible]	38.0	35.8	35.9	40.1	31.7	31.5	38.0	32.8	38.2	38.0	31.2
13	34.0	35.8	38.8	35.8	35.8	39.6	32.1	----	35.5	32.1	31.7	35.8	30.9
20	34.9	38.1	--	38.5	34.9	39.2	39.1	32.8	----	31.1	38.8	35.8	30.0
28	38.4	34.8	----	35.5	----	----	----	32.9	----	----	------	----	----
Feb. 31	33.0	----	----	38.8	38.0a	38.8	38.4	----	----	----	----	----	----
Mar. 7	32.7	----	----	-	-	-	-	----	----	----	----	----	----
31	38.[illegible]	----	----	38.0	31.0	35.8	38.[illegible]	----	----	----	----	----	----
Apr. 30	38.0a	----	----	38.[illegible]	31.0a	38.8	38.9	----	----	----	----	----	----
May 30	----	----	----	38.5	35.0	38.8	31.0	----	----	----	----	----	----

[a] Highest and lowest values found on day tested.

TABLE 25.—VOLUME (cc.) OF FRUIT TESTED IN DETERMINING SEASONAL CHANGES IN PERCENTAGE OF JUICE BY VOLUME.

Date	Salt River Valley (12 groves)							Yuma (5 groves)					
	1935	1936	1937	1938	1939	1939 High[a]	1939 Low[a]	1936	1937	1938	1939	1939 High[a]	1939 Low[a]
Sept. 8	272	---	269	313	316	342	294	---	394	358	349	312	342
16	285	357	268	330	328	358	346	---	345	393	388	360	360
23	305	---	283	393	332	363	329	---	441	428	421	321	456
30	322	384	308	370	372	371	323	441	418	435	400	340	452
Oct. 7	338	410	339	384	387	400	432	448	434	451	377	308	430
14	352	419	325	402	391	396	429	---	474	481	386	344	406
21	352	439	330	392	405	428	436	468	467	481	407	344	471
28	361	---	308	432	396	454	398	493	499	491	434	364	442
Nov. 3	390	449	369	474	434	458	473	494	500	497	449	377	385
11	390	482	369	481	443	417	400	532	491	506	433	377	389
18	402	490	351	454	456	387	392	511	539	539	479	439	478
25	412	548	352	420	394	350	392	577	541	536	494	392	523
Dec. 2	416	516	405	436	500	531	542	588	532	519	470	402	500
9	431	491	347	465	417	402	406	560	552	565	474	425	429
16	409	518	346	448	445	452	492	---	594	548	505	421	542
23	438	528	347	527	484	464	508	524	554	561	463	425	475
30	456	516	421	507	494	504	425	---	550	573	529	467	529
Jan. 6	455	530	361	510	464	492	465	517	544	563	505	442	544
13	444	525	365	495	518	511	566	---	596	605	576	502	586
20	400	525	---	450	513	550	577	507	---	650	531	458	573
28	425	528	---	507	---	---	---	513	---	---	---	---	---
Feb. 21	458	---	---	483	596	573	598	---	---	---	---	---	---
Mar. 7	485	---	---	---	---	---	---	---	---	---	---	---	---
21	500	---	---	531	609	571	581	---	---	---	---	---	---
Apr. 20	515	---	---	562	623	618	637	---	---	---	---	---	---
May 22	---	---	---	615	633	625	573	---	---	---	---	---	---

[a] Highest and lowest values found on day tested.

TABLE 26.—AVERAGE SEASONAL CHANGES IN PERCENTAGE OF JUICE BY VOLUME CONVERTED TO EQUIVALENT OF SIZE 80.

Date	Salt River Valley (12 groves)							Yuma (5 groves)					
	1935	1936	1937	1938	1939	1940		1936	1937	1938	1939	1938	
						High[a]	Low[a]					High[a]	Low[a]
Sept. 7	80.4	----	82.8	88.7	87.7	82.4	78.6	----	80.0	82.2	80.0	88.4	87.6
14	81.6	88.7	84.0	88.0	84.2	84.4	78.6	----	24.4	84.1	82.3	89.4	22.2
21	84.8	----	86.4	89.0	82.0	87.4	76.0	----	22.5	86.2	83.4	85.4	22.4
28	86.8	88.8	88.6	88.0	84.2	87.8	82.0	87.7	88.2	88.0	86.2	88.0	22.2
Oct. 7	88.4	89.0	89.3	88.3	87.5	88.7	83.0	88.4	27.8	88.7	87.0	89.0	85.6
14	89.4	88.0	88.0	88.3	87.7	83.0	84.0	----	28.4	89.6	88.0	89.4	86.5
21	83.0	88.7	82.8	81.0	83.0	88.0	84.0	88.7	88.7	89.0	83.0	88.0	88.8
28	83.0	---1	82.5	84.8	83.0	88.0	84.0	88.6	88.6	89.0	88.7	89.0	89.3
Nov. 3	88.8	85.0	88.1	83.3	81.5	85.6	88.4	88.6	82.8	82.5	88.1	84.3	89.4
11	88.2	85.3	88.0	84.8	88.9	87.4	80.4	88.7	84.1	84.0	88.4	86.1	80.0
18	88.6	86.8	88.0	85.8	85.1	88.5	88.4	88.4	84.8	84.1	88.4	86.1	87.7
25	88.0	87.0	88.5	84.7	84.6	88.0	81.8	88.6	85.4	84.7	88.4	84.0	85.5
Dec. 2	84.0	86.7	85.4	84.8	84.6	87.0	88.0	88.0	88.3	84.1	88.0	87.6	81.8
9	84.0	86.7	84.6	87.0	85.7	84.0	88.3	88.0	86.2	86.1	88.0	86.6	80.8
16	88.6	87.0	88.6	88.6	85.7	87.0	88.1	----	83.5	85.0	83.0	84.0	30.6
23	84.0	87.1	88.0	35.0	84.0	88.1	88.3	88.0	88.7	84.0	83.0	36.0	31.1
30	84.0	87.0	88.0	35.7	84.0	89.6	88.4	----	84.2	84.1	83.0	30.1	82.5
Jan. 6	88.0	88.0	83.7	85.7	85.7	40.0	88.5	88.4	84.9	84.7	83.7	88.6	32.6
13	83.4	86.0	84.0	88.0	88.0	40.2	88.7	----	85.1	84.4	88.7	86.0	31.0
20	83.4	87.0	----	86.0	85.6	40.7	88.1	88.0	----	84.5	88.4	85.6	32.0
27	88.5	85.0	----	88.0	----	----	----	88.0	----	----	----	----	----
Feb. 1	88.0	----	----	84.4	85.3	88.4	88.7	----	----	----	----	----	----
Mar. 7	81.7	----	----	-	-	-	--	----	----	----	----	----	----
21	84.0	----	----	85.0	83.7	87.5	88.5	----	----	----	----	----	----
Apr. 20	87.0	----	----	37.7	84.6	88.8	89.5	----	----	----	----	----	----
May 22	----	----	----	41.4	88.1	42.2	83.0	----	----	----	----	----	----

[a]Highest and lowest values found on day tested.

TABLE 87.—AVERAGE SEASONAL CHANGES IN PERCENTAGE OF JUICE BY WEIGHT.

Date	Salt River Valley (12 groves)					Yuma (5 groves)				
	1837	1838	1838	1838		1837	1838	1838	1838	
				High[a]	Low[a]				High[a]	Low[a]
Sept. 8	[illegible]	37.5	38.0	36.0	33.3	38.0	39.0	38.0	39.0	38.7
16	36.7	37.0	39.0	39.0	34.4	40.0	40.8	37.0	40.0	34.6
24	41.7	40.0	40.0	40.7	39.6	40.0	41.6	40.0	42.0	36.9
30	40.7	40.0	40.0	43.0	38.0	42.0	40.0	41.0	46.0	38.3
Oct. 7	48.0	43.0	44.0	46.0	37.0	48.0	44.0	43.0	47.0	41.7
14	46.0	46.5	48.0	47.0	38.7	46.7	44.0	44.0	47.0	42.7
21	48.0	45.8	44.3	48.0	41.0	46.8	47.0	46.4	52.0	44.1
28	47.0	47.9	48.5	48.0	46.0	47.0	47.0	46.0	49.0	44.0
Nov. 4	48.1	48.0	48.2	50.7	48.0	48.4	46.4	47.4	50.0	45.0
11	47.7	48.0	47.8	49.8	48.0	48.1	48.0	46.7	49.0	46.0
18	48.0	48.0	46.0	43.8	48.0	46.0	49.0	48.0	52.0	48.6
25	48.0	48.0	46.0	44.7	46.0	46.0	48.4	48.0	50.0	48.5
Dec. 2	46.0	46.1	46.6	47.4	44.0	46.7	50.0	48.0	54.0	47.1
9	49.3	51.8	50.7	44.1	46.0	50.2	49.6	48.0	50.2	46.4
16	47.2	51.4	50.5	50.0	48.2	49.1	48.7	47.0	46.1	45.3
23	46.0	48.6	46.6	54.1	46.5	47.7	47.8	49.0	50.5	47.8
30	47.8	49.9	46.0	48.5	48.0	[illegible]	[illegible]	48.0	51.6	47.1
Jan 6	46.0	46.0	40.0	44.5	46.0	46.0	46.0	46.3	48.0	47.0
13	[illegible]	46.4	40.0	44.1	47.0	46.0	48.3	48.2	48.0	46.0
20	[illegible]	46.0	49.0	44.4	44.0	[illegible]	47.2	48.1	46.0	46.0
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb. 3	[illegible]	46.4	48.0	46.0	46.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mar. 7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	47.7	46.9	46.0	36.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Apr. 4	[illegible]	49.8	46.5	50.0	46.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May 2	[illegible]	50.7	47.9	50.4	46.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Highest and lowest values found on the day tested.

juice occurred in the early fall, reaching the maximum in late November and December, A decrease occurred in the early spring, followed by an increase in late April and May.

Yearly variations in percentage of juice by weight are proportionately less than those based on volume. Differences between Yuma and Salt River Valley fruit are also less marked. A wide range, however, exists between the high and low percentages obtained on any given date. This variability is greater in the Salt River Valley than in the Yuma district.

Relation of Percentage of Juice by Weight to Maturity

The percentage of juice by weight bears a general relationship of the palatability of the fruit in that higher amounts of juice are found in the more palatable fruit. Since the different thicknesses of peel have less relative significance in weight determination, percentages by weight may have greater value than percentages by volume as a measurement of maturity.

Seasonal Changes in Percentage of Juice by Weight in Peeled Fruit

By deducting the weight of the peel from the weight of the fruit and calculating the percentage of juice on the basis of this weight, the seasonal changes of the juice in the edible portions of the fruit have been determined. Since this method also largely eliminates the effect of different sizes, more accurate comparisons may be made.

The data in Table 28 reveal that the juice in the edible portions increased uniformly from about 60 per cent in early September to an average of about 77 per cent in December. No significant changes occurred during the remainder of the season.

A rather wide difference in percentage of juice in the peeled fruit from groves in both the Salt River Valley and the Yuma district occurred. The maximum percentages varied from 71.6 to 82.5 in the Salt River Valley, with a narrower range in the Yuma district.

If allowance is made for size, the data pertaining to increases in juiciness during the fall indicate, in general, that the fruit which had a high percentage of juice by volume and by weight contained a high percentage in the edible portion, although a few exceptions were found*

TABLE 28.—AVERAGE SEASONAL CHANGES IN THE PERCENTAGE OF JUICE BY WEIGHT IN PEELED FRUIT,

Date	Salt River Valley (12 groves)					Yuma (5 groves)				
	1937	1938	1939	1939		1938	1938	1939	1939	
				High[a]	Low[a]				High[a]	Low[a]
Sept. 8	[illegible]	81.4	69.8	85.5	49.0	[illegible]	88.4	84.8	[illegible]	59.0
14	88.0	81.0	67.8	88.5	55.5	89.2	87.2	80.3	88.8	69.0
20	88.0	84.4	69.9	85.8	58.4	88.7	88.3	86.5	88.8	69.8
30	89.0	88.3	85.7	71.5	68.6	88.0	89.8	70.8	88.9	00.0
Oct. 7	69.8	67.5	89.2	78.5	83.2	69.2	88.0	71.2	78.3	69.0
14	72.0	72.1	69.0	72.8	80.5	70.8	69.4	72.2	74.2	70.0
21	72.2	89.5	71.6	75.5	85.9	72.8	72.8	73.6	76.8	71.2
28	78.7	78.4	72.8	78.4	88.8	73.7	78.9	78.8	75.7	70.8
Nov. 3	04.8	01.4	74.1	00.0	71.1	76.8	08.0	74.8	78.9	72.0
11	00.6	04.4	74.4	08.0	07.1	74.8	03.7	75.8	78.3	71.3
18	00.1	06.4	75.9	09.0	01.7	75.0	04.7	75.0	78.4	73.6
24	00.0	06.6	76.4	08.8	07.6	76.1	08.0	74.8	08.8	72.8
Dec. 2	78.0	78.8	75.9	80.4	68.8	76.1	74.0	78.0	00.0	74.4
9	78.0	78.6	78.1	79.7	70.8	78.0	78.0	78.0	00.0	74.0
16	78.0	78.2	78.4	80.6	74.0	75.5	78.0	74.8	00.0	78.0
23	78.0	78.4	78.0	81.0	75.9	74.8	78.1	78.2	09.0	78.4
30	78.8	78.0	78.8	79.0	78.0	[illegible]	74.4	78.5	00.0	74.0
Jan. 6	78.8	00.1	78.5	82.5	74.4	77.2	00.3	77.0	09.0	00.0
13	[illegible]	00.0	78.2	81.7	78.0	76.1	00.9	77.9	01.0	00.0
20	[illegible]	00.0	78.6	82.4	78.0	[illegible]	.7	76.6	00.0	00.4
28	[illegible]	00.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb. 21	[illegible]	77.0	06.9	09.8	04.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mar. 21	[illegible]	78.0	07.7	01.4	03.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Apr. 8	[illegible]	79.0	08.0	09.5	01.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May 3	[illegible]	78.8	08.3	08.9	03.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Highest and lowest values found on the day tested.

TABLE 29.—AVERAGE SEASONAL CHANGES IN PERCENTAGE OF PEEL BY WEIGHT.

Date	Salt River Valley (12 groves)					Yuma (5 groves)				
	1937	1938	1938	1938		1937	1938	1938	1939	
				High[a]	Low[a]				High[a]	Low[a]
Sept. 8	40.9	38.6	46.5	50.0	43.0	----	40.0	44.8	46.0	41.8
16	39.8	38.4	44.4	47.7	41.4	37.6	40.0	43.8	45.3	40.7
23	39.1	37.6	40.2	44.0	37.4	38.0	39.1	41.3	44.0	37.5
30	37.2	36.1	42.4	43.0	37.6	38.6	37.4	40.4	42.2	36.8
Oct. 7	37.8	36.0	39.6	42.0	36.2	36.6	37.4	38.6	41.1	34.8
14	36.4	35.6	37.8	40.4	34.5	38.6	36.0	37.0	39.1	34.8
21	35.8	34.1	36.8	38.0	33.4	38.5	37.0	37.0	38.4	33.4
28	35.8	34.7	36.1	41.8	34.0	38.0	36.0	36.8	37.4	33.1
Nov. 8	35.7	34.7	37.8	38.8	34.1	35.8	35.0	36.1	38.5	33.8
11	35.2	34.8	35.6	38.6	31.1	36.5	34.4	35.2	36.0	33.8
18	36.1	34.3	34.7	37.6	30.7	35.5	35.4	35.3	37.0	33.8
25	35.0	34.1	38.8	37.8	33.5	35.1	35.6	35.8	36.0	33.8
Dec. 2	36.1	33.6	34.7	37.7	31.4	35.4	35.1	35.8	37.8	31.0
9	36.4	34.1	34.0	37.4	31.1	34.7	35.0	35.7	37.0	30.4
16	37.4	34.0	34.8	37.7	30.0	35.6	35.7	36.7	38.0	34.4
23	37.0	35.5	37.1	40.0	33.0	35.1	36.0	36.0	38.8	34.0
30	37.0	34.7	36.2	39.6	33.4	34.8	35.8	36.0	38.6	34.4
Jan. 6	38.0	35.8	35.1	38.4	33.6	36.7	37.0	36.0	38.0	34.0
13	----	35.0	36.0	38.6	34.0	36.6	38.0	38.1	40.0	34.0
20	----	35.0	36.6	40.0	33.7	----	38.5	37.0	38.0	34.0
28	----	35.1	----	----	----	----	----	----	----	----
Feb. 1	----	35.0	37.5	40.0	35.0	----	----	----	----	----
Mar. 1	----	37.0	40.0	46.0	34.4	----	----	----	----	----
Apr. 30	----	37.7	40.2	45.5	35.7	----	----	----	----	----
May 2	----	35.7	37.2	41.1	38.6	----	----	----	----	----

[a]Highest and lowest values found on the day tested.

A closer relationship appeared to exist between palatability and percentage of juice in the edible portion of the fruit than when percentage of juice was calculated on the whole fruit either by volume or by weight.

Percentage and Thickness of Peel

Seasonal Changes

Studies were made of the seasonal changes in the percentage of peel by weight in 1937, 1938, and 1939. The changes in thickness of the peel were studied in one grove in 1939-40. Data derived from these investigations are presented in Tables 29 and 30.

TABLE 30.—SEASONAL CHANGES IN THICKNESS OF PEEL IN RELATION TO GROWTH OF FRUIT,[a] SALT RIVER VALLEY, 1939-40.

Date	Thickness of peel (mm.)	Peel (%)	Volume of fruit tested (cc.)	Growth of fruit[b] (cc.)
Sept. 7	10.7	46.0	320	301
22	10.2	40.1	354	326
Oct. 5	9.2	38.6	349	351
19	9.2	38.0	375	375
NOT. 2	8.9	36.5	399	395
16	8.4	34.9	401	415
Dec. 2	9.0	36.0	434	440
13	9.1	37.0	442	455
28	9.2	36.8	472	476
Jan. 18	9.0	37.6	476	493
Feb. 6	10.4	39.3	561	512
20	10.4	39.7	558	542
Mar. 5	10.5	40.8	541	571
19	10.5	42.3	549	596
Apr. 2	11.1	43.4	624	614
16	10.2	42.2	604	616

[a]Average data, sixty fruit from a single grove each date.
[b]Growth of seventy-five fruit from measurements by Harris (12).

The percentage of peel, which is typically high in September, decreases rapidly to a low point in October or November. A gradual increase then takes place until the maximum is attained in early April, followed by a decrease in late April and May.

Since the percentage of peel is higher in large fruit, a considerable part of the increase in peel percentage dur-

ing the late fall and early winter is related to the increase in size of fruit tested. The decrease in peel in the late spring appears to be associated with the shrinkage of the fruit.

Yearly differences in the percentage of peel were rather wide. In the Salt River Valley the 1937 fruit contained the highest percentage of peel recorded. In 1938 the lowest percentage of peel was found. In the Yuma district narrower yearly variations occurred, but slightly lesser amounts of peel were found in 1937.

The thickness of the peel (Table 30) decreased in the fall until mid-November, paralleling the decrease in percentage. As the fruit became larger, peel thickness increased, reaching its maximum in early April.

Relation to Maturity

The decrease in percentage of peel in the early fall accompanies an increase in percentage of juice and an improvement of quality and edibility of the fruit. The wide range in percentages of peel and in peel thickness makes absolute values for these factors meaningless insofar as maturity measurements are concerned.

Percentage of Rag

Seasonal Changes

The term "rag" is used to designate the membranous tissue surrounding the segments together with the fibrous material remaining after the juice has been removed by squeezing.

The percentage of rag in the fruit was studied in 1938 and 1939. Data are not presented in tabular form. They revealed that the rag decreased gradually from about 21 per cent in September to about 13 per cent by mid-December. Changes after January 1 were slight and inconclusive. Average changes in fruit from the Yuma area rather closely paralleled those of the Salt River Valley.

The percentage of rag is related to palatability in that it reflects the increase in the juice. Since the decrease is within rather narrow limits and has considerable variation, the establishment of values related to maturity appeared to be impractical.

Seasonal Changes in California Desert Grapefruit

Sixty-six tests were made on grapefruit from several groves in the Imperial and Coachella valleys of California in 1937 and 1939. The data in Table 31 indicate that the same type of seasonal trends occur in these areas as are found in Arizona, The actual values of measured characteristics differed considerably from those of Arizona. In the Coachella Valley Brix values appeared to be low. In 1937 a low acid was found so that the ratio was considerably higher than in Arizona. In 1939 the acid was high and a low ratio resulted which did not change materially during the test period.

TABLE 31.—SEASONAL CHANGES IN IMPERIAL VALLEY AND COACHELLA VALLEY GRAPEFRUIT.

Date		Brix (degrees)	Acid (%)	Brix: acid ratio	Juice by volume (%)	Vol. of fruit (cc.)	Juice converted to size 80 (%)	Color (%)	Juice by weight (%)	Juice in peeled fruit (%)
Imperial Valley 1937[a]										
Sept.	21	11.28	1.66	6.79	28.1	398	26.6	21	39.0	62.0
	29	11.33	1.67	6.79	32.7	381	30.8	20	45.2	68.7
Oct.	6	11.15	1.65	6.73	32.9	432	32.0	33	45.4	69.8
	12	11.23	1.65	6.81	34.0	427	33.0	30	46.3	70.3
	20	11.20	1.60	7.02	35.5	468	55.4	38	48.0	70.3
	26	11.28	1.63	7.01	35.3	409	35.0	36	47.4	71.0
Nov.	4	11.24	1.62	6.98	37.5	449	37.0	48	50.4	75.5
	16	11.45	1.66	6.97	37.3	448	36.8	69	50.3	75.8
Coachella Valley 1936[b]										
Oct.	6	9.95	1.44	6.91	36.8	337	34.0	33	47.7	70.8
	16	10.08	1.35	7.48	35.0	492	35.3	41	46.7	70.0
	22	9.98	1.27	7.86	36.1	502	36.6	38	47.6	71.4
	28	10.02	1.32	7.66	35.9	550	37.4	31	48.1	72.0
Nov.	5	10.02	1.37	7.30	40.9	487	41.1	34	51.3	73.0
	10	10.00	1.37	7.30	39.2	431	58.4	40	51.0	74.2
Coachella Valley 1939[c]										
Oct.	10	9.85	1.62	6.10	39.9	343	37.4	37	50.4	73.3
	28	9.80	1.63	6.04	42.5	335	39.8	36	53.6	76.5
Nov.	3	9.87	1.61	6.14	43.4	322	40.4	41	54.4	76.1
Dec.	1	9.98	1.63	6.13	43.8	347	41.3	91	55.6	79.8
	15	10.02	1.65	6.27	43.8	358	41.4	96	55.7	79.7

[a]Average of five groves.
[b]Average of two groves.
[c]Average of three groves.

A loss in volume took place during shipment of the fruit tested so that juice percentages by volume were probably 1 to 2 per cent higher than regular field samples. The percentage of juice by volume was approximately the same in Imperial Valley fruit as in Arizona fruit. The Coachella Valley fruit had a lesser amount of peel so the percentage of juice was from 3 to 5 per cent higher than in Arizona. The actual juice in the peeled fruit, however, increased at about the same rate and attained approximately the same levels.

Summary of Part II

Coloration of grapefruit occurred gradually through the fall and early winter and in many cases was accompanied by an increase in palatability. However, a wide range in color existed between fruits which were equally palatable. The extent of coloration, therefore, was not in itself entirely adequate as a measure of maturity.

The color of the juice was found to change from an oyster white to a sulphur yellow and did not appear to be closely related to maturity.

The total soluble solids (Brix) increased gradually from early October to midwinter and decreased in the spring. The percentage of acid decreased rapidly to early November, changed little until February, then decreased at an accelerated rate in the spring. In the Salt River Valley the average total soluble solids to acid ratio attained a value of 6.00:1 in late September and increased to 6.5:1 by early November. From then until late January it increased slightly, due to the increase in solids during that period. After February the ratio increased uniformly to late May, due entirely to the decrease in percentage of acid.

While the Brix:acid ratio increased with maturity, it was evident that the numerical value of this ratio was not alone a satisfactory measure of maturity.

The percentage of juice by volume increased rapidly during the early fall. This increase occurred more slowly as the maximum was approached in early December. The percentage of juice by weight follows the same trend as that by volume. The data pertaining to the juice in the edible portion of the fruit indicate that there are no actual changes in percentage of juice after December.

Juiciness of the fruit was related to maturity but did not in itself provide an accurate measurement.

The percentage of peel decreased in September and October, gradually increased as the fruit became larger, and reached its maximum in early April at the time of maximum size of the fruit. A decrease in the peel was found in late spring. The changes in percentage of peel were responsible for the major variations noted in percentage of juice by volume and the lesser variations in percentage of juice by weight.

The percentage of rag decreased from about 20 per cent in September to approximately 13 per cent in December. No significant changes occurred thereafter.

Limited tests on grapefruit from the Imperial and Coachella valleys of California indicated that seasonal trends of chemical and physical change are similar to those of Arizona. Actual values for some of the characteristics differed considerably.

TABLE 32.—SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF GRAPEFRUIT FOR EACH YEAR.[a]

Year	Brix	Acid (%)	Brix: acid ratio	Juice by volume (%)	Vol. per fruit (cc.)	Comparable juice size 80 (%)	Color (%)	Juice by weight (%)	Juice in peeled fruit (%)
Salt River Valley									
1935	11.72	1.82	6.44	34.8	438	34.1	77	———	
1936	11.23	1.61	6.96	36.0	519	36.6	80	. . . . .	
1937	11.50	1.71	6.74	36.0	370	33.8	62	48.1	76.4
1938	12.06	1.78	6.78	35.8	479	36.0	70	50.2	77.1
1939	11.85	1.85	6.41	35.3	479	35.5	54	49.9	77.5
Yuma									
1936	10.78	1.41	7.66	33.6	540	33.1	88	----	----
1937	10.72	1.63	6.59	33.8	551	35.3	65	49.0	76.1
1938	11.30	1.59	6.10	32.7	581	35.3	82	48.7	77.1
1939	10.94	1.62	6.76	32.6	501	33.4	75	48.5	76.6

[a] Average of all field tests between December 1 and January 15.

[b] Average percentage of color for November.

PAET III.—ANALYSIS OF DATA WITH REFERENCE TO THE IMPROVEMENT OF LEGAL MATURITY STANDARDS

The data showing seasonal chemical and physical changes associated with the attainment of maturity reveal three important points bearing on the establishment of legal maturity standards.

1. The improvement in eating quality of grapefruit is gradual. This makes it technically impossible to fix an exact date or an exact point in seasonal changes at which grapefruit becomes mature.
2. The external color of the fruit, Brix:acid ratio, and percentage of juice are all related to maturity and to a degree can be used as measures. However, no single feature can be used as a basis of determining maturity.
3. An inverse relation frequently occurred between Brix:acid ratio and percentage of juice in equally palatable fruit.

The Relation of Individual Physical and Chemical Characteristics to Maturity

When the fruit from each grove tested was considered sufficiently palatable to be consumed, its physical and chemical characteristics were noted. The characteristics of the 1938 fruit, shown in Table 33, are typical of the data obtained each year. To eliminate the effect of size of the fruit on the percentage of juice by volume, the equivalent percentage of juice for size 80 fruit has been included.

The 1938 data show that some Salt River Valley grapefruit became sufficiently palatable to be consumed on October 3, and others not until November 18—and all had a wide variation in chemical and physical characteristics. Brix varied from 9.98 to 12.32; per cent of acid from 1.51 to 1.92; and Brix:acid ratio from 6.04 to 7.20. Percentage of juice (size 80) ranged from 29.8 to 36.0 per cent. Fruit having 28 to 97 per cent color was found, but usually it was above 35 per cent. Lesser ranges occurred in fruit from the Yuma area.

The yearly averages set forth in Table 34 show that Salt River Valley fruit is characterized by a lower Brix:acid ratio and a higher percentage of juice than Yuma fruit. While these averages indicate a rather uniform situation in each area, individual samples revealed a wide range in the

TABLE 33.—PHYSICAL AND CHEMICAL CHARACTERISTICS OF GRAPEFRUIT FROM SEVENTEEN SALT RIVER VALLEY AND FIVE YUMA GROVES WHEN DEEMED MATURE, 1938.

Date when mature	Brix	Acid (%)	Brix: acid ratio	Juice by vol. (%)	Vol. per fruit (cc.)	Comparable juice size 80 (%)	Juice in peeled fruit (%)	Color (%)
Salt River Valley								
Oct. 3	11.19	1.81	6.18	30.8	425	29.8	----	30
3	11.49	1.80	6.38	31.5	447	30.7	—	28
3	9.98	1.57	6.36	34.3	407	32.8	—	32
3	10.43	1.51	6.90	31.1	525	32.0	—	35
7	10.78	1.64	6.58	35.8	457	35.4	----	30
7	11.11	1.70	6.53	35.3	378	33.4	—	40
14	10.93	1.81	6.04	35.0	415	33.7	74.6	38
14	12.11	1.92	6.31	33.8	402	32.2	73.0	39
14	11.34	1.76	6.44	33.5	456	33.0	74.6	47
21	12.32	1.71	7.20	34.6	363	32.3	69.2	54
28	11.86	1.80	6.59	37.0	404	35.6	72.9	46
28	11.96	1.70	6.98	37.7	400	36.2	73.3	42
28	11.18	1.80	6.22	35.6	421	34.4	75.2	44
Nov. 3	11.39	1.86	6.12	34.1	437	33.3	71.0	97
3	11.60	1.69	6.87	35.7	471	35.6	72.2	62
11	11.45	1.63	7.02	32.2	580	34.2	72.7	60
18	11.50	1.82	6.32	38.3	366	36.0	75.4	92
Average	11.84	1.84	6.54	34.5	433	33.6	73.1	48
Yuma								
Oct. 4	11.93	1.69	7.06	24.4	604	27.0	66.3	32
11	10.61	1.63	6.50	37.3	365	34.9	73.1	38
11	11.21	1.68	6.68	31.0	435	30.2	73.4	34
11	11.28	1.68	6.72	29.8	454	29.5	69.6	38
11	11.11	1.65	6.72	31.0	477	31.0	72.0	39
Average	11.02	1.66	6.61	30.7	467	30.5	70.1	36

time of maturity and the physical and chemical characters of mature fruit.

Salt River Valley fruit became palatable between October 3 and December 19 during the period from 1935 to 1939. The extreme range in the characters of this fruit was as follows: Brix:acid ratio 5.55:1 to 7.59:1; percentage of juice by volume (size 80) 29.1 to 38.5; percentage of color 20 to 100. Yuma fruit had a narrower range, becoming mature between September 29 and October 24. The extreme variability in the character of this latter fruit was as follows:

TABLE 34.—AVERAGE PHYSICAL AND CHEMICAL CHARACTERISTICS OF GRAPEFRUIT WHEN DEEMED MATURE.

Year	No. tests	Brix	Acid (%)	Brix: acid ratio	Juice by vol. (%)	Vol. per fruit (cc.)	Comparable juice size 80 (%)	Juice in peeled fruit (%)	Color (%)
				Salt River Valley					
1935	16	11.46	1.85	6.15	34.6	365	32.3	----	58
1936	10	11.08	1.69	6.57	34.7	443	34.1	-	32
1937	13	11.14	1.69	6.59	34.5	343	32.0	71.6	31
1938	17	11.32	1.84	6.54	34.5	433	33.6	73.1	48
1939	14	11.54	1.80	6.47	33.7	446	33.2	75.2	53
				Yuma					
1936	5	10.79	1.39	7.78	29.7	449	29.2	-	32
1937	5	10.70	1.52	7.05	20.3	443	28.7	68.2	35
1938	5	11.02	1.66	6.61	30.7	467	30.5	70.1	36
1939	5	10.80	1.67	6.56	31.0	420	29.9	72.6	36

Brix:acid ratio 6.44:1 to 8.40:1; percentage of juice by volume (size 80) 27.0 to 31.4; percentage of color 27 to 41.

These values represented extremes. In all instances the minimum values for any one factor were associated with higher values for other factors. For example, fruit having a Brix:acid ratio as low as 5.38:1 was fully colored on the tree and contained a high percentage of juice.

The Interrelation of Physical and Chemical Characteristics and Maturity

The detailed data pertaining to mature grapefruit revealed that in many instances fruit which had attained a high Brix:acid ratio was relatively low in percentage of juice by volume, and vice versa. This situation also was found in the study of Fancy and Choice fruit (Table 11), inside and outside fruit (Tables 7 and 8), and in the analysis of fruit from single trees (Table 9). Using all data obtained between 1935 and 1939 pertaining to the characteristics of mature fruit having 35 per cent color, the Brix:acid ratio was plotted against the percentage of juice by volume. These data showing the linear relationship are set forth in Figure 7. The scatter of the points is rather wide and not very conclusive; however, it suggests that an inverse rela-

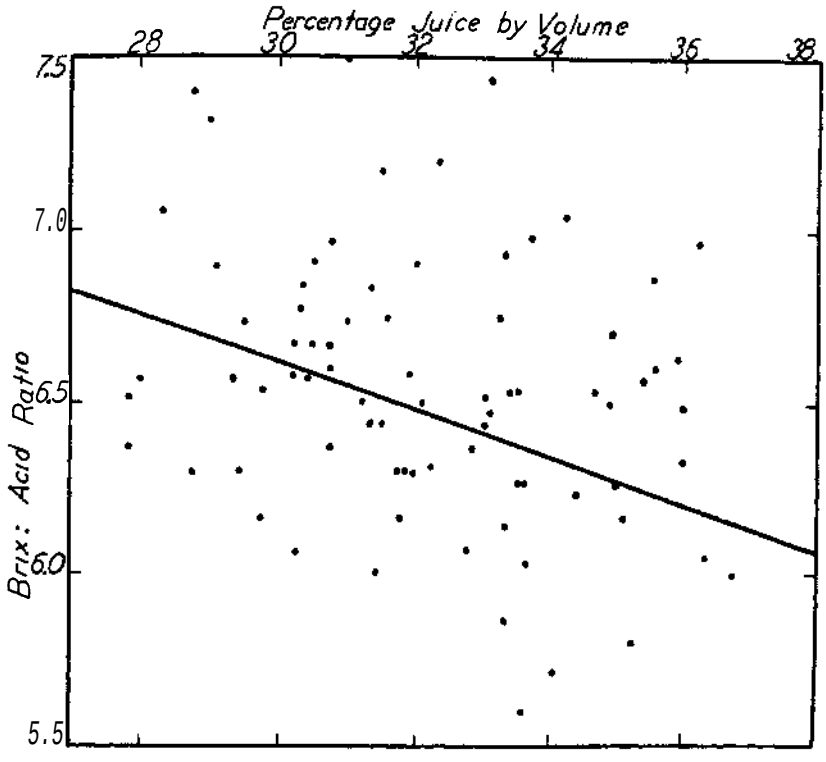

Figure 7.—Scatter diagram showing linear relationship between Brix:acid ratio and percentage of juice by volume (size 80) in equally palatable Arizona grapefruit having a minimum of 35 per cent color.

tionship exists between Brix:acid ratio and percentage of juice in equally palatable fruit. From this trend it appears that size 80 fruit having a minimum of 35 per cent color is equally palatable if it has the following relationships between the Brix:acid ratio and percentage of juice by volume:

Percentage juice	28	30	32	34	36
Brix:acid ratio	6.75	6.62	6.48	6.34	6.20

Suggestions for Tentative Maturity Standards

The wide range in the physical characteristics of equally palatable fruit makes the establishment of entirely satisfactory maturity standards extremely difficult.

If average values are considered a standard requiring 35 per cent color, 6.3:1 Brix:acid ratio and 32 per cent juice

would be most satisfactory for the Salt River Valley. In the Yuma area 35 per cent color, 6.5:1 ratio, and 29 per cent juice would be most satisfactory. However, a fixed inflexible standard would probably be unsatisfactory in years which deviate markedly from the average.

A tentative standard based upon a minimum color of 35 per cent and Brix:acid ratio values which vary inversely with the percentage of juice values is set forth in Table 35.

TABLE 35.—TENTATIVE STANDARD INVOLVING BASIC RELATIONSHIPS BETWEEN BRIX:ACID RATIO AND PERCENTAGE OF JUICE BY VOLUME (SIZE 80)

	Combinations which are equally palatable				
Juice (size 80) (%)	29	30	31	32	33
Brix:acid ratio	6.80	6.65	6.50	6.35	6.20

This standard provides that size 80 fruit which meets any of the combinations indicated is equally mature if 35 per cent color has been attained on the tree.

In developing standards for the percentage of juice, size 80 fruit has been used for convenience. The corresponding percentages for the other sizes which are equivalent to 28 per cent, 30 per cent, etc. in size 80 are presented in Table 36.

TABLE 36.—PERCENTAGES OF JUICE REQUIRED FOR DIFFERENT SIZES OF FRUIT EQUIVALENT TO 28, 30, 32, AND 34 PER CENT FOR SIZE 80.

Approx. com'l size	Volume	5-year maximum av.[a]	28 per cent for size 80	30 per cent for size 80	32 per cent for size 80	34 per cent for size 80
126	300	39.9	31.5	33.5	35.5	37.5
	350	38.9	30.5	32.5	34.5	36.5
100	400	37.9	29.5	31.5	33.5	35.5
	450	36.9	28.5	30.5	32.5	34.5
80	475	35.4	28.0	30.0	32.0	34.0
	500	35.9	27.5	29.5	31.5	33.5
70	550	34.9	26.5	28.5	30.5	32.5
	600	33.9	25.5	27.5	29.5	31.5
64	650	32.9	24.5	26.5	28.5	30.5

[a]From Table 5,

By combining the percentages of juice required for each size (Table 36) and the Brix:acid ratio for each size (Table

6) with the inverse relationship established for size 80 in Table 35, the tentative standard presented in Table 37 is developed. This tentative standard provides that fruit having 35 per cent color and the relationships between Brix:acid ratio and percentage of juice by volume shown for each size would all be considered equally edible and mature.

TABLE 37.—TENTATIVE STANDARD INVOLVING BASIC RELATIONSHIPS BETWEEN SIZE, BRIX:ACID RATIO AND PERCENTAGE OF JUICE FOR ARIZONA GRAPEFRUIT WITH 35 PER CENT COLOR.

Approx. com'l size	Vol. of fruit (cc.)	Percentage juice, Brix:acid ratio, and fruit size combinations for mature fruit									
		% Juice	Brix: acid ratio	% juice	Brix: acid ratio	% juiee	Brix: acid ratio	% juice	Brix: acid ratio	% juice	Brix: acid ratio
126	300	32.5	6.7	33.5	6.55	34.5	6.4	35.5	6.25	36.5	6.1
	350	31.5	6.7	32.5	6.55	33.5	6.4	34.5	6.25	35.5	6.1
100	400	30.5	6.8	31.5	6.65	32.5	6.5	33.5	6.35	34.5	6.2
	450	29.5	6.8	30.5	6.65	31.5	6.5	32.5	6.35	33.5	6.2
80	475	29.0	6.8	30.0	6.65	31.0	6.5	32.0	6.35	33.0	6.2
	500	28.5	6.8	29.5	6.65	30.5	6.5	31.5	6.35	32.5	6.2
70	550	27.5	6.9	28.5	6.75	29.5	6.6	30.5	6.45	31.5	6.3
	600	26.5	6.9	27.5	6.75	28.5	6.6	29.5	6.45	30.5	6.3
64	650	25.5	6.9	26.5	6.75	27.5	6.6	28.5	6.45	29.5	6.3

Analysis of Suggested Tentative Standard

The tentative standard involving the percentage of juice and Brix:acid ratio relationships of Table 37 was applied to the field data obtained during this investigation. The purpose was to test the accuracy and usableness of such a standard.

This analysis (Table 38) indicates that the sliding standard of ratio and percentage of juice is reasonably satisfactory for all Arizona fruit. However, this standard could be improved by providing for modification in years in which extreme variations occur.

Fruit which passes this standard early in the season would usually pass later, because (1) the higher percentage of juice in the fruit later in the season offsets decreases which may occur in the Brix:acid ratio and (2) variations related to sampling are minimized since individual fruit on the same tree tend to vary according to the standard.

TABLE 38.—PERCENTAGE OF SAMPLES STUDIED IN VARIOUS YEARS PASSING REQUIREMENTS OF THE TENTATIVE STANDARD SUGGESTED IN TABLE 37.

Date	Salt River Valley					Yuma			
	1935	1936	1937	1938	1939	1936	1937	1938	1939
Sept. 8	0	--	0	0	0	---	0	0	0
16	0	0	0	0	0	---	0	0	0
23	0	--	0	0	0	---	0	0	0
30	0	0	0	0	0	20	0	0	0
Oct. 7	13	30	8	8	0	40	20	20	0
14	22	60	46	33	0	---	60	40	20
21	36	90	62	83	33	100	100	100	80
28	40	--	77	83	41	100	80	100	40
Nov. 3	43	70	100	83	33	100	100	80	80
11	45	90	92	92	58	100	100	100	100
18	43	90	100	100	67	100	100	100	80
25	43	90	100	100	67	100	100	100	100
Dec. 2	67	80	92	100	58	100	100	100	100
9	71	90	77	100	75	100	100	100	80
16	67	90	100	100	67	100	100	100	100

Summary of Part III

The range in Brix:acid ratio, color, and percentage of juice between equally edible grapefruit, and the gradual changes in these features, creates a difficult problem in the establishment of satisfactory legal requirements. It is probable that any standard devised will allow the shipment of small quantities of relatively unpalatable fruit and prevent the shipment of small quantities of relatively palatable fruit.

The 1933 Arizona legal requirements of 25 per cent color and six parts total soluble solids to one part acid are frequently inadequate to prevent the shipment of unpalatable fruit. The stipulation which deems all fruit legally mature after December 15 appears to be justified.

The palatability of the fruit harvested early in the season would tend to be improved by the addition of a minimum juice requirement. From the data obtained from field samples, it appears that a minimum value for percentage of juice by volume of 29 per cent (size 80) in the Yuma area and 32 per cent (size 80) in the Salt River Valley area would be reasonably satisfactory. Provision for establishing higher values in seasons when thinner peel prevails would be desirable.

If the percentage of juice by volume is incorporated in the requirements, provision should be made to determine this value soon after picking and prior to coloring the fruit. Shrinkage of the peel produces an increase in the percentage of juice by volume. As varying amounts of shrinkage can be obtained during coloring, difficulty would be encountered in evaluating juice content of colored fruit. This situation may require altering the Standardization Service practice of certification of the fruit in the bins prior to shipment and substituting certification of the fruit in the grove similar to the method used in Texas.

The most satisfactory standard indicated by these studies requires 35 per cent minimum color and a total soluble solids (Brix) to acid ratio which varies inversely with the percentage of juice by volume, the latter values to be dependent upon the size of the fruit. The tentative requirements embodying these principles are presented in Table 37.

While it appears that the values set forth in Table 37 would constitute a reasonably satisfactory standard, its operation could be improved by provision for modification in years which deviate markedly from the average. From the deviations which have occurred to date it appears that modifications could be confined to increasing or decreasing the minimum percentages of juice by not more than 1.5 per cent and the Brix:acid ratio by not more nor less than 0.2. The basic inverse relationships between ratio and percentage of juice should remain relatively constant, with modifications confined to the entire relationship.

It is emphasized that this tentative standard has been developed from tests on fruit from a relatively small number of groves, if the total number in the State are considered. Should a minimum juice requirement be added to the maturity law, a large amount of data would soon be acquired which would be useful in farther improving the standards in future years.

It appears advisable that no definite fixed standard be adopted. A possible solution to the problem would appear to lie in the establishment of a maturity authority. This individual or group should be empowered either to modify the standard presented in Table 37 or to establish such standards for each season as may be deemed advisable to prevent the shipment of unpalatable fruit.

PART IV.—CULTURAL AND ENVIRONMENTAL FACTORS AFFECTING MATURITY

In the preceding sections various physical and chemical changes in the fruit have been reported as criteria of maturity. The values for them have varied between seasons, districts, and individual groves. Data pertaining to factors which appear to cause these variations have been obtained during these studies.

Heat Summation[3]

Two aspects of the influence of heat summation were studied on fruit from the same six grapefruit groves in the Salt River Valley between 1935 and 1939 inclusive, and five in the Yuma district from 1936 to 1939 inclusive. These were:

1. The relationship between the summation of heat units and the time of attainment of a 6.3:1 Brix:acid ratio.

2. The relationship between the summation of heat units up to November 1 and the physical and chemical characteristics of grapefruit on that date.

In Table 39 the relation of the summation of heat units to the attainment of a 6.3:1 Brix:acid ratio is shown.

In the Salt River Valley the heat units from blossoming to the date on which trends indicated a 6.3:1 Brix:acid ratio varied from 5,585 to 6,531 with an average of 5,969. In the Yuma area the variation was from 5,681 to 6,153 with an average of 5,886 for the 4-year period. This range appears to be related to the temperatures occurring during the 60-day period immediately preceding the attainment of the 6.3:1 Brix:acid ratio. Thus, while in 1939 the largest total number of heat units accrued from blossoming to attainment of the 6.3:1 ratio, the final 60-day period had the lowest number. Similarly, with the exception of 1938 fewer heat units were noted in the Yuma area than in the Salt River Valley, but in all instances more heat units accumulated in Yuma during the final 60-day interval.

[3]Temperatures were evaluated on the basis of heat units calculated upon the mean daily temperature above 50 degrees F. Salt River Valley temperatures were obtained at Camelback Station on Chicago Avenue at the Arizona Canal; Yuma Mesa temperatures were obtained at the Yuma Mesa Citrus Experiment Station.

TABLE 39.—RELATION OF SUMMATION OF HEAT UNITS TO ATTAINMENT OF 6.3:1 BRIX:ACID RATIO.

	1935	1936	1937	1938	1939
		Salt River Valley			
Date full bloom	Apr. 5	Mar. 22	Apr. 8	Apr. 12	Apr. 5
Date 6.3:1 ratio	Oct. 25	Oct. 7	Oct. 3	Oct. 10	Nov. 10
Heat units (bloom to 6.3:1 ratio)	5,930	5,996	5,803	5,585	6,531
Heat units 60 days prior[a]	1,676	2,019	2,269	1,812	1,415
		Yuma			
Date full bloom		Mar. 18	Mar. 25	Mar. 29	Mar. 28
Date 6.3:1 ratio		Sept. 5	Sept. 11	Sept. 27	Sept. 26
Heat units (bloom to 6.3:1 ratio)		5,683	5,681	6,028	6,153
Heat units 60 days prior[a]		2,484	2,631	2,407	2,356

[a]Summation of heat units during 60-day period prior to attainment of 6.3:1 Brix:acid ratio.

An evaluation of the effect of the summation of heat units upon the physical and chemical characteristics of the fruit on November 1 is set forth in Table 40.

TABLE 40.—RELATION OF SUMMATION OF HEAT UNITS TO MATURITY MEASUREMENTS ON NOVEMBER 1.[a]

Year	Brix	Acid	Brix: acid ratio	Juice size 80 (%)	Color (0	Heat units (bloom to Nov. 1)	Heat units (Sept. and Oct.)	Heat units (Sept.)
				Salt River Valley				
1935	11.31	1.78	6.36	31.8	53	6009	1574	945
1936	11.13	1.71	6.51	35.0	57	6550	1599	969
1937	11.17	1.63	6.86	32.9	35	6461	1839	1098
1938	11.47	1.74	6.60	34.8	48	6093	1685	1046
1939	11.61	1.85	6.28	31.8	42	6348	1600	930
				Yuma				
1936	10.46	1.40	6.83	34.0	76	7263	1741	1031
1937	10.67	1.49	7.16	32.2	41	7230	2018	1206
1938	11.06	1.60	6.92	33.2	60	6979	1986	1146
1939	10.87	1.63	6.67	32.8	46	6920	1690	996

[a]The average physical and chemical characteristics of the fruit were computed for November 1 each year by averaging the three weekly tests closest to that date.

Yuma fruit attains a higher ratio, suggesting a direct relationship between total heat units and Brix:acid ratio. A closer relationship appears to exist between the temperatures during September and October and the Brix:acid ratio on November 1. Heat units during this period closely follow the ratios except for the Yuma district in 1936, Heat units during September were closely correlated with the ratio on November 1 in all cases.

No relationship appears to exist between the summation of heat units, or the heat units in the early fall, and the percentage of juice by volume attained on November 1. In the Salt River Valley this varied in alternate years with 1936 and 1938 having the higher percentages.

It should be pointed out that the evaluation of temperature conditions by the heat unit theory has definite limitations. It fails among other things to evaluate daily range in temperature, duration of temperature, daily extremes of temperature, and the stage in the development of the fruit at which they occur.

Irrigation during Ripening Period

Records were made of the irrigation dates in all groves sampled during this investigation. Data from the regular weekly fruit tests made before and after irrigation were used. In evaluating the effect of irrigation, the changes recorded before and after irrigation must be compared with the normal seasonal trends for the same period. These normal changes were computed by averaging all of the tests made during the interval, The average data obtained are set forth in Table 41.

It appears that no significant changes occur in the Brixsacid ratio, which can be attributed to the immediate effect of irrigation, and that irrigation may retard the normal rate of increase in percentage of juice by volume. No direct data have been obtained to explain this, However, measurements by Harris (13) indicate that if soil moisture is low, the fruit may shrink in diameter. After irrigating, a rapid increase in size takes place. It is probable that this increase in volume is confined largely to the peel, thus the percentage of juice by volume would be reduced.

TABLE 41.—EFFECT OF IRRIGATION UPON BRIX:ACID RATIO AND PERCENTAGE OF JUICE.

		1935 Sept. and Oct.	1936 Oct. and Nov.	1937 Sept. and Oct.	1938 Sept.	1938 Oct.	1938 Nov.	1938 Dec.	1939 Oct.
No. of comparisons		12	9	8	8	5	6	6	7
Av. interval between tests (days)		7	13	9	9	7	8	14	11
Brix (degrees)	Before	10.93	11.20	11.37	11.08	11.37	11.59	12.19	11.39
	After	11.03	11.23	11.40	11.28	11.61	11.58	12.08	11.52
Acid (%)	Before	1.94	1.73	1.85	2.03	1.81	1.74	1.75	1.86
	After	1.88	1.75	1.84	1.91	1.79	1.75	1.75	1.87
Brix:acid ratio	Before	5.65	6.47	6.15	5.46	6.34	6.66	6.97	6.12
	After	5.94	6.42	6.19	5.90	6.49	6.62	6.90	6.16
Change		+0.29	−0.05	+0.04	+0.44	+0.15	−0.04	−0.07	+0.04
Normal change during interval		+0.21	+0.05	+0.19	+0.41	+0.07	+0.07	−0.06	+0.07
Volume (cc. per fruit)	Before	311	442	271	328	386	427	420	363
	After	320	440	282	352	408	458	463	388
Juice (% by volume)	Before	26.8	34.2	30.3	27.5	33.3	36.7	36.6	31.9
	After	26.5	35.3	31.2	28.5	32.5	35.3	36.3	31.7
Change		−0.3	+1.1	+0.9	+1.0	−0.8	−1.4	−0.3	−0.2
Normal change during interval		+1.52	+0.97	+1.95	+2.05	+1.10	+0.29	+0.2	+1.88

Age of the Tree

Wood and Reed (21) have reported that old trees mature their fruit earlier than young trees because higher Brix values and Brix:acid ratio values occur in fruit from the older trees. Throughout the present studies data were obtained on fruit from old and young trees. Table 42 presents typical data obtained in 1937 comparing the fruit from 7-year-old trees with fruit from 24-year-old trees. These

TABLE 42.—INFLUENCE OF THE AGE OF THE TREE UPON MATURITY OF FRUIT.

1937		Brix		Acid (%)		Brix:acid ratio		Juice in peeled fruit (%)		Color	
		Young	Old	Young	Old	Young	Old	Young	Old	Young	Old
Sept.	10	10.74	12.06	1.74	2.05	6.17	5.88	58.3	62.4	7	14
	16	10.72	12.20	1.66	1.99	6.46	6.13	66.0	62.9	9	16
	22	10.99	12.09	1.67	2.00	6.58	6.05	69.9	65.3	12	18
	30	10.80	11.95	1.53	1.85	7.06	6.46	70.6	67.8	10	20
Oct.	16	10.73	12.06	1.58	1.88	6.79	6.41	71.6	71.2	15	30
	23	10.93	12.12	1.53	1.85	7.14	6.55	70.7	71.4	25	39
NOT.	6	10.85	12.35	1.57	1.86	6.91	6.64	76.0	71.1	30	54
	19	11.26	12.36	1.49	1.78	7.56	6.94	75.4	76.2	37	98
Dec.	4	10.87	11.96	1.62	1.89	6.71	6.33	77.7	75.9	75	100
	18	10.97	12.46	1.59	1.95	6.90	6.39	76.8	75.7	100	100
	31	10.93	12.05	1.65	1.97	6.62	6.12	74.2	74.7	100	100
Jan.	15	11.42	12.88	1.70	1.94	6.72	6.64	78.5	76.3	100	100

trees were growing in the Salt River Valley under rather comparable conditions with regard to location, temperatures, soil type, and fertility.

The data indicated that fruit from old trees generally had a higher Brix value and a higher percentage of acid and contained a lower Brix:acid ratio than fruit from young trees. The rate of coloration was usually more rapid in fruit from old trees. The percentage of juice in the edible portion of the fruit increased slightly more rapidly and attained slightly higher levels in the fruit from the young trees.

These studies indicate that old trees are later in maturing their fruit with respect to Brix:acid ratio than young trees, which is the reverse of the situation reported in Texas. Causes of these differences are unknown.

Fertilizing Elements

Studies of grapefruit fertilization have been conducted by the Arizona Experiment Station on the Yuma Mesa. The plan of this experiment has been discussed in detail elsewhere (9, 10). All plots except the control received a base application of 3 tons of manure per acre each February. At the same time supplemental fertilization with commercial nitrogen, phosphorus, and potash, singly or in combination, was made. No fertilizers were applied at any other time. Two plots received 9 and 3 tons of manure respectively with no additional fertilization.

The physical and chemical character of the fruit produced in several of these different plots was studied during the 1937-38 and 1938-39 seasons. Samples of twelve fruit, selected from three trees in each plot, were tested at 2-week intervals from early September to March. The same trees were sampled both seasons, and the usual chemical and physical measurements made. The data obtained during September, October, and November revealed that only slight differences between individual plots were evident throughout the season, as has been previously reported for similar studies (15). To provide a summary of the physical and chemical characteristics, an average has been made of the six samples analyzed between December 1 and February 17. These values are presented in Table 43.

The chief difference appeared to be between the group of plots receiving commercial nitrogen and those which did not. If the data are studied with reference to these two groups, certain slight differences are evident, particularly in 1938-39.

No significant influence upon the total soluble solids is evident. The higher values in 1938-39 suggest a seasonal influence. The acid, however, tends to be lower in the fruit from the plots which received commercial nitrogen in February, This is reflected in a higher Brix:acid ratio. These plots also tended to produce fruit containing larger amounts of juice in the edible portions. The rate of coloration of the fruit was slightly retarded in the commercial nitrogen plots.

It should be noted that the plots receiving commercial nitrogen produced many more fruits per tree than those not receiving it. Hence, differences in maturity may have been related to the numbers of fruit on the tree rather than to a direct effect of the nitrogen application.

TABLE 43.—INFLUENCE OF FERTILIZER TREATMENT UPON MATURITY.

Plot[a]	Fertilizer	Lbs. per tree	Brix	Acid (%)	Brix: acid ratio	Juice in peeled fruit wt. (%)	Coloration[b]
			1937-38				
A	Amm. sulph,	10	11.06	1.48	7.48	74.7	47
B	Cal. nitrate	6	11.10	1.52	7.30	74.4	48
C	Amm. sulph,	5					
	Treb. superphos.	2.5	11.00	1.50	7.33	76.0	44
D	Amm. phos.	8	11.35	1.52	7.47	74.4	51
E	Treb. superphos,	2.5	10.81	1.58	6.84	75.0	48
F	Manure	200	11.09	1.54	7.20	73.7	49
G	Manure	65	11.07	1.58	7.01	75.7	47
E	Control	0	11.09	1.54	7.20	71.6	56
			1938-39				
A	Amm. sulph.	10	11.54	1.48	7.80	75.9	58
B	Cal. nitrate	6	11.63	1.51	7.70	72.9	66
C	Amm. sulph.	5					
	Treb. superphos.	2.5	11.75	1,56	7.52	76.2	54
D	Amm. phos.	8	11.74	1.53	7.68	74.6	55
E	Treb. superphos.	2.5	11.60	1.54	7.53	71.7	70
F	Manure	200	11.46	1.53	7.49	71.4	61
G	Manure	65	11.67	1.54	7.58	72.6	57
H	Control	0	11.65	1.59	7.33	71.3	61

[a] Plots A B C D E received in addition manure at rate of 3 tons per acre.
[b] Average color for October and November.

While wide differences in yield have been consistently obtained between the plots receiving commercial nitrogen in February and those not receiving it, comparable differences in quality of fruit or maturity have not occurred. Under the conditions of this experiment there has been no evidence to indicate that phosphorus hastens maturity or improves the quality of the fruit.

Tree Vegetativeness

In December, 1937, an investigation of the relation of the fruiting behavior of grapefruit trees to tree vegetativeness was initiated on the Yuma Mesa by the Arizona Experiment Station (18). The cultural practices used in this study were designed to produce different degrees of vegetativeness at different seasons of the year, A high nitrogen

condition was induced by applications of nitrogen in the form of calcium nitrate at appropriate seasons, A low vegetative condition was induced by growing cover crops of barley in the winter and Sudan grass in the spring and summer. The plots studied were treated to produce the following effects. Plot 1: high vegetativeness throughout the year. Plot 2: high vegetativeness in the winter; low vegetative condition in the late spring, summer, and early fall. Plot 4: low vegetativeness throughout the year.

Samples of twelve fruit from three trees in each of the several plots were tested at 2-week intervals from early September to March in the 1938-39 season and again in the 1939-40 season. The data obtained in 1938-39, presented in Figure 8, are similar to those obtained in 1939-40 except for Plot 4.

In evaluating the data difficulty was encountered due to the difference in size of the fruit. Fruit from Plot 1 was large and coarse, while fruit from Plots 2 and 4 was small and smooth. Thus it was not possible to separate entirely the effect of size from the effect of the treatment. Since large fruit normally attains a higher Brix:acid ratio than small fruit, the differences noted with respect to this factor are in reality more significant than the actual values indicate. Juice has been determined by weight on a peeled basis, thus largely eliminating the effect of size.

The data of Figure 8 reveal that a condition of high vegetativeness throughout the year (Plot 1) tended to reduce the total soluble solids and maintain a relatively high acid in proportion to total soluble solids, thus producing a low Brix:acid ratio. The rate of increase in the Brix:acid ratio was retarded after September as was the rate of coloration. A large amount of juice was found in the edible portions of the fruit but the peel was thick.

The trees of Plot 4 reached an extreme condition of low vegetativeness in 1939-40 which appeared to affect maturity, so that considerable difference existed in the fruit of this plot during the 2 years studied. In 1938-39 when the trees were moderately vegetative, the total soluble solids in the fruit were increased. A high acid was found in the early fall which decreased rapidly during the season. Thus the ratio was low in the fall and high in the spring. Lower amounts of juice were found in the edible portion of the fruit, particularly in 1939-40. The rate of coloration was the most rapid of the three plots.

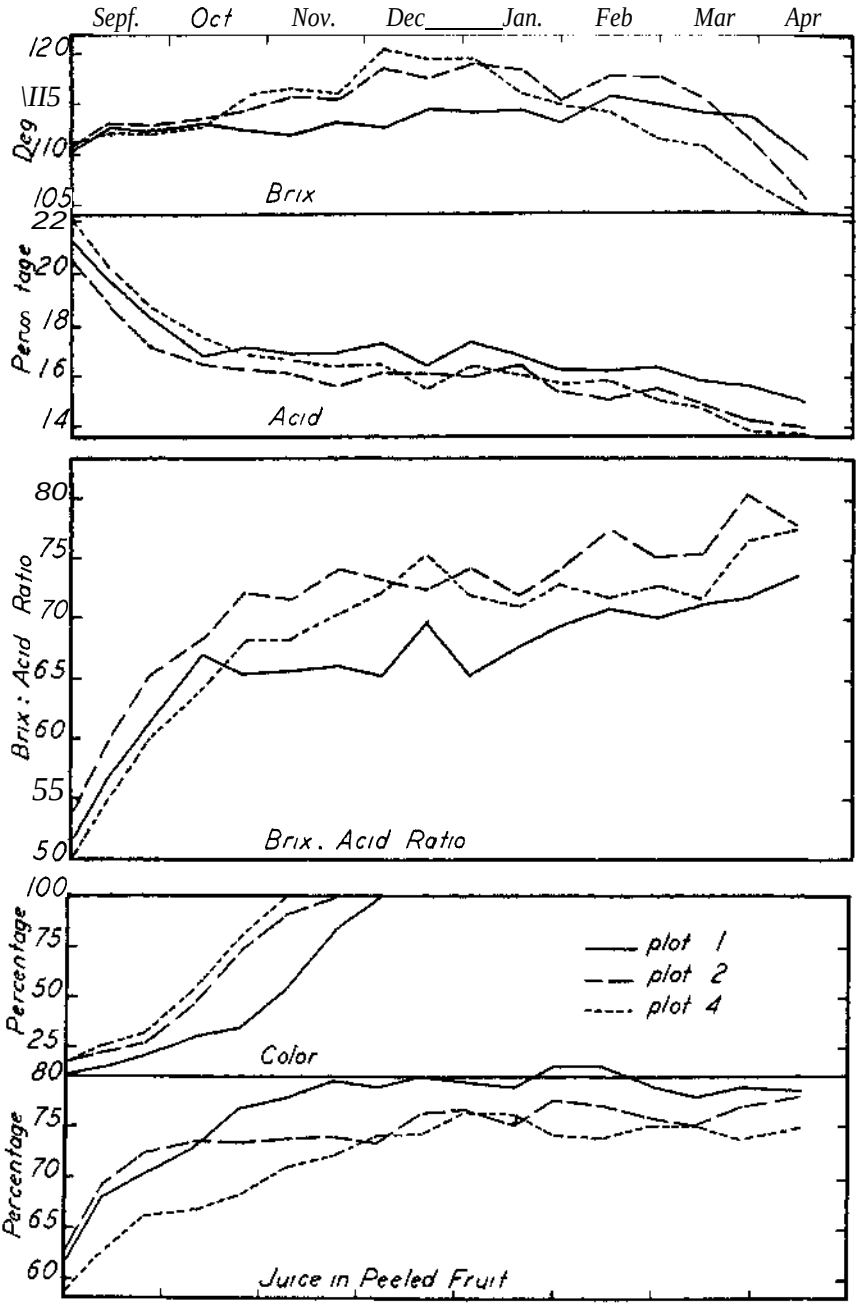

Figure 8.—Seasonal changes in Brix, Brix:acid ratio, and percentage of acid, color, and juice in the peeled fruit by weight in trees having different degrees of vegetativeness, 1938-39.

Low vegetativeness during the summer and fall (Plot 2) following a condition of relatively high vegetativeness in the spring tended to increase the total soluble solids and reduce the acid, thus producing high ratios. The rate of coloration was accelerated. Relatively large amounts of juice in the edible portion of the fruit were maintained.

This investigation indicates that a high vegetative condition during the summer and fall tends to produce the following effects in the fruit: a low amount of total soluble solids and a relatively large amount of acid, so that the ratio is lowered and its rate of increase retarded; a large amount of juice in the edible portion of the fruit; a retarded rate of coloration* A low vegetative condition tends to produce the opposite effects. Combinations of these conditions at different seasons of the year indicate that a close relationship exists between vegetative condition during the late summer and early fall and maturity characteristics.

Summary of Part IT

The summation of heat required to attain a 6.3:1 Brix:acid ratio averaged 5,930 units. Wide variations occurred which appeared to be related to temperatures during September and October.

Fruit on old trees tended to color more rapidly and to contain larger amounts of acid and a lower Brix:acid ratio than fruit on young trees. No significant effect upon the rate of increase in juice was found, but the amount appeared to be slightly larger in the fruit from young trees.

Irrigation during the fall appeared to have no immediate effect upon the total soluble solids to acid ratio. The rate of increase in the percentage of juice by volume was apparently retarded following an irrigation.

Fertilization on the Yuma Mesa with different forms of nitrogen in February tended to produce fruit with a lower acid, higher Brix:acid ratio and juice than unfertilized trees or trees fertilized with manure. The addition of phosphate to nitrogen fertilizer did not influence these changes.

A high vegetative condition of the tree throughout the year tended to produce fruit with a low Brix and a relatively high acid, and to retard the rate of increase in their ratio as the fruit matured. It tended to increase the percentage of juice in the peeled fruit and retard the rate

of coloration. i moderately low vegetative condition of the tree throughout the year tended to produce fruit having opposite characteristics. A combination of high vegetative condition in winter and low in summer tended to produce fruit with a moderately high Brix and low acid, a high Brix:acid ratio, an average percentage of juice in the edible portion, and an intermediate rate of coloration.

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