JOURNAL OF AGRICULTURAL RESEARCH

VOL. VIII WASHINGTON, D. C., JANUARY 22, 1917 NO. 4

EFFECT OF FERTILIZERS ON THE COMPOSITION AND QUALITY OF ORANGES[1]

By H. D. YOUNG,

Assistant in Agricultural Chemistry, Agricultural Experiment Station of the University of California

INTRODUCTION

Of the great amount of work which has been done with fertilizers, only a relatively small proportion deals with their effects on the quality of the crop. This is especially true of fruits, partly because of the length of time required and partly because of the conflicting factors which enter into a long-time experiment.

The material presented in this paper has to do with oranges (*Citrus aurantium*). The quality of this crop may offer an easier subject for study than most fruits, as the factors affecting it, such as the percentages of sugar and acid, the texture of the fruit as a whole (its specific gravity), and the proportions of juice and rind, can be accurately measured.

HISTORICAL REVIEW

There have been a number of theories and expressions of opinions put forth as to the effect of the usual fertilizers on the composition of oranges. Webber (7), basing his conclusions largely on the experience of intelligent orange growers in Florida, wrote:

(1) By a proper combination of the various elements used in fertilization one can undoubtedly largely govern the quality and flavor of the fruit.

(2) To obtain a fruit with thin rind, use nitrogen from inorganic sources in moderate quantities, with considerable potash and lime.

(3) To sweeten the fruit, use sulphate of ammonia in considerable abundance, decreasing the amount of potash.

(4) To render the fruit more acid, increase the amount of potash and use nitrogen from organic sources.

(5) If it is desired to increase the size of the fruit, as is sometimes the case, apply a comparatively heavy dressing of nitrogen in some organic form and slightly decrease the other elements. In the case of the tangerine and mandarin, where a larger size is usually desired, a heavy dressing of nitrogen fertilizers would favor this end, and is not objectionable unless carried to excess.

[1] Paper No. 32, Citrus Experiment Station, College of Agriculture, University of California, Riverside, Cal.

These conclusions were accepted by Rolfs (6, p. 19).[1] Hart (4, p. 565) states:

> Closely connected with the subject of soil is that of fertilizers, by the understanding use of which almost any kind of orange may be, as it were, manufactured to order. Free use of potash thickens and toughens the rind, giving the firmness and durability requisite to bear transportation and rough handling, but at the expense of saccharine qualities. The latter may be increased and acidulous qualities modified by the use of more phosphoric acid. Highly nitrogenous applications give fruit surcharged with insipid juice, and cause a lush growth of wood that never properly ripens, inviting attacks of insects and fungi. Composts from the barnyard, or those containing much decomposing animal matter, must be used sparingly, if at all. The most wholesome growth and finest-flavored fruit comes from judicious employment of the best high-grade commercial fertilizers.

The first conclusions based on experimental work in Florida are apparently those of Collison (2). In the valuable report presented he has tabulated a large number of analyses of oranges from trees receiving high- and low-potash fertilizers and high- and low-phosphoric-acid fertilizers. He finds that a high-potash fertilizer does not make a sweeter fruit than the low-potash, "contrary to the very general opinion," but that much potash does increase the amount of acid, an opinion previously reported by Webber. Collison found further that phosphoric acid "probably had no material influence on the variation in the sugar and acid content of the fruit." Unfortunately, he was unable to obtain satisfactory samples from which to draw conclusions in regard to the effect of nitrogen.

The figures on which this paper was based have since been published in full (3).

Colby (1) has made a large number of analyses of oranges grown commercially. In discussing the results obtained, Hilgard (5, p. 181), after discussing the unsatisfactory nature of the experiment (due to poor sampling, conflicting factors, and the short period of time), concluded as follows:

> The oranges not fertilized (No. 2), those fertilized with potash and nitrogen (No. 8), and with nitrate of soda (No. 3) are all about alike, though No. 8 was a little sweeter than No. 2. The latter is a pleasant orange, though somewhat lacking in character (i. e., sprightliness and tartness).
>
> In character the oranges from the "Complete fertilizer" (No. 10) are above those fertilized with nitrate of soda alone (No. 4), and while high in flavor, are not equal to those from the superphosphate group (No. 4).
>
> The highest citrus qualities are possessed by the oranges fertilized with superphosphate alone (No. 4), and next by those from the "Complete fertilizer" (No. 10), and both rank high in flavor.
>
> In sweetness the oranges fertilized with potash and nitrogen (No. 8) and with nitrate of soda are above those not fertilized.
>
> The oranges from the nitrogen and phosphoric acid lot (No. 6) are not as good as those from the superphosphate alone (No. 4), and have less character than those not fertilized (No. 2). Those from the potash and phosphoric acid lot (No. 9) are not of as good quality and are more variable than the above.

[1] Reference is made by number to "Literature cited," p. 138.

From the ultimate analyses of the oranges, Colby found the lowest nitrogen content in those samples which had received no nitrogenous fertilizer, from which he deduced a lack of nitrogen in the soil. The samples not receiving phosphates showed the lowest percentage of phosphoric acid, from which the need of a fertilizer of that nature was deduced. The percentage of potash was not appreciably affected by the presence or absence of fertilizers, showing that potash was not deficient in the soil.

DESCRIPTION OF THE EXPERIMENTAL PLOTS

The University of California Citrus Experiment Station has maintained a continuous fertilizer experiment at Riverside with Citrus trees since 1907. The experiment is composed of 20 plots, with six trees each of Washington Navel oranges, Valencia oranges, Eureka lemons, and Lisbon lemons in each plot. The experiment as laid out consists of four tiers of plots from east to west and five from north to south. The ground slopes from northwest to southeast. The soil is not entirely uniform, being a fairly light sandy loam at the upper end and considerably heavier, with a denser subsoil, at the lower end. Pipe lines are run at the head of each tier of plots in order to provide for the independent irrigation of each plot. The trees of each plot have been managed as uniformly as possible.

The plan of the experiment provided for the addition of the same quantities of the different elements of fertility, from whatever source derived. Every plot receiving a nitrogenous fertilizer, for example, has received the same quantity of nitrogen. Up to the end of 1914, the total amounts applied to each tree had been approximately 6 pounds of nitrogen and potash each, and 12 pounds of phosphoric acid.

EXPERIMENTAL WORK

A study of the quality and composition of the fruit was first taken up with the crop of 1914. In this work a sample of 10 fruits was taken from each tree, and a composite of these fruits taken for analysis. Individual records for each tree were thereby obtained. In order to eliminate diurnal variations, the sample from one tree of each of the 20 plots was picked and analyzed on the same day. In all cases but one the fruit from the individual trees of each plot was picked on successive days. The Valencia samples of the crop of 1914 were picked on alternate days.

The samples were first weighed and the specific gravity of the fruits taken by immersing them in jars of alcohol of varying specific gravity until the fruit and liquid were in equilibrium, the specific gravity of the liquid being taken as that of the fruit. It was then peeled and ground through a food chopper. The ground sample was placed in a double cheesecloth bag and pressed in a 2-quart fruit press for 20 minutes. The peel, material left in the bags, and juice were weighed; and from these figures the percentage of juice was obtained. All other determinations were

made on the juice, its specific gravity being determined by a spindle and calculated to 15° C. Total sugars, after inversion by Clerget's method, were determined by the Bertrand method, and the sugar calculated as reducing sugars. The acidity was determined by titration with *N/10* alkali with phenolphthalein and the results expressed as anhydrous citric acid. The nitrogen was determined by the Gunning method.

There was some variation in the results obtained from the different trees of a given plot, particularly in the percentage of sugar, but in those cases where notable effects were produced by the fertilizer used, as, for example, the nitrogen content, the variations were nearly always within the limit of experimental error. Table I presents the individual tree records of a plot chosen at random, to show the range of variation. The plot shown is F, fertilized with stable manure.

TABLE I.—*Composition of oranges from individual trees of a single plot*

No.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.	Phosphate (P_2O_5).	Potash (K_2O).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
F 282	0.88	37.9	10.74	1.02	0.117	0.052	.....
F 283	.87	40.7	10.40	.89	.116	.050	0.21
F 284	.89	39.8	10.46	1.05	.109	.051	.23
F 286	.88	37.3	10.47	.97	.113	.052	.23
F 287	.90	42.1	9.09	.94	.117	.052	.....
F 288	.88	40.1	9.18	.91	.121	.052	.23
Average	.88	39.6	10.06	.96	.115	.052	.23

For the sake of brevity the data have been compiled by plots, the figures presented being merely the averages of the individual tree records obtained. These averages have been assembled with a view to facilitating comparisons of the effect of different fertilizers. In Tables II and III are presented the data from the check plots, those treated with nitrogen, potash, or phosphates only, and the complete-fertilizer plots.

Under the conditions of this experiment, neither potash nor phosphate exercised any effect on the sugar content, but nitrogenous fertilizers, alone or in combination with potash and phosphate, depressed the sugar content. Averaging the figures for sugar in the two crops of each variety, the potash plots show 9.37 per cent, the check plots 9.36 per cent, and the phosphate plots 9.25 per cent. These variations are all within the limits of analytical error. The plots treated with nitrogen alone and those treated with complete fertilizer contained 8.85 per cent and 8.81 per cent, respectively, or about 0.5 per cent less than the other plots. This is a recognizable difference and constant enough to be ascribed to the treatment. It is interesting to note that the effects are greater in the 1915 crops, which were harvested about two months later, than in the

1914 crops. This indicates that nitrogen produced an effect other than that of merely delaying the time of maturity.

The percentage of acid shows the same kind of variation, but in the opposite direction. The check, potash, and phosphate plots contained 0.92 per cent as an average of two crops of each variety, the three being in exact agreement, while the plots treated with nitrogen and a complete fertilizer show 0.94 and 0.96 per cent, respectively. While this is an extremely slight variation, it is interesting to note that it would still further tend to accentuate the lower sugar content in its effect on the quality of the fruit. The specific gravity of the fruit varied slightly, averaging for the four crops as follows: Potash 0.92, phosphate 0.91, check 0.91, nitrogen 0.90, and complete fertilizer 0.90. This confirms the popular contention that potash fertilizers produce a finer fruit and nitrogen a coarser one. The percentage of juice varied with the specific gravity, the averages being 49.2 for potash, 49.2 for controls, 48.2 for phosphate, 47 for nitrogen, and 47.4 for the complete fertilizer.

The quantity of nitrogen present in the juice of the fruit is definitely correlated with the application of nitrogenous fertilizers. In every case the fruit from plots to which nitrogen has been applied shows an increased percentage of nitrogen. This would seem to corroborate the figures on yields, which show nitrogen to be a limiting factor in crop production in this experiment.

TABLE II.—*Composition of navel oranges fertilized differently*

Fertilizer and plot.	Crop of 1914.					Crop of 1915.				
	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dried blood, plot C	0.91	47.1	9.28	1.09	0.088	0.89	40.4	10.11	0.98	0.130
Nitrate of soda, plot H	.90	45.5	9.11	1.09	.095	.87	38.2	9.26	.94	.137
Dried blood, plot S	.88	44.5	8.86	1.13	.102	.88	40.7	10.05	.99	.117
Average	.90	45.7	9.08	1.10	.095	.88	39.8	9.81	.97	.128
Sulphate of potash, plot D	.92	45.5	9.65	1.08	.076	.91	44.4	10.92	.97	.086
Muriate of potash, plot I	.91	46.9	9.44	1.11	.075	.92	45.0	10.46	.96	.093
Sulphate of potash, plot R	.89	45.9	9.04	1.12	.081	.90	43.9	9.92	.97	.081
Average	.91	46.1	9.34	1.10	.077	.91	44.4	10.43	.97	.087
Steamed bone, plot E	.90	46.9	9.69	1.01	.082	.90	42.9	10.82	.90	.093
Superphosphate, plot J	.90	47.5	8.79	1.08	.081	.90	40.1	10.41	.97	.098
Superphosphate, plot N	.89	47.0	9.00	1.10	.070	.89	41.7	10.12	1.02	.097
Steamed bone, plot P	.90	47.8	9.14	1.13	.082	.89	41.4	10.47	.98	.097
Average	.90	47.3	9.15	1.08	.079	.90	41.5	10.46	.97	.096
Complete fertilizer, plot A	.90	47.3	9.06	1.11	.087	.88	41.7	9.46	.98	.126
Complete fertilizer, plot Q	.89	44.8	9.05	1.13	.102	.88	41.1	9.99	1.00	.124
Average	.90	46.1	9.06	1.12	.095	.88	41.4	9.73	.99	.125
Check, plot B	.91	47.5	9.39	1.06	.072	Missing.	.....	.....	.....	.....
Check, plot M	.89	46.9	9.04	1.07	.084	.90	43.1	10.23	.98	.096
Check, plot T	.88	45.8	9.47	1.12	.082	.90	43.6	10.80	.92	.087
Average	.89	46.7	9.30	1.08	.079	.90	43.4	10.51	.95	.092

TABLE III.—*Composition of Valencia oranges fertilized differently*

Fertilizer and plot.	Crop of 1914.					Crop of 1915.				
	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dried blood, plot C	0.92	52.5	8.68	0.97	0.116	0.92	53.6	8.37	0.66	0.128
Nitrate of soda, plot H	.92	52.0	8.40	1.01	.130	.91	52.8	7.01	.74	.139
Dried blood, plot S	.89	47.4	7.84	.97	.124	.91	48.9	9.26	.78	.141
Average	.91	50.6	8.31	.98	.123	.91	51.8	8.21	.73	.136
Sulphate of potash, plot D	.94	53.3	9.04	.98	.089	.95	55.3	9.09	.60	.080
Muriate of potash, plot I	.92	52.0	8.59	.97	.095	.94	56.7	9.28	.67	.094
Sulphate of potash, plot R	.90	49.4	8.22	.96	.107	.92	53.8	8.94	.67	.099
Average	.92	51.6	8.62	.97	.097	.94	55.3	9.10	.65	.091
Steamed bone, plot E	.91	52.5	8.66	.92	.095	.93	53.3	9.16	.64	.108
Superphosphate, plot J	.91	50.1	8.46	.96	.108	.94	54.8	9.39	.68	.119
Superphosphate, plot N	.91	51.0	8.24	.90	.089	.93	53.0	8.95	.67	.111
Steamed bone, plot P	.90	50.0	7.99	.94	.110	.92	50.8	9.07	.71	.114
Average	.91	50.9	8.34	.93	.101	.93	53.0	9.14	.68	.113
Complete fertilizer, plot A	.93	53.9	8.07	1.01	.124	.92	53.1	7.93	.76	.141
Complete fertilizer, plot Q	.89	47.5	7.84	1.00	.130	.91	48.5	9.01	.81	.146
Average	.91	50.7	7.96	1.01	.127	.92	50.8	8.47	.74	.144
Check, plot B	.92	53.0	8.89	1.02	.088	.92	55.9	8.58	.65	.071
Check, plot M	.91	51.8	8.39	.94	.094	.93	56.1	8.75	.67	.095
Check, plot T	.90	49.1	8.26	.99	.104	.94	53.6	10.00	.65	.103
Average	.91	51.3	8.51	.98	.095	.93	55.2	9.11	.66	.090

To show still further the specific effect of the nitrogenous fertilizers, Tables IV and V have been prepared, in which the plots receiving nitrogen, either alone or in any combination, are grouped together and contrasted with all the plots not receiving that element.

TABLE IV.—*Comparison of navel oranges fertilized with and without nitrogen*

CROP OF 1914

Fertilized with nitrogen.						Not fertilized with nitrogen.					
Plot.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.	Plot.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0.90	47.3	9.06	1.11	0.087	B	0.90	47.3	9.04	1.11	0.087
C	.91	47.1	9.28	1.09	.088	D	.92	45.5	9.65	1.08	.076
F	.90	44.7	9.08	1.13	.088	E	.90	46.9	9.69	1.01	.082
G	.90	46.0	9.01	1.02	.091	I	.91	46.9	9.44	1.11	.075
H	.90	45.5	9.11	1.09	.095	J	.90	47.5	8.79	1.08	.081
L	.90	47.2	8.75	1.09	.095	K	.90	47.8	8.98	1.13	.069
O	.89	43.2	9.16	1.14	.096	M	.89	46.9	9.04	1.07	.084
Q	.89	44.8	9.05	1.13	.102	N	.89	47.0	9.00	1.10	.070
S	.88	44.6	8.86	1.13	.102	P	.90	47.8	9.14	1.13	.082
						R	.89	45.9	9.04	1.12	.081
						T	.88	45.8	9.47	1.12	.082
Average	.90	45.6	9.04	1.10	.094	Average	.90	46.8	9.21	1.10	.079

TABLE IV.—*Comparison of navel oranges fertilized with and without nitrogen*—Contd.

CROP OF 1915

Fertilized with nitrogen.						Not fertilized with nitrogen.					
Plot.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.	Plot.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
A	0.88	41.7	9.46	0.98	0.126	B	(a)	(a)	(a)	(a)	(a)
C	.89	40.4	10.11	.98	.130	D	0.91	44.4	10.92	0.97	0.086
F	.88	39.6	10.06	.96	.115	E	.90	42.9	10.82	.90	.093
G	.87	38.0	9.62	1.01	.132	I	.92	45.0	10.46	.96	.093
H	.87	38.2	9.26	.94	.137	J	.90	40.1	10.41	.97	.098
L	.88	41.1	9.73	.94	.121	K	.89	43.4	9.98	1.00	.112
O	.87	37.5	10.08	1.01	.097	M	.90	43.1	10.23	.98	.096
Q	.88	41.1	9.99	1.00	.124	N	.89	41.7	10.12	1.02	.097
S	.88	40.7	10.05	.99	.117	P	.89	41.4	10.47	.98	.097
						R	.90	43.9	9.92	.97	.081
						T	.90	43.6	10.80	.92	.087
Average	.88	39.8	9.82	.98	.122	Average	.90	43.0	10.41	.96	.094

[a] No analysis because of failure of the crop.

TABLE V.—*Comparison of Valencia oranges fertilized with and without nitrogen*

CROP OF 1914

Fertilized with nitrogen.						Not fertilized with nitrogen.					
Plot.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.	Plot.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0.93	53.9	8.07	1.01	0.124	B	0.92	53.0	8.89	1.02	0.088
C	.92	52.5	8.68	.97	.116	D	.94	53.3	9.04	.98	.089
F	.92	51.1	8.27	.98	.117	E	.91	52.5	8.66	.92	.095
G	.92	52.3	8.35	.97	.119	I	.92	52.0	8.59	.97	.095
H	.92	52.0	8.40	1.01	.130	J	.91	50.1	8.46	.96	.108
L	.92	51.6	8.05	1.02	.132	K	.91	51.3	8.15	.92	.097
O	.89	49.5	8.07	.96	.118	M	.91	51.8	8.39	.94	.094
Q	.89	47.5	7.84	1.00	.130	N	.91	51.0	8.24	.90	.089
S	.89	47.4	7.84	.97	.124	P	.90	50.0	7.99	.94	.110
						R	.90	49.4	8.22	.96	.107
						T	.90	49.1	8.26	.99	.104
Average	.91	50.9	8.17	.99	.123	Average	.91	51.2	8.44	.95	.098

CROP OF 1915

A	0.92	53.1	7.93	0.76	0.141	B	0.92	55.9	8.58	0.65	0.071
C	.92	53.6	8.37	.66	.128	D	.95	55.3	9.09	.60	.080
F	.92	52.1	8.67	.71	.125	E	.93	53.3	9.16	.64	.108
G	.92	52.4	8.40	.75	.143	I	.94	56.7	9.28	.67	.094
H	.91	52.8	7.01	.74	.139	J	.94	54.8	9.39	.68	.119
L	.92	52.6	7.79	.72	.148	K	.92	53.2	8.19	.69	.108
O	.92	49.9	8.86	.75	.135	M	.93	56.1	8.75	.67	.095
Q	.91	48.5	9.01	.81	.146	N	.93	53.0	8.95	.67	.111
S	.91	49.0	9.26	.78	.141	P	.92	50.8	9.07	.71	.114
						R	.92	53.8	8.94	.67	.099
						T	.94	53.6	10.00	.65	.103
Average	.92	51.6	8.37	.74	.138	Average	.93	54.2	9.04	.66	.100

The averages of all plots receiving nitrogen agree closely, whether the nitrogen was applied singly or in combination with other fertilizers, as shown by Table VI.

TABLE VI.—*Average composition of oranges when fertilized with nitrogen alone and in combination*

Fertilizer.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Checks	0.91	49.2	9.36	0.92	0.089
Nitrogen alone	.90	47.0	8.85	.94	.121
Nitrogen with other fertilizers	.90	47.0	8.84	.95	.119

It may be concluded, then, that nitrogen exercised a definite influence on the composition of the crop, whether applied with or without other fertilizers.

The average composition with and without potash is shown in Table VII.

TABLE VII.—*Comparison of the averages of all plots receiving potash and those not receiving potash*

Fertilizer.	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Check	0.91	49.2	9.36	0.92	0.089
Potash	.91	48.5	9.02	.94	.105
Without potash	.91	47.6	9.12	.93	.105

These averages are somewhat lower than those of the plots receiving potash only. This, however, does not necessarily indicate that the percentages (of sugar, for example) have been increased by the use of potash alone as compared with potash in combination with other fertilizers, but rather that the depressing effect of nitrogen appears in the latter case. This is more clearly shown by contrasting the average of plot L, which received potash and nitrogen, with plot R, which is nearly adjacent and received potash alone. The average percentage of sugar in the fruit from plot L was 8.58, somewhat lower than that of the plots fertilized with nitrogen only, while R showed 9.03 per cent.

On the whole, then, Table VII, when considered in conjunction with Table VI, lends but little support to the view that potash fertilizers materially modify the composition of oranges. A careful study of the data in Tables II and III will likewise show but little effect from phosphate. It is only fair to state, however, that this soil is naturally well supplied with both potash and phosphate, and therefore conclusions should not be drawn with reference to the effects of potash and phosphate fertilizers on the composition of oranges generally.

EFFECT OF SOIL DIFFERENCES

Since the most evident contrast in soil type met with in these experiments occurs in the extreme upper and lower tiers of plots, where the fertilizer treatments have been duplicated, it is of interest to compare the composition of the fruit in the two cases. Such a comparison should throw some light on the question of whether or not the variability of the soil was great enough to vitiate the results in general. As already stated, the soil in the upper tier of plots is lighter in character than that in the lower tier.

The data for the upper and lower tiers of plots have been assembled in Table VIII.

TABLE VIII.—*Composition of oranges from light and heavy soil*

NAVEL ORANGES, 1914

Light soil.						Heavy soil.					
Plot.[a]	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.	Plot.[a]	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0.90	47.3	9.06	1.11	0.087	P	0.90	47.8	9.14	1.13	0.082
B	.91	47.5	9.39	1.06	.072	Q	.89	44.8	9.05	1.13	.102
C	.91	47.1	9.28	1.09	.088	R	.89	45.9	9.04	1.12	.081
D	.92	45.5	9.65	1.08	.076	S	.88	44.6	8.86	1.13	.102
E	.90	46.9	9.69	1.01	.082	T	.88	45.8	9.47	1.12	.082
Average..	.91	46.9	9.41	1.07	.081	Average..	.89	45.8	9.11	1.13	.090

NAVEL ORANGES, 1915

A	0.88	41.7	9.46	0.98	0.126	P	0.89	41.4	10.47	0.98	0.097
B						Q	.88	41.1	9.99	1.00	.124
C	.89	40.4	10.11	.98	.130	R	.90	43.9	9.92	.97	.081
D	.91	44.4	10.92	.97	.086	S	.88	40.7	10.05	.99	.117
E	.90	42.9	10.82	.90	.093	T	.90	43.6	10.80	.92	.087
Average..	.90	42.4	10.33	.96	.109	Average..	.89	42.1	10.25	.97	.101

VALENCIA ORANGES, 1914

A	0.93	53.9	8.07	1.01	0.124	P	0.90	50.0	7.99	0.94	0.110
B	.92	53.0	8.89	1.02	.088	Q	.89	47.5	7.84	1.00	.130
C	.92	52.5	8.68	.97	.116	R	.90	49.4	8.22	.96	.107
D	.94	53.3	9.04	.98	.089	S	.89	47.4	7.84	.97	.124
E	.91	52.5	8.66	.92	.095	T	.90	49.1	8.26	.99	.104
Average..	.92	53.0	8.67	.98	.102	Average..	.90	48.7	8.03	.97	.115

VALENCIA ORANGES, 1915

A	0.92	53.1	7.93	0.76	0.141	P	0.92	50.8	9.07	0.71	0.114
B	.92	55.9	8.58	.65	.071	Q	.91	48.5	9.01	.81	.146
C	.92	53.6	8.37	.66	.128	R	.92	53.8	8.94	.67	.099
D	.95	55.3	9.09	.60	.080	S	.91	49.0	9.26	.78	.141
E	.93	53.3	9.16	.64	.108	T	.94	53.6	10.00	.65	.103
Average..	.93	54.2	8.63	.66	.106	Average..	.92	51.1	9.26	.72	.121

[a] The fertilizers applied to the different plots are given in Table X.

The average sugar content for the two crops of each variety is 9.19 for the upper tier and 9.16 for the lower, showing very close agreement. In every case, except that of the Valencia crop for 1915, the individual plots of the lower tier (P, Q, R, S, T) show the same characteristics as those of the nitrogen plots in general—that is, the fruit from them had a lower sugar content, a little more acid, a slightly lower specific gravity and percentage of juice, and a higher nitrogen content than that from other plots not fertilized. While the data indicate a somewhat richer soil in the lower tier of plots, the differences are not sufficiently great to affect materially any conclusions that may be drawn from the experiment as a whole.

COMPARISON OF ORANGES FERTILIZED WITH COMMERCIAL FERTILIZER AND ORGANIC MATTER

The plots in the fertilizer experiment have been kept in clean cultivation throughout the experiment. In adjacent plots on the same type of soil are trees of the same age which have received large amounts of stable manure, together with rock phosphate and a leguminous cover crop. The trees on these plots present a thriftier appearance and bear more fruit than the trees in the fertilizer experiment. There is a general impression that the use of a cover crop and organic matter tends to produce oranges of coarser texture and poorer quality. Analyses of fruit from the cover-cropped plots were made along with those from the fertilizer plots. The results obtained do not indicate any great difference, and although some variations appear, the closeness of the agreement is rather striking, as is shown by Table IX.

TABLE IX.—*Composition of oranges fertilized with commercial fertilizer and with organic matter*

Crop.	Fertilized plots.					Cover-crop plot.				
	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen	Specific gravity.	Juice.	Sugar.	Acid.	Nitrogen.
Navel:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1914.....	0.90	45.7	9.13	1.10	0.087	0.89	45.8	9.15	1.05	0.104
1915.....	.88	41.4	10.12	.98	.108	.86	37.8	9.96	.95	.129
Valencia:										
1914.....	.91	51.1	8.31	.97	.111	.91	47.3	8.51	.92	.128
1915.....	.93	52.9	8.69	.70	.119	.91	50.0	8.44	.79	.135

Two explanations suggest themselves as accounting for the greater quantity of nitrogen found in the fruit from plots to which nitrogen has been applied. (1) In the presence of a greater quantity of available nitrogen in the soil the orange tree is able to absorb this element in excess of its needs. (2) The greater quantity of nitrogen was necessary for the promotion of more normal growth. It seemed rather improbable

that the small quantities being added increased the amount available to the tree to a point where it would be taken up in excess. No direct evidence was obtained, however, since the same quantity was applied in each case.

THE EFFECT OF FERTILIZERS ON THE PHOSPHORIC-ACID AND POTASH CONTENT OF ORANGES

Although this investigation was undertaken primarily to determine whether the fertilizers affected those characteristics of the orange usually considered in connection with its quality, the results obtained in the nitrogen determination suggested that work be undertaken in regard to the absorption of other elements of fertility. Accordingly, the phosphoric-acid content was determined in the Valencia crop of 1914 and the navel crop of 1915. In the 1915 crop the percentage of potash was also determined. Table X presents the results.

TABLE X.—*Effect of various fertilizers on the phosphoric-acid and potash content of Valencia and navel oranges*

Plot.	Fertilizer applied.	Per cent of phosphoric acid Valencia oranges, 1914.	Per cent of phosphoric acid navel oranges, 1915.	Per cent of potash navel oranges, 1915.
A	Complete, nitrate of soda, blood, bone, sulphate of potash	0.059	0.051	0.23
B	Check	.066	.....	.....
C	Dried blood	.059	.052	.23
D	Sulphate of potash	.072	.056	.....
E	Steamed bone	.063	.051	.22
F	Stable manure	.056	.052	.23
G	Nitrate of soda, blood, and steamed bone	.055	.052	.24
H	Nitrate of soda	.055	.053	.24
I	Muriate of potash	.061	.052	.....
J	Superphosphate	.058	.052	.23
K	Bone and sulphate of potash	.059	.051	.23
L	Nitrate of soda	.059	.052	.23
M	Check	.060	.052	.23
N	Superphosphate	.062	.053	.23
O	Stable manure and raw phosphate rock	.055	.047	.23
P	Steamed bone	.057	.051	.23
Q	Complete, like A, except superphosphate instead of bone	.057	.050	.23
R	Sulphate of potash	.055	.052	.22
S	Dried blood	.056	.050	.23
T	Check	.059	.051	.23

There was no increase in the amount of either phosphate or potash in the fruit brought about by the quantities applied in this experiment. The averages from those plots receiving fertilizers are almost identical with those not fertilized. This gives further significance to the increase in nitrogen content brought about by nitrogen fertilization and supports the view that nitrogen is the limiting factor in the production of oranges on this soil.

SUMMARY

(1) Nitrogen is the only fertilizer which in this experiment seemed to exercise a specific effect on the composition of oranges.

(2) Applications of nitrogen to the soil resulted in a slightly lower amount of sugar, a somewhat coarser fruit, and a little less juice in the orange.

(3) The effect of nitrogen was the same, whether applied alone, in combination with either potash or phosphoric acid, or both.

(4) The effect of nitrogen was greater in 1915 than in 1914. As the crop was picked about two months later in 1915, it would indicate that some effect other than delayed maturity was caused by the nitrogen.

(5) Comparison with fruit from similar trees grown outside the fertilizer plots shows a fair agreement of composition and quality.

(6) The analyses show a higher percentage of nitrogen from all plots receiving it, while no such effect was obtained with either phosphoric acid or potash.

LITERATURE CITED

(1) COLBY, G. E.
1898. Effects of fertilization on citrus fruits. *In* Cal. Agr. Exp. Sta. Rpt. 1895/97, p. 163–178.

(2) COLLISON, S. E.
1913. Influence of soil and fertilizer on citrus fruits. *In* Proc. 26th Ann. Meeting Fla. State Hort. Soc. 1913, p. 168–172, 3 pl.

(3) ———
1913. Sugar and acid in oranges and grapefruit. Fla. Agr. Exp. Sta. Bul. 115, 23 p.

(4) HART, E. H.
1897. Subtropical fruits. *In* Thomas, J. J. American Fruit Culturist . . . ed. 20, p. 557–623, fig. 785–796. N. Y.

(5) HILGARD, E. W.
1898. Results deducible from the above experiments [by G. E. Colby]. *In* Cal. Agr. Exp. Sta. Rpt. 1895/97, p. 178–181.

(6) ROLFS, P. H.
1906. Citrus fruit growing in the Gulf states. U. S. Dept. Agr. Farmers' Bul. 238, 48 p., 17 fig.

(7) WEBBER, H. J.
1895. Fertilization of the soil as affecting the orange in health and disease. *In* U. S. Dept. Agr. Yearbook, 1894, p. 193–202, fig. 18–19.