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INHERITANCE OF COMPOSITION IN FRUIT THROUGH VEGETATIVE PROPAGATION.

BUD VARIANTS OF EUREKA AND LISBON LEMONS.

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WITH AN INTRODUCTION

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INTRODUCTION.

A study of the physical characteristics of striking bud variations of the important commercial citrus varieties was begun in 1909 in southern California, to determine the extent and frequency of the occurrence of these bud variations and their relation to commercial orcharding. While some variations in trees and fruits have been found to be due to varying environmental conditions, others have proved to be inherent. These inherent variations were studied in progeny rows in experimental orchards in several places in southern California. From the data on the behavior of these progenies, a distinction between the fluctuating and the inherent variations has been established beyond any question of doubt (*5, 6*).[2]

In the course of the study of the physical characteristics of the bud variations, and of the trees and fruits arising from them, as found in established citrus groves in southern California, it was suggested that a knowledge of the chemical composition of the fruits

[1] C. P. Wilson, C. O. Young, and R. H. Kellner, of the Laboratory of Fruit and Vegetable Chemistry, collaborated in the analytical work. The authors also wish to express their gratitude to Dr. G. F. McEwen, of the Scripps Institution for Biological Research, for his advice and cooperation.

[2] Italic figures in parentheses throughout this bulletin refer to Literature cited, page 18.

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from typical trees of the strains arising from bud sports might be of value. In developing a method for conducting such a study, it was decided to analyze samples of fruit from some of the strains having distinctly different physical characteristics.

The object of the work was to determine whether or not there are characteristic differences in the composition of citrus fruits which can be correlated with the physical characteristics of the fruit produced by trees or branches of trees belonging to different strains. If such differences of composition exist, the results obtained in these studies will be of value in measuring the progress of the work for the improvement of citrus varieties through bud selection based upon systematic individual tree performance records. This bulletin gives the data from the analyses of samples of lemons borne on trees belonging to distinct strains of the Eureka and Lisbon varieties.

The results of this work have also suggested the possibility of securing through bud selection, based upon performance records which include a comparison of the fruits and their physical characteristics, strains adapted particularly for oil production, acid production, or other specific purposes of lemon by-products manufacture. In any event, it gives a more definite measure of the comparative quality of the fruits than is possible from any other method of study thus far tested.

With these preliminary studies and the records of production, including the quantity and commercial quality of the fruits produced by typical parent trees of the different strains of the lemon varieties, and with adequate progenies from these trees now coming into full bearing, it is hoped that these investigations may be continued to a point where they can be made of practical value in the selection of strains for commercial propagation for specific purposes, and for the selection of individual trees in those strains as sources of budwood which will be used in propagating important strains for commercial orcharding.

THE PROBLEM.

The work here reported was done with the hope of showing the extent to which fruit from different Eureka and Lisbon lemon trees varies in composition, whether or not this variation is greater between different strains of trees than between individual trees, and whether or not the peculiarities of composition found in the fruit of parent trees are transmitted to the fruit of progeny trees by vegetative propagation.

Some characteristics, of course, are inherited by certain species. For example, the acid and sugar contents of lemons differ from those of oranges and pomelos. Moreover, certain strains of navel oranges are so different from other strains as to be readily recognized without chemical analysis. Thus Washington Navel oranges differ from Thomson oranges, such differences apparently being transmitted to offspring by budding.

The extent to which inheritance of composition prevails is of interest to plant breeders and to citrus growers. Certain strains of Eureka and Lisbon lemons have physical differences which they transmit to their progeny. An effort will be made to determine how far this property extends to the elements of composition. If productiveness and shape of fruit are inherited from tree to tree, or transmitted by strains of trees to their progeny, perhaps specific gravity, percentage of rind, and acidity of juice are also transmitted properties.

Elements of composition are more readily influenced by environment than are many physical characteristics of fruit, so that it is difficult to prove that composition is inheritable. Decided variation in the composition of fruit from a single tree occurs, two fruits from the same spur often differing markedly in composition. The position of the fruit on the tree, the quantity of water used in irrigation, fertilization, cultivation, and the stage of maturity of the fruit when gathered, all influence its composition. By careful methods of sampling, and the selection of healthy trees which have received identical treatment, the influence of these factors may be reduced to a minimum.

EXPERIMENTAL PROCEDURE.

SAMPLING.

The original plan was to select a few trees of each of the well-defined strains isolated by Shamel and his coworkers (*5*, *6*), together with some single trees of sporting strains, and to ascertain by the data obtained from monthly sampling and analyses the differences which might be expected in the progeny. This plan, however, had to be modified, for it soon became apparent that trees of nonproductive strains would not mature enough fruit at certain seasons of the year to permit satisfactory sampling. Sampling was continued in all cases, however. Although some of the data obtained may not be strictly comparable where strains of trees are being considered, they may be useful in studying inheritance in individual trees.

Study of the data derived from analyses of samples over an extended period showed that not enough trees had been selected to make certain that the errors due to variation between trees of the same strain had been obviated. As it was impossible to increase the number of trees and maintain the analyses on the original scale, the number of determinations on each sample was reduced, samples were taken less frequently, and as many trees as possible were included.

The monthly samples consisted of from 18 to 24 fruits. These were as nearly as possible representative of the commercial fruit upon the tree and were selected for size without regard to color. They were packed in cartons and mailed to the laboratory at Los Angeles, where analysis was begun, usually within 48 hours after picking. When any delay was necessary, the fruit was left in the cartons, which were placed in storage at from 35° to 45° F.

In the second period of the work, samples from several trees of each strain, consisting usually of 25 or more fruits, were taken. These samples were subdivided into lots of 5 to 7 fruits each, and each lot was analyzed separately. This method afforded a good opportunity to observe the variability of fruit from individual trees.

SIGNIFICANCE OF DETERMINATIONS MADE.

Several points were involved in selecting the elements of composition to be determined. The feasibility of making the determination on a large number of samples was considered, as well as whether or not the element would vary, and whether or not the variation was sufficient to be commercially important. The object being to discover chemical or physical differences existing between strains of fruit of the same variety, the outstanding characteristics were chosen for observation. Whenever possible, characteristics had been studied in the field by A. D. Shamel and his associates (*5*, *6*), so that the data here reported are the results of laboratory work alone. Thus, the tree characteristics and the yield, color, shape, and size of fruit, and its seed content, were determined in the field; while specific gravity of the fruit, percentage of rind, oil, pulp, and juice, and percentage of acid and sugar in the juice, were determined in the laboratory. In the second phase of the work, the determinations were confined to specific gravity of the fruit, percentage of peel, and percentage of acid in the juice.

Specific gravity is of value in judging the quality of citrus fruit. First, and probably of greatest importance, is the compactness of the fruit. Puffy, coarse-textured, hollow-centered fruit has a low specific gravity. As the juice constitutes nearly two-thirds of citrus fruit by weight, the specific gravity of the juice, to that extent, determines the specific gravity of the fruit. For this reason, considering oranges of equal size, the heaviest ones are usually the sweetest. The texture of the rind perhaps plays but a small part in determining the specific gravity. Coarse rind, however, is usually accompanied by coarse rag and flesh and hollow centers.

The oil content of citrus fruit is of importance only in so far as oil is a by-product of the citrus industry. Other factors being equal, however, the fruit producing oil in greatest quantity and of highest quality is of most value. Oil occurs in comparatively small quantities and a decided variation in the content is necessary to appreciably affect the value of the fruit.

Rind, pulp, and juice, of course, are primary factors in judging the quality of citrus fruits. A fruit with a thin rind may not ship as well as one with a thicker and tougher covering, but the consumer will choose the former where opportunity offers.

Insoluble solids in the pulp indicate its texture, coarse, tough pulp having a high content of insoluble solids. Cell and partition walls are included in the material measured by this determination.

Sugar, of prime importance in oranges and grapefruit, is of little value in lemons. There seems to be some difference, however, in the quantity contained in lemons of different strains.

Acid is of great importance in all classes of citrus fruit. In oranges and grapefruit it is an indication of immaturity; in lemons it is the valuable constituent of the juice, both when the fruit is sold fresh and when it is used for the manufacture of citric acid.

METHODS OF ANALYSIS.

The methods of the Association of Official Agricultural Chemists were used in making the determinations, wherever such methods existed. Otherwise, others of recognized accuracy were employed.

Specific gravity of the fruit was determined by weighing it first in air and then under water. No difficulty was experienced with air bubbles clinging to the fruit.

The volatile oil in the peel was determined by the method of Wilson and Young (*8*), using the whole fruit finely ground. No method has been discovered by which the peel can be removed from the fruit without loss of part of the oil which it contains. Where oil was determined, half of the sample was taken for the oil determination, division as to color and size being made as evenly as possible. The fruit for the other determinations was then pared, as little as possible of the white rag being left adhering to the pulp. Both the rind and pulp were weighed, and the percentage of each was calculated, any loss falling where it had occurred. The pulp was passed through a food grinder several times and thoroughly mixed, and samples were taken for the determination of insoluble solids. Each sample was washed with cold water, placed in a Gooch crucible, and dried at the temperature of boiling water.

In determining the juice content, a purely arbitrary method was adopted. The pulp was considered to be the sum of the juice plus the insoluble solids. The percentage of insoluble solids was obtained by actual determination, and the percentage of juice was calculated. This method gives a result somewhat higher than could be obtained by using mechanical methods, but these methods are arbitrary and have the disadvantage of being almost impossible of standardization, so that duplication of one analyst's results is rarely possible, while those obtained by several analysts vary greatly. The figures given, therefore, represent the theoretical quantity of juice present. The best mechanical devices, unless extraction with water was used, would recover scarcely 80 per cent of the quantity indicated in the tables.

Total sugar was obtained by inversion with hydrochloric acid, and reducing sugars were determined by the methods of the Association of Official Agricultural Chemists. The optional method, treating the cuprous oxide with ferric sulphate and titrating the resulting ferrous salt with potassium permanganate, was used.

Acidity was determined by titrating the cold juice, diluted with distilled water, with standard alkali solution, using phenolphthalein as indicator. Repeated determinations, titrating after boiling and while hot, did not materially change the results. Apparently any error due to the presence of carbon dioxide is less than that caused by the difficulty of determining the end point.

RESULTS.

The results obtained are given in Tables 1 to 6, inclusive. The description of the physical characteristics of these trees, and of the yields obtained from them, may be found in the bulletins of Shamel and his coworkers (*5*, *6*).

Table 1 gives data derived from monthly analyses of the fruit of trees representing two strains of the Eureka variety—the Eureka and the Shade Tree.

TABLE 1.—*Composition of Eureka lemons of different strains (monthly samples).*

Sample No.	Month picked.	Specific gravity of fruit.	Average weight of fruit.	Oil.	Rind.	Pulp.	Juice.	Insoluble solids in pulp.	Total sugar in juice.	Acid in juice.
EUREKA STRAIN (TREE 34-57-5).			*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1563	June	0.9416	115.1	0.35	38.8	60.7	59.7	1.54	1.11	4.91
1589	July	.9355	133.3	.28	46.4	52.9	51.2	3.24	2.23	4.32
1599	August	.9394	141.2	.33	38.5	61.1	59.6	2.46	2.23	4.68
1608	September	.9437	123.3	.57						5.60
B607	October	.9624	117.8	.44	30.5	69.6	68.0	2.24	2.99	4.58
B621	November	.9080	123.7	.61	41.0	58.5	57.2	2.33	2.17	4.96
B659	December	.9098	125.0	.67	43.4	56.3	55.2	1.81	1.93	4.98
B711	January	.9133	118.5	.53	40.6	58.9	58.0	1.65	1.95	5.01
B772	February	.9087	123.0	.56	44.4	55.4	54.7	1.33	1.98	5.04
B830	March	.9086	126.6	.45	44.7	54.0	53.0	1.98	1.69	4.90
1093	October	.9527	101.0	.69	35.6	64.4	62.9	2.39	2.23	4.70
1107	November	.9588	104.8	.66	36.6	64.1	62.7	2.17	2.34	5.09
1133	December	.9457	119.2	.61	37.8	62.1	61.0	1.69	2.65	5.12
1144	January	.9322	113.3	.57	38.6	61.4	60.4	1.65	2.52	5.15
1172	March		120.2	.53	40.8	58.6	57.8	1.39	2.47	5.22
1186	April	.9238	111.9	.52	42.6	57.2	56.4	1.31	1.87	6.21
1201	May	.9308	107.4	.54	42.8	57.2	56.4	1.46	1.59	4.86
Average		**.9322**	**119.1**	**.52**	**40.2**	**59.5**	**58.4**	**1.92**	**2.12**	**5.02**
		±.003		**±.02**	**±.7**			**±.09**	**±.07**	**±.05**
EUREKA STRAIN (TREE 34-75-12).										
1538	May	.9234	121.1	.36	36.5	61.9	60.8	1.78	2.24	5.61
1565	June	.9342	112.3	.36	37.3	61.6	60.5	1.65	2.16	5.21
1595	July	.9382	89.2	.39	32.5	67.6	66.5	1.54	1.83	5.02
1602	August	.9825	107.5	.39	31.0	68.3	66.6	2.44	3.20	4.67
1606	September	.9639	116.1	.46	33.5	65.8	64.5	2.07	3.25	4.75
B605	October	.9707	116.2	.46	29.5	70.4	68.8	2.28	2.92	4.26
B720	January	.9352	108.0	.60	24.0	75.4	74.6	1.15	3.25	4.85
B784	February	.9148	122.3	.49	37.4	62.5	61.3	1.90	2.98	5.25
B836	March	.9305	119.0	.45	34.4	65.0	63.5	2.21	2.49	5.15
B887	April	.9264	129.7	.48	35.2	64.1	63.2	1.35	2.28	5.41
B934	May	.9454	112.5	.53	32.8	66.6	65.2	1.89	2.21	5.79
1134	January	.9631	109.1	.63	30.9	69.2	68.0	1.87	2.77	5.12
1154	February	.9517	105.6	.60	34.2	65.2	64.1	1.69	2.76	5.22
1173	March	.9500	122.9	.54	34.7	65.9	64.8	1.60	2.65	5.22
1190	April	.9277	114.3	.50	41.1	58.9	58.0	1.58	2.43	5.06
1202	May	.9360	120.0	.52	41.9	57.7	56.1	1.93	2.20	4.99
Average		**.9434**	**114.1**	**.48**	**34.2**	**65.4**	**64.1**	**1.81**	**2.60**	**5.10**
		±.003		**±.01**	**±.7**			**±.06**	**±.08**	**±.05**
EUREKA STRAIN (TREE 34-4-8).										
1532	May	.9268	110.9	.41	35.8	63.2	62.0	1.75	2.33	5.46
1564	June	.9262	121.4	.28	40.6	58.6	57.6	1.69	1.91	5.14
1590	July	.9444	115.0	.37	39.3	60.2	59.0	2.05	1.95	5.10
1600	August	.9667	123.9	.35	34.3	65.0	63.4	2.56	2.55	4.65
1607	September	.9631	121.4	.57						5.44
B607	October	.9624	117.8	.44	30.5	69.6	68.0	2.24	2.99	4.58
B622	November	.9500	126.3	.74	34.9	64.8	61.6			4.98
B668	December	.9480	114.3	.67	35.0	64.8	63.6	1.86	2.74	5.76
B712	January	.9054	121.7	.58	41.1	58.5	57.6	1.47	2.48	5.07
B777	February	.9178	126.1	.48	30.8	69.1	67.6	2.19	2.25	5.44
B829	March	.9149	128.5	.46	41.1	57.7	56.4	2.26	1.98	5.22
B931	May	.9494	121.0	.65	34.6	65.4	64.2	1.77	1.86	5.68
B987	June	.9690	118.8	.51	34.8	65.6	64.0	2.50	2.30	4.83
B1066	September	.9774	114.8	.42	30.6	68.8	67.3	2.15	2.94	5.09
1092	October	.9705	106.1	.69	30.3	68.7	67.2	2.12	1.78	5.02
1105	November	.9564	107.4	.72	31.5	67.8	66.2	2.35	2.45	5.31
1132	January	.9563	112.7	.60	31.9	68.2	66.7	2.18	2.68	5.15
1150	February	.9475	103.0	.61	33.3	66.6	65.3	1.98	2.59	5.12
1171	March	.9074	122.0	.41	35.1	64.6	63.8	1.34	1.97	5.09
1200	May	.9522	110.5	.57	38.4	61.3	60.4	1.47	1.88	5.22
Average		**.9456**	**117.2**	**.53**	**35.0**	**64.6**	**63.3**	**2.00**	**2.31**	**5.17**
		±.003		**±.02**	**±.6**			**±.06**	**±.06**	**±.04**
SHADE TREE STRAIN (TREE 34-54-11).										
619	November	0.9178	143.0	0.52	39.7	59.9	58.5	2.27	2.35	4.67
774	March	.9140	153.4	.55	43.8	55.8	55.0	1.46	2.46	4.67
1110	November	.9592	117.5	.54	36.0	63.7	62.0	2.57	2.63	4.96
1127	December	.9502	115.3	.60	34.4	65.7	64.4	2.12	2.72	4.64
1151	January	.9396	115.2	.53	38.4	61.3	60.1	1.89	2.87	4.85
1169	March	.9235	133.1	.47	39.8	59.8	59.0	1.44	2.60	4.80
1189	April	.9405	116.9	.48	38.1	60.8	59.9	1.56	2.27	4.96
1198	May	.9447	113.6	.52	35.6	64.5	63.6	1.34	2.24	4.42
Average		**.9362**	**126.0**	**.53**	**38.2**	**61.4**	**60.3**	**1.83**	**2.52**	**4.75**
		±.004		**±.01**	**±.7**			**±.12**	**±.06**	**±.05**

TABLE 1.—*Composition of Eureka lemons of different strains (monthly samples)*—Continued.

Sample No.	Month picked.	Specific gravity of fruit.	Average weight of fruit.	Oil.	Rind.	Pulp.	Juice.	Insoluble solids in pulp.	Total sugar in juice.	Acid in juice.
SHADE TREE STRAIN (TREE 34–74–4).										
			Grams.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1537	May	0. 9583	136. 5	0. 26	45. 7	54. 1	52. 8	2. 45	2. 24	5. 00
1567	June	. 9862	112. 6	. 30	46. 7	53. 2	51. 7	2. 82	2. 38	4. 45
1593	July	. 9673	135. 3	. 31	43. 6	56. 2	54. 4	3. 21	3. 27	4. 41
1604	August	. 9688	131. 7	. 36	37. 9	62. 0	60. 4	2. 54	3. 46	4. 66
1610	September	. 9533	136. 6	. 44	41. 6	58. 4	56. 8	2. 64	3. 12	4. 44
B604	October	. 9620	115. 6	. 59	31. 9	68. 0	66. 1	2. 73	2. 83	4. 80
B632	November	. 9476	125. 3	. 59	35. 1	64. 3	62. 6	2. 75	3. 04	4. 87
B677	December	. 9599	108. 5	. 64	33. 6	66. 2	64. 5	2. 57	2. 06	4. 87
B721	January	. 9356	121. 9	. 51	37. 0	62. 7	61. 3	2. 28	3. 24	4. 51
B785	March	. 9323	116. 8	. 57	41. 0	58. 6	57. 3	2. 24	2. 68	4. 83
B837	April	. 9516	126. 7	. 46	40. 5	59. 1	57. 7	2. 41	2. 21	4. 83
1095	October	. 9672	104. 8	. 74	41. 8	58. 2	56. 8	2. 40	2. 49	4. 90
1111	November	. 9688	108. 7	. 59	30. 2	69. 7	67. 9	2. 53	2. 53	5. 09
1139	January	. 9543	113. 9	. 59	33. 6	66. 1	64. 7	2. 18	3. 02	4. 85
1155	February	. 9694	108. 8	. 58	37. 9	61. 9	60. 6	2. 07	3. 09	5. 06
1176	March	. 9531	132. 5	. 46	40. 0	59. 8	58. 6	1. 87	2. 43	5. 01
Average		. 9585 ±. 002	121. 0	. 50 ±. 02	38. 6 ±. 9	61. 2	59. 6	2. 48 ±. 05	2. 75 ±. 08	4. 78 ±. 04
SHADE TREE STRAIN (TREE 34–74–13).										
719	January	0. 9276	127. 5	0. 50	36. 8	62. 6	61. 3	2. 09	2. 68	5. 35
782	March	. 8930	129. 8	. 49	39. 8	59. 4	58. 2	2. 00	2. 89	4. 87
1106	November	. 9546	116. 0	. 63	33. 1	66. 7	64. 9	2. 72	2. 51	5. 34
1137	January	. 9616	110. 6	. 65	33. 5	66. 0	64. 7	2. 02	2. 59	5. 33
1175	March	. 9440	126. 7	. 51				1. 96	2. 23	5. 12
Average		. 9362 ±. 009	122. 1	. 56 ±. 03	35. 8 ±1. 2	63. 7	62. 3	2. 16 ±. 10	2. 58 ±. 08	5. 20 ±. 07
SHADE TREE STRAIN (TREE 34–75–14).										
1539	May	0. 9467	125. 9	0. 37	39. 1	60. 3	59. 0	2. 10	2. 20	5. 31
1566	June	. 9548	123. 3	. 39	39. 6	60. 1	58. 9	1. 99	2. 12	4. 86
1596	July	. 9663	112. 8	. 30	35. 1	64. 6	63. 0	2. 47	2. 43	4. 95
1601	August	. 9588	125. 0	. 38	37. 6	62. 2	60. 6	2. 57	3. 64	4. 33
1605	September	. 9500	128. 0	. 38	35. 4	64. 4	62. 8	2. 45	3. 90	4. 17
B606	October	. 9717	122. 0	. 41	30. 3	69. 7	68. 2	2. 15	4. 08	4. 19
B783	March	. 9036	125. 9	. 51	37. 9	61. 4	60. 3	1. 80	2. 89	4. 48
B888	April	. 9397	129. 3	. 44	36. 9	62. 8	61. 6	1. 86	2. 47	4. 90
B935	May	. 9554	122. 4	. 53	34. 8	63. 9	62. 8	1. 80	2. 25	5. 36
1131	January	. 9491	114. 7	. 67	33. 0	67. 1	65. 7	2. 07	3. 09	4. 71
1174	March	. 9385	127. 6	. 51	38. 2	61. 5	60. 6	1. 59	2. 88	4. 72
1191	April	. 9475	117. 6	. 48	35. 8	63. 8	62. 8	1. 54	2. 01	4. 59
1205	May	. 9556	120. 1	. 54	40. 5	59. 5	58. 6	1. 61	2. 59	4. 70
Average		. 9491 ±. 003	122. 7	. 45 ±. 02	36. 5 ±. 5	63. 2	61. 9	2. 00 ±. 07	2. 81 ±. 14	4. 71 ±. 07

Table 2 contains data derived from monthly analyses of the fruit of trees representing three strains of the Lisbon variety—the Bull, the Open, and the Dense Unproductive.

TABLE 2.—*Composition of Lisbon lemons of different strains (monthly samples).*

Sample No.	Month picked.	Specific gravity of fruit.	Average weight of fruit.	Oil.	Rind.	Pulp.	Juice.	Insoluble solids in pulp.	Total sugar in juice.	Acid in juice.
BULL STRAIN (TREE 1-56-12).			*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1545	June	0.8914	135.6	0.31	45.4	53.9	53.1	1.53	1.53	5.48
1569	July	.9286	121.8	.40	41.5	58.1	57.3	1.35	1.22	4.83
B617	November	.8903	125.5	.69	43.6	55.6	54.3	2.39	2.19	4.96
B645	December	.8863	133.1	.56	42.7	57.0	55.8	2.16	2.45	5.30
B692	January	.9065	128.4	.72	39.9	59.3	58.1	1.92	2.28	5.30
B739	February	.9032	111.9	.63	39.5	59.7	58.3	2.32	2.15	5.35
B803	March	.9032	120.0	.50	38.2	61.6	60.5	1.91	2.29	5.38
B868	April	.8825	140.1	.49	42.6	57.1	56.4	1.27	1.34	5.07
B911	May	.9142	124.6	.50	37.3	62.5	61.8	1.07	1.06	4.91
B959	June	.9116	127.3	.56	39.5	60.1	59.4	1.33	1.04	4.91
1093A	October	.9348	114.7	.69	34.1	65.7	64.4	1.98	2.38	5.54
1109	November	.9002	67.6	.65	34.5	65.6	63.9	2.59	2.64	5.86
1120	December	.9140	117.9	.56	35.8	64.1	62.6	2.37	2.68	------
1145	January	.8728	121.3	.56	39.5	60.2	59.1	1.89	------	5.34
1158	February	.8928	128.2	.51	39.5	60.4	59.4	1.67	1.26	5.51
1178	March	.8953	121.6	.44	41.3	58.4	57.4	1.73	2.05	5.44
1207	June	.8361	142.1	.37	44.1	53.7	52.7	1.89	1.58	4.61
Average		**.8979**	**122.5**	**.54**	**40.0**	**59.6**	**58.5**	**1.85**	**1.88**	**5.24**
		±.003		**±.02**	**±.5**			**±.08**	**±.11**	**±.06**
OPEN STRAIN (TREE 1-26-9).										
1548	May	0.9176	123.9	0.36	32.8	66.4	65.3	1.61	1.62	5.08
1584	July	.9204	129.5	.28	31.8	67.6	66.6	1.55	1.48	5.31
1597	August	.9113	111.4	.42	27.0	72.5	71.4	1.50	1.52	5.21
B653	December	.8989	130.5	.47	38.2	60.9	59.3	2.65	2.31	4.93
B702	January	.8756	115.7	.48	32.7	67.0	65.6	2.14	2.29	4.77
B758	February	.9177	112.0	.46	33.2	66.5	65.2	2.04	2.38	4.95
B810	March	.8995	125.4	.30	37.2	62.7	61.6	1.81	1.74	4.83
B866	April	.9046	128.4	.39	33.7	66.0	64.8	1.77	1.83	4.71
B914	May	.9189	129.3	.36	36.3	63.4	62.5	1.44	1.79	4.83
B947	June	.9087	120.3	.39	37.5	62.4	61.2	1.91	1.65	4.64
1100	November	.9493	107.1	.63	31.0	68.9	67.0	2.69	3.84	5.66
1122	December	.9426	112.7	.54	32.2	67.8	66.3	2.30	3.11	5.47
1148	January	.9142	118.1	.52	36.5	63.2	61.8	2.27	3.17	5.36
1162	February	.9119	121.1	.47	37.7	62.1	60.9	1.84	2.91	5.34
1182	April	.9063	128.1	.41	39.3	60.6	59.6	1.68	2.43	5.22
1197	May	.8550	123.8	.44	38.8	60.6	59.8	1.35	1.81	4.80
Average		**.9095**	**121.1**	**.43**	**34.8**	**64.9**	**63.7**	**1.91**	**2.24**	**5.07**
		±.003		**±.01**	**±.6**			**±.07**	**±.12**	**±.06**
DENSE UNPRODUCTIVE STRAIN (TREE 1-29-12).										
1547	June	0.9303	137.8	0.34	34.9	64.8	64.0	1.32	1.11	5.22
1581	July	.9486	115.2	.44	31.9	67.7	66.7	1.45	1.09	5.32
B618	November	.9138	123.7	.69	36.2	62.8	61.4	2.22	1.74	5.25
B652	December	.9006	128.7	.72	38.3	59.7	58.7	1.65	1.98	5.10
B695	January	.8554	121.1	.75	38.6	60.8	59.8	1.66	2.00	4.90
B750	February	.9239	113.6	.73	34.7	65.1	64.1	1.48	1.94	4.95
B807	March	.8996	126.3	.66	37.9	61.6	60.8	1.30	1.53	5.06
B865	April	.9015	130.7	.73	38.7	61.0	60.3	1.21	1.29	5.25
B907	May	.9143	131.4	.66	31.5	68.0	67.5	.81	1.24	5.33
B950	June	.9124	128.7	.85	34.3	65.5	64.7	1.25	.82	5.39
1092A	October	.9227	103.0	.85	34.1	65.9	64.4	2.29	1.87	5.58
1123	December	.9414	110.1	.52	36.9	63.1	61.9	1.87	1.84	5.55
1146	January	.9280	116.0	.65	40.0	59.7	58.7	1.56	2.69	5.47
1159	February	.9253	123.0	.58	40.1	59.4	58.4	1.66	2.02	5.28
1181	April	.9255	120.2	.60	39.4	59.7	58.9	1.44	1.89	5.25
1195	May	.8934	124.1	.55	37.8	62.1	61.2	1.39	1.44	4.93
Average		**.9148**	**122.1**	**.64**	**36.6**	**62.9**	**62.0**	**1.54**	**1.66**	**5.24**
		±.003		**±.02**	**±.5**			**±.06**	**±.08**	**±.03**

Table 3 gives the results of analyses when the work was extended to a greater number of Eureka trees, and Table 4 the results when the work was extended to a greater number of Lisbon trees.

TABLE 3.—*Composition of strains of Eureka lemons.*

Tree No.	No. of fruits.	Specific gravity.	Rind.	Acid in juice.
EUREKA STRAIN.				
June, 1920:			*Per cent.*	*Per cent.*
34-75-12	15	0.945±0.002	48.9±1.5	5.2±0.03
34-73-7	15	.952± .002	46.3±1.0	5.5± .04
February, 1921:				
34-75-20	19	.930± .004	37.0± .8	4.8± .12
34-73-17	25	.927± .004	38.8± .4	4.6± .05
34-76-13	40	.923± .002	35.1± .3	4.7± .03
34-74-21	40	.926± .002	35.9± .6	4.4± .04
34-73-13	30	.931± .006	38.0± .9	4.6± .10
34-77-17	35	.925± .003	37.6± .3	4.7± .07
June, 1921:				
34-77-22	33	.902± .002	42.1± .2	4.89± .02
34-73-21	35	.906± .002	41.8± .3	4.90± .04
34-74-7	25	.896± .001	45.2± .8	4.94± .04
34-74-20	20	.897± .003	42.3± .7	4.80± .03
34-75-12	20	.903± .004	41.9± .3	4.79± .05
34-73-7	35	.915± .002	40.7± .5	5.15± .03
34-73-17	23	.900± .003	43.3± .8	5.01± .02
34-76-13	30	.895± .003	44.6± .6	4.58± .06
34-74-21	25	.904± .003	43.3± .9	4.62± .04
34-76-23	30	.907± .004	44.1± .3	4.97± .07
34-73-6	27	.908± .002	42.1± .4	5.20± .01
November, 1921:				
34-73-7	27	.966± .001	31.6± .3	4.44± .03
34-73-17	31	.959± .002	34.7± .6	4.27± .04
34-74-21	25	.952± .001	33.8± .5	4.53± .06
34-75-12	30	.963± .002	31.7± .5	4.29± .06
34-76-13	32	.947± .001	35.4± .3	4.69± .05
SMALL OPEN STRAIN.				
June, 1921:				
34-76-14	20	.910± .003	38.9±1.0	4.80± .07
34-73-2	25	.906± .003	41.0± .4	4.75± .06
34-73-1	23	.912± .003	41.9± .6	4.93± .03
34-77-13	20	.915± .002	43.5± .9	4.96± .08
34-74-2	15	.896± .003	44.4± .4	4.67± .02
34-73-8	24	.917± .004	38.5± .7	5.04± .07
November, 1921:				
34-76-14	30	.961± .001	33.8± .6	4.78± .05
34-77-13	35	.961± .002	34.9± .4	4.39± .06
SHADE TREE STRAIN.				
June, 1920:				
34-74-4	15	.966± .003	50.4±1.4	4.5± .08
34-75-42	15	.954± .002	52.0± .9	4.6± .02
34-75-14	15	.959± .001	48.5± .6	4.4± .09
34-75-15	15	.962± .002	46.9±1.3	4.6± .07
34-76-56	18	.963± .001	53.1± .4	4.9± .04
February, 1921:				
34-75-52	35	.920± .002	41.2± .4	4.7± .03
34-74-5	35	.921± .003	39.6± .4	4.8± .03
34-75-14	40	.932± .002	34.3± .6	4.4± .05
34-67-12	30	.910± .004	36.6± .9	4.4± .04
34-75-15	25	.931± .002	34.0± .4	4.1± .05
June, 1921:				
34-75-52	15	.926± .002	43.6± .5	4.70± .06
34-76-56	25	.908± .002	43.8± .5	5.08± .05
34-75-42	27	.917± .003	39.8± .5	4.52± .02
34-75-14	23	.937± .002	38.9± .5	4.76± .03
34-67-12	25	.957± .003	46.6± .7	4.90± .06
34-74-56	20	.919± .002	45.2± .5	4.76± .05
34-74-54	20	.915± .003	42.6± .8	4.67± .05
November, 1921:				
34-74-4	30	.947± .002	34.9± .5	4.76± .04
34-75-14	31	.945± .001	34.3± .4	4.18± .04
34-75-42	25	.936± .003	35.9± .3	4.62± .04
34-75-52	35	.945± .002	36.9± .5	4.74± .04
34-76-56	8	.954± .002	37.6± .4	5.08± .01
34-75-15	30	.954± .001	33.8± .6	3.76± .06

TABLE 3.—*Composition of strains of Eureka lemons*—Continued.

Tree No.	No. of fruits.	Specific gravity.	Rind.	Acid in juice.
DENSE UNPRODUCTIVE STRAIN.				
June, 1920:			*Per cent.*	*Per cent.*
34-74-40	11	0.958±0.002	55.0±1.3	4.7±0.08
34-76-4	10	.957± .003	49.4± .8	5.0± .04
34-77-4	15	.959± .003	47.6±1.1	4.7± .05
34-77-23	26	.962± .008	51.2± .1	4.8± .04
February, 1921:				
34-75-37	35	.924± .003	37.3± .5	4.3± .05
34-77-14	40	.925± .002	35.1± .6	4.3± .01
34-76-3	40	.926± .003	39.9± .5	4.9± .04
34-76-4	35	.915± .003	39.7± .5	4.7± .04
34-73-3	30	.932± .004	36.8± .7	4.6± .08
34-74-40	40	.923± .003	40.0± .6	4.6± .03
June, 1921:				
34-74-40	13	.940± .008	37.4± .9	4.94± .05
34-76-4	20	.920± .004	39.5± .7	4.47± .04
34-75-37	28	.934± .002	40.8±1.0	4.89± .02
34-77-14	25	.925± .002	40.8± .2	4.62± .03
34-77-23	20	.925± .004	43.5± .8	4.70± .04
34-76-3	24	.920± .002	39.9± .3	4.49± .03
34-73-3	20	.938± .002	39.5± .4	4.73± .05
November, 1921:				
34-73-37	29	.943± .002	35.4± .4	4.15± .05
34-73-3	30	.947± .001	34.7± .3	4.30± .02
34-74-40	27	.945± .002	36.7± .4	4.18± .07
34-76-4	35	.947± .001	33.0± .4	5.07± .03
34-77-14	35	.946± .001	30.8± .4	4.40± .04

TABLE 4.—*Composition of strains of Lisbon lemons.*

Tree No.	No. of fruits.	Specific gravity.	Rind.	Acid in juice.
LISBON STRAIN.				
November, 1920:			*Per cent.*	*Per cent.*
1-27-10	45	0.904±0.001	41.5±0.4	6.3±0.05
1-27-11	35	.898± .001	41.6± .3	6.2± .07
1-26-11	35	.911± .001	40.8± .5	6.1± .08
1-27-16	50	.915± .002	37.5± .5	6.2± .02
February, 1921:				
1-28-8	40	.884± .001	41.8± .3	5.8± .04
1-26-8	40	.890± .003	42.0± .7	5.8± .03
1-35-9	40	.893± .003	39.9± .4	5.4± .05
1-27-9	40	.893± .002	40.5± .3	6.0± .06
1-28-10	40	.897± .003	42.2± .1	5.7± .04
May, 1921:				
1-28-10	25	.869± .003	41.4± .7	5.2± .03
1-28-8	30	.871± .001	41.3± .5	5.5± .05
1-26-8	34	.867± .002	42.0± .3	5.3± .04
1-27-9	30	.874± .002	42.9± .4	5.6± .02
1-28-14	34	.867± .002	43.6± .2	5.4± .05
1-29-16	25	.875± .004	42.6± .7	5.6± .03
1-27-17	25	.869± .002	44.1± .3	5.3± .03
1-28-16	29	.864± .001	43.4± .5	5.5± .03
1-27-10	32	.870± .004	43.2± .9	5.6± .03
1-27-16	29	.875± .002	43.3± .3	5.4± .04
January, 1922:				
1-35-9	25	.891± .003	39.6± .3	5.4± .02
1-28-14	30	.897± .003	38.5± .5	5.7± .03
1-29-16	35	.897± .002	38.5± .4	5.8± .02
1-27-17	30	.897± .002	40.3± .6	5.6± .03
1-28-16	35	.900± .002	37.3± .6	5.7± .05
1-27-10	30	.894± .002	39.2± .5	5.7± .03
1-27-11	40	.887± .002	40.6± .4	5.7± .03
1-27-16	35	.893± .003	40.3± .4	5.7± .05
OPEN STRAIN.				
November, 1920:				
1-33-8	50	.910± .002	38.0± .4	5.6± .04
1-26-9	50	.920± .001	36.4± .4	5.4± .03
1-33-11	50	.924± .001	36.8± .3	5.4± .04
February, 1921:				
1-31-10	35	.887± .002	42.0± .4	5.2± .10
1-26-13	40	.884± .001	41.1± .5	5.4± .06
1-29-13	40	.894± .002	38.1± .8	5.4± .07
1-34-9	32	.887± .002	39.8± .4	5.2± .04
1-29-14	40	.885± .002	40.6± .6	5.3± .07

TABLE 4.—*Composition of strains of Lisbon lemons*—Continued.

Tree No.	No. of fruits.	Specific gravity.	Rind.	Acid in juice.
OPEN STRAIN—continued.				
May, 1921:			*Per cent.*	*Per cent.*
1-33-14	28	0. 900±0. 003	42. 9±0. 5	5. 5±0. 04
1-32-10	19	. 893± . 004	41. 0± . 8	5. 2± . 03
1-27-12	24	. 890± . 003	40. 1± . 5	5. 0± . 02
1-34-16	25	. 871± . 003	40. 2± . 4	5. 1± . 04
1-33-9	18	. 903± . 005	41. 0± . 4	5. 0± . 02
1-34-18	24	. 909± . 005	39. 7± . 8	5. 1± . 03
1-29-13	22	. 889± . 003	41. 5± . 8	4. 9± . 06
January, 1922:				
1-33-11	30	. 897± . 004	37. 0± . 7	5. 1± . 06
1-31-10	40	. 890± . 003	38. 0± . 4	5. 3± . 03
1-29-13	35	. 888± . 003	38. 5± . 3	5. 5± . 03
1-32-10	35	. 891± . 004	36. 6± . 4	5. 2± . 05
1-34-9	25	. 900± . 003	37. 1± . 8	5. 2± . 03
1-29-14	29	. 881± . 002	39. 2± . 2	5. 5± . 03
1-33-9	34	. 903± . 002	37. 0± . 5	5. 2± . 03
DENSE UNPRODUCTIVE STRAIN.				
November, 1920:				
1-29-12	50	. 896± . 002	39. 9± . 4	6. 2± . 03
1-29-9	35	. 911± . 001	40. 0± . 4	5. 9± . 06
1-30-9	30	. 893± . 002	41. 5± . 3	6. 0± . 03
1-30-12	35	. 892± . 001	39. 9± . 3	5. 9± . 01
February, 1921:				
1-29-8	40	. 898± . 003	39. 3± . 8	5. 5± . 04
1-30-7	40	. 895± . 002	40. 7± . 4	5. 4± . 04
1-29-11	40	. 895± . 002	40. 0± . 4	5. 6± . 03
1-29-7	40	. 889± . 004	40. 7± . 4	5. 5± . 03
1-30-9	40	. 901± . 002	41. 5± . 4	5. 4± . 04
May, 1921:				
1-29-11	30	. 895± . 003	37. 7± . 4	5. 2± . 03
1-30-9	20	. 889± . 002	41. 5± . 5	4. 9± . 11
1-30-12	18	. 904± . 002	41. 6±1. 0	5. 1± . 02
1-29-12	21	. 893± . 002	40. 8± . 3	5. 3± . 04
1-30-7	31	. 894± . 002	39. 3± . 3	5. 0± . 02
1-29-8	20	. 906± . 003	37. 6± . 7	5. 0± . 05
1-29-7	17	. 899± . 005	38. 6±1. 5	5. 1± . 04
January, 1922:				
1-29-11	28	. 913± . 004	39. 6± . 4	5. 6± . 05
1-29-7	24	. 909± . 002	40. 3± . 5	5. 6± . 03
1-29-12	25	. 908± . 004	40. 1± . 2	5. 5± . 05
1-30-9	25	. 894± . 004	41. 0±1. 0	5. 5± . 03
1-30-12	30	. 906± . 004	40. 6± . 4	5. 4± . 04
1-29-8	30	. 908± . 004	40. 1± . 6	5. 4± . 05
BULL STRAIN.				
February, 1921:				
1-57-16	44	. 888± . 002	44. 3± . 5	5. 6± . 10
1-57-11	40	. 892± . 003	42. 2± . 4	5. 2± . 05
1-57-12	35	. 896± . 003	40. 0± . 6	5. 0± . 05
1-56-12	40	. 894± . 002	42. 0± . 7	5. 2± . 07
1-56-17	40	. 889± . 003	42. 2± . 3	5. 7± . 04
1-57-13	40	. 896± . 003	41. 3± . 6	5. 0± . 06
1-57-14	40	. 903± . 002	42. 4± . 6	5. 2± . 03
1-57-17	40	. 882± . 002	43. 3± . 6	5. 7± . 03
May, 1921:				
1-57-12	25	. 873± . 002	45. 2± . 5	5. 1± . 03
1-56-17	29	. 868± . 004	44. 1± . 7	5. 4± . 03
1-57-14	30	. 877± . 002	44. 6± . 4	5. 1± . 04
1-56-13	25	. 868± . 002	43. 5± . 4	5. 1± . 03
1-57-16	26	. 860± . 004	46. 4± . 2	5. 2± . 05
1-57-11	28	. 875± . 003	43. 4± . 5	5. 2± . 05
1-57-17	25	. 860± . 001	45. 4± . 6	5. 2± . 04
1-56-14	30	. 878± . 001	44. 6± . 4	5. 2± . 03
1-56-12	35	. 871± . 003	43. 9± . 5	5. 2± . 08
1-56-15	27	. 860± . 002	45. 8± . 1	5. 4± . 03
January, 1922:				
1-56-15	35	. 880± . 004	39. 2± . 7	5. 6± . 05
1-57-12	35	. 881± . 002	41. 3± . 5	5. 6± . 03
1-56-12	40	. 874± . 003	41. 2± . 6	5. 4± . 03
1-56-17	35	. 876± . 002	40. 7± . 2	5. 9± . 02
1-57-16	40	. 885± . 002	39. 7± . 2	5. 8± . 04
1-57-11	40	. 892± . 002	38. 3± . 5	5. 8± . 04

Table 5 contains a summary of the data in Table 3, and Table 6 a summary of the data in Table 4. The probable error of the average, the combined average, and the combined probable error, were calculated by using Mellor's formulas (*3*).

TABLE 5.—*Average composition of strains of Eureka lemons* (*Table 3*).

Date.	Number of trees sampled.	Number of fruits analyzed.	Specific gravity.	Rind.	Acid in juice.
EUREKA STRAIN.					
1920:				Per cent.	Per cent.
June	2	30	0.948±0.0014	47.1±0.84	5.31±0.024
1921:					
February	6	189	.927± .0011	36.9± .17	4.60± .020
June	11	303	.901± .0006	42.4± .11	5.05± .007
November	5	145	.956± .0005	33.4± .17	4.43± .019
Combined averages			.932± .0003	39.1± .08	4.96± .006
SMALL OPEN STRAIN.					
1921:					
June	6	127	.910± .0011	42.1± .23	4.80± .014
November	2	65	.961± .0009	34.6± .33	4.62± .038
Combined averages			.939± .0007	39.6± .19	4.78± .013
SHADE TREE STRAIN.					
1920:					
June	5	78	.961± .0006	51.4± .30	4.64± .017
1921:					
February	5	165	.926± .0010	37.7± .21	4.58± .017
June	7	155	.925± .0008	42.6± .21	4.67± .014
November	6	159	.948± .0006	35.3± .19	4.49± .019
Combined averages			.945± .0004	40.4± .11	4.61± .008
DENSE UNPRODUCTIVE STRAIN.					
1920:					
June	4	62	.958± .0014	51.2± .10	4.84± .024
1921:					
February	6	220	.925± .0012	38.3± .23	4.37± .010
June	7	150	.929± .0009	40.3± .14	4.73± .013
November	5	156	.946± .0005	34.2± .17	4.47± .014
Combined averages			.934± .0004	44.3± .07	4.52± .006

TABLE 6.—*Average composition of strains of Lisbon lemons (Table 4).*

Date.	Number of trees sampled.	Number of fruits analyzed.	Specific gravity.	Rind.	Acid in juice.
LISBON STRAIN.					
1920:				*Per cent.*	*Per cent.*
November	4	165	0.905±0.0006	40.9±0.20	6.20±0.018
1921:					
February	5	200	.888± .0008	41.9± .09	5.75± .018
May	10	293	.869± .0005	43.2± .11	5.47± .010
1922:					
January	8	260	.895± .0008	39.4± .15	5.64± .010
Combined averages			.886± .0003	41.8± .06	5.64± .006
OPEN STRAIN.					
1920:					
November	3	150	.921± .0007	37.0± .21	5.50± .021
1921:					
February	5	187	.886± .0007	40.7± .22	5.24± .027
May	7	160	.891± .0013	40.9± .20	5.08± .011
1922:					
January	7	228	.893± .0010	38.3± .13	5.32± .013
Combined averages			.900± .0004	39.5± .12	5.23± .007
DENSE UNPRODUCTIVE STRAIN.					
1920:					
November	4	150	.900± .0008	40.4± .17	5.94± .009
1921:					
February	5	200	.897± .0010	40.6± .19	5.50± .016
May	7	157	.896± .0011	39.6± .15	5.09± .012
1922:					
January	6	162	.907± .0013	40.1± .15	5.51± .016
Combined averages			.899± .0005	40.2± .08	5.57± .006
BULL STRAIN.					
1921:					
February	8	319	.892± .0008	42.2± .17	5.38± .015
May	10	280	.869± .0006	45.5± .08	5.22± .011
1922:					
January	6	225	.882± .0009	40.1± .13	5.72± .013
Combined averages			.877± .0004	43.8± .06	5.42± .007

DISCUSSION OF RESULTS.

VARIABILITY IN CITRUS FRUITS.

Certain differences in the data reported exist. It is necessary to ascertain whether these differences in composition are inherent in the fruits of individual trees or whether they extend beyond the individual tree and constitute a difference between strains.

Citrus fruits are variable in composition, and the time of year in which lemons mature has a bearing upon their composition (*1*). In comparing the composition of fruit from different trees, therefore, it is impossible accurately to compare samples from two trees unless the fruit was gathered at approximately the same time. This does not mean that the samples must be picked the same day, or even perhaps the same week, but they should be picked in the same month. Certainly samples gathered during different seasons of the year are not comparable. Such precautions become unnecessary only when the number of samples is so great as to preclude the probability of error from seasonal variations in composition. Therefore the comparisons obtained in the later experiments are between lots of fruit gathered at approximately the same time.

In order to determine the significance of any difference, not only the variation in composition between samples of fruit from the same tree, but also the variation in composition existing between samples of fruit from different trees of the same strain must be carefully observed. Only in cases where the difference as a whole between strains is greater than that between trees of the same strain can it be safely assumed that a significant difference exists.

DIFFERENCES IN COMPOSITION OF FRUIT FROM THE SAME TREE AND FROM TREES OF THE SAME STRAIN.

The variability in fruit from the same tree is shown best by the probable errors given with each determination in Tables 3 and 4.

As the number of subsamples making up each sample to some extent affects the probable error, unusually large errors were sometimes due to the small number of subsamples taken. The difference in composition of samples from the same tree gathered at different times also varies. Notwithstanding these facts, it seems that, as a whole, where 25 or more fruits constitute a sample, different trees show approximately equal probable errors.

The variation in specific gravity of Eureka lemons, as shown by the probable error, is from 0.001 to 0.008, being in most cases from 0.002 to 0.003. Only 3 of the 77 samples reported in Table 3 show probable errors in specific gravity greater than 0.004. Naturally the variation in rind is greater than that in either specific gravity or acidity of the juice. This is due in part to the nature of the fruit and in part to the accuracy with which the analytical determinations can be made. The probable errors in this determination vary from 0.1 to 1.5, with an average error of approximately 0.6. Eight samples have errors of 1 or more, but 6 of the 8 samples consisted of 15 fruits or fewer. The samples are rather uniform in acidity, the probable errors ranging from 0.01 to 0.12, the average being close to 0.05.

The variation in the specific gravity of Lisbon lemons is from 0.001 to 0.005, with an average midway between these limits. The probable errors for the rind vary from 0.1 to 1.5, with an average of approximately 0.5. The probable error of the acidity results vary from 0.01 to 0.11, the average being approximately 0.04.

Any differences in uniformity can be accounted for by the fact that the Lisbon variety afforded a better opportunity to get uniform samples. The average number of fruits to a sample was 33 for the Lisbon, against 26 for the Eureka; but the number of samples containing less than 25 fruits was 29 in the case of the Eureka, with only 10 in the case of the Lisbon.

Taken as a whole, the variability in fruit from the same trees is not great in either variety; neither is the variability of the fruit from different trees of the same strain. The probable errors of the three determinations are about equal when comparisons between strains are made. Isolated cases of high average probable errors are usually due to the fact that a single instance of a high probable error has affected the average.

When the differences in composition of fruit from trees belonging to the same strain are considered, only a few trees have fruit which varies greatly from the general average. Both the monthly samples and those taken later have instances of variation, however.

In the case of the Eureka trees, the results on the monthly samples (Table 1) show that the fruit from tree 34–57–5 has a lower specific gravity and a higher percentage of rind than the other two trees of the Eureka strain; also the percentage of sugar in the juice is somewhat lower than that shown by the others. The later results (Table 3) show that the lemons from tree 34–73–7 had a higher specific gravity and a lower percentage of rind than any of the other samples of the group taken at the same time. The fruit of the Shade Tree strain (tree 34–74–13) (Table 1) is high in acid, but only five monthly samples were available for consideration. Among the trees sampled later, tree 34–76–56 (Table 3) of this strain shows one peculiarity; each of the three times it was sampled the fruit from this tree had a higher acidity than that from any of the other trees of the group sampled at the same time.

There are similar instances in the Lisbon variety. Tree 1–27–10 of the Lisbon strain has a higher acidity than most of the other trees of the strain. The two samples taken from tree 1–27–11 have low specific gravity and high percentage of rind. In the Dense Unproductive strain the four samples from tree 1–30–9 have a high percentage of rind and low specific gravity. Tree 1–29–8 apparently produces fruit with a tendency in the opposite direction. The fruit of tree 1–29–12 has a high percentage of acidity. In the Bull strain, tree 1–56–17 has fruit with the highest acidity of the group, but there seem to be no other instances of consistent tendencies.

Considering the matter as a whole, differences in composition of fruit from different strains of trees are not greatly affected by the unusual composition of fruit from the few trees consistently above or below the average.

DIFFERENCES IN COMPOSITION OF FRUIT FROM TREES OF DIFFERENT STRAINS.

Some differences in the composition of lemons from different strains of trees exist. Are these differences significant? What constitutes a significant difference for this purpose?

When the methods of comparison of Wood (*9*) and Pearl and Miner (*4*) were used, practically all of the strains showed great differences. When the numbers of items in the series to be compared were about the same, use was made of "Student's" method (7), casting out the items most favorable to the desired result to make the items even in number. None of these methods, however, were satisfactory in most cases. The method of Dr. George F. McEwen, of the Scripps Institution for Biological Research, at La Jolla, Calif., therefore, was used (2) and Doctor McEwen's advice was followed in the treatment of all comparisons. Even when all the methods showed significant differences, these differences were not considered strongly positive unless a majority of the group samples (Tables 3 and 4) showed the difference. No case was considered strongly positive when any one group of the three or four showed a reversal of the tendency.

EUREKA VARIETY.

The samples of the Eureka lemons show few marked differences. The greatest difference is in the acidity of the fruit of the Eureka and Shade Tree strains (Tables 1 and 3). All the monthly samples of the Eureka strain trees had a higher acidity than any of the Shade Tree strain, excepting tree 34–74–13. Of the five samples obtained from this tree, four were unusually high in acidity as compared with other samples from trees of the same strain.

The next greatest difference is that in acidity between the Eureka strain and the Dense Unproductive strain (Table 3). As no monthly samples of the latter were obtained, the comparison is based on the samples obtained in 1920–21. The difference in acidity between samples of these strains taken in June 1920 and June 1921 is highly significant. Although the February and November samples do not maintain the differences, they do not show a reversal. The best that can be said of this difference is that it is possible.

At first glance a difference may seem to exist in the specific gravity of the Eureka and Shade Tree strains, but further study shows that this is only barely possible. The results from the monthly samples are not convincing, for while the difference is slightly in favor of a higher specific gravity for the Shade Tree fruit, it is not sufficiently great to be conclusive. The June 1920 and June 1921 samples show a difference in favor of the Shade Tree strain. The February 1921 group shows no differences and the November group shows a decided reversal.

No consistent differences in specific gravity of the fruit, percentage of rind, or acidity of the juice between the strains of the Eureka variety are shown. Some differences may exist in the constituents determined on the monthly samples, but these data were not derived from a sufficient number of trees to make conclusions from them possible.

LISBON VARIETY.

The greatest difference shown by the Lisbon variety is that of acidity of juice between the Lisbon and Open strains. As no monthly samples of the Lisbon strain were collected, conclusions are based on the later samples (Table 4). In each of the four groups the chances are very high that the difference occurring is significant. In November 1920 the lowest acidity of the Lisbon strain fruit is higher than the highest of the Open strain. In February the lowest acidity of the Lisbon fruit is equal to the highest acidity of the Open strain fruit. In May 1921 and January 1922, while the results for the fruit from the two strains overlap, the chances are exceedingly high that the difference is significant. The highly significant difference shown favors the conclusion that the acidity of the Lisbon strain is greater than that of the Open strain.

Another marked difference in acidity exists between the fruit of the Lisbon and Dense Unproductive strains. In each group of samples the highest acidity shown by the fruit of the Dense Unproductive strain is only slightly higher than the lowest acidity shown by the fruit of the Lisbon strain. In each case the chances are high that the differences shown are significant, and it seems probable that this difference is characteristic of the strains.

A difference may also exist between the acidity of the fruit of the Bull strain and that of the Lisbon. Although there are but three comparable groups, the May 1921 samples show great odds that the Lisbon fruit is more acid than that from the Bull strain trees. The odds are not so great in February 1921 but are still in favor of the Lisbon strain, while the January 1922 samples show no appreciable difference. With two high chances out of three, a difference may exist.

One other difference in acidity in this variety may be classed as probable. With a single exception, the fruit of the Dense Unproductive strain has a higher acid content than that of the Open strain. The two trees compared when the monthly samples were taken, showed this difference to some degree, but the chances that the difference was significant were not high. In the November 1920 group the lowest acidity of any of the Dense Unproductive strain fruit is distinctly higher than the highest acidity of any of the Open strain fruit. The chances that this difference is significant are very high. This difference is strongly evident in the January 1922 group, and to a smaller extent in the February 1921 group. The May 1921 group shows practically no difference in acidity. In four out of five cases the Dense Unproductive strain is higher in acidity than the Open strain.

Several differences in the percentages of rind, between the strains of the Lisbon variety, are worthy of consideration.

The tree of the Bull strain sampled monthly bore fruit with a higher percentage of rind than that borne by any of the other trees sampled at that time. The greatest difference shown was between the Bull and Open strains, and the chances are high that the difference shown is significant. This difference is maintained in the groups of samples taken later (Table 4). In the May 1921 group the lowest figure for the Bull strain is higher than all but two of those for the Open strain, and in the other two groups the overlapping is slight. There seems to be little doubt that a probable difference in this respect exists.

The fruit of the Bull strain tree sampled monthly is also higher in rind than that of the Dense Unproductive tree. This difference is again noticeable in the February and May groups of the later samples. In the May group there is no overlapping of samples, the lowest proportion of rind in any of the Bull strain fruit being nearly 2 per cent higher than that in the highest Dense Unproductive fruit. The January 1922 group shows no difference, however.

The fruit in all three groups of the later Bull strain samples shows a higher percentage of rind than the Lisbon fruit. This difference is greatest in the May 1921 group but is also decidedly marked in the January 1922 group. The samples taken in February 1921 show the difference but to a smaller degree than the others. Altogether, it seems that a probable difference exists.

The only difference in specific gravity between the strains of the Lisbon variety occurs between the fruit of the Dense Unproductive and the Bull strains. In May 1921 and January 1922 the specific gravity of the lowest Dense Unproductive samples was higher than that of the highest Bull samples. In the February samples the difference was not maintained, but the monthly samples show a significant difference in this respect. Therefore a probable difference exists.

SUMMARY.

From the data presented it may be concluded that the following probable differences exist:

In the Lisbon variety.—The Dense Unproductive strain has a higher specific gravity than the Bull strain. The Bull strain has the highest proportion of rind found in any of the strains of this variety. The Lisbon strain is more highly acid than either the Open or the Dense Unproductive strain. The Dense Unproductive strain is also more acid than the Open strain.

In the Eureka variety.—The Eureka strain is more acid than the Shade Tree strain. Other differences may exist, but the data at hand are inconclusive in these cases.

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