neath most of the green trees in chlorotic groves was slightly acid in reaction.

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THE EFFECT OF FERTILIZER TIMING AND RATE OF APPLICATION ON FRUIT QUALITY AND PRODUCTION OF HAMLIN ORANGES

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Experiments have been conducted, both in pot cultures (4) and in the field, in an attempt to discover relationships between the use of variable amounts of fertility elements and the growth and yield of citrus. Little information is available, however, concerning the effects of timing or rates of application of a definite ratio of fertility elements on the production and quality of citrus under commercial practices. In the experiments to be described in this progress report nitrogen, phosphorus, potash, magnesium, manganese and copper were not varied independently, instead they were used in the same ratio at different times of the year in the timing experiment and in the same ratio but at different amounts in the rate experiment.

A block of Hamlin oranges* was offered for such experiments in cooperation with the Citrus Experiment Station at Lake Alfred in the fall of 1948. At that time the trees were 8 years old and producing about 4 boxes per tree. Starting with the November 10, 1948 fall application the timing experiment was begun in which two plots of 32 trees each received fertilizer applications three times per year, i.e., fall, spring and summer. Three other plots of 32 trees each received an equivalent amount of fertilizer but in two equal applications per year. These applications were made either in the fall and spring, fall and summer or spring and summer, thus omitting one of the usual application dates.

In the fall of 1949 the rate portion of the experiment was begun in which three plots in duplicate received variable amounts of fertilizer. Two plots in the timing experiment which received fertilizer three times per year were used for the highest rate of application.

It is the purpose of this report to describe in terms of yield, fruit quality, leaf analysis and soil analysis the results obtained to date under the different fertilizer rates and timing which were used.

PROCEDURE

Total amounts of each fertilizer component applied per year per tree are listed in Table 1. All trees in the timing experiment received an amount of mixed fertilizer which would supply 0.4 pound of N per box of fruit per year. During the period from 1949 through 1951 an anticipated average production of 4 boxes of fruit per tree was used as the basis for calculating total fertilizer poundage. This figure was increased to 6 boxes after 1951. These anticipated production figures were also used for the rate of application experiment. The rates of application of the mixed fertilizer were

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* The authors wish to express their appreciation to the Haines City Citrus Growers Association for making this block of oranges available and for furnishing the fertilizers, sprays, and labor required to conduct the experiments.

arbitrarily based on supplying a given quantity of nitrogen per box of fruit per year. Letters a, b, c and d were used as fertilizer rate designations as shown in Table 2. It should be made clear that nitrogen was not an individual variable. Consequently, as the

Table 1. Amounts of Fertilizer Material Applied per Year, Timing Experiment.

Season	Pounds per Tree per Year					
	N	P_2O_5	K_2O	MgO	MnO	CuO
1949 -1951(1)	1.62	1.08	2.16	1.21	.14	.14
1952 - To date(2)	2.40	1.60	3.20	1.80	.20	.20

Trees receiving three applications per year received a 10-0-10-7-1-1 top-dresser in spring and a 6-6-8-4 1/2-1/2-1/2 in the summer and fall. All other applications were made with a 6-4-8-4 1/2-1/2-1/2 mixture. Where three applications were made, 1/3 of poundage listed in table was applied at each application. One-half the poundage listed in the table was applied per application when two applications per year were made.

(1) Estimated anticipated production 4 boxes per tree per year.
(2) " " " 6 " " " " " " .

Table 2. Amounts of Fertilizer Material Applied per Year, Rate Experiment.

Season	Rate Designation	Pounds per Tree per Year(3)					
		N	P_2O_5	K_2O	MgO	MnO	CuO
1950 - 1951(1)	a	.56	.36	.68	.41	.05	.05
	b	.78	.48	.94	.57	.07	.07
	c	1.24	.84	1.52	.91	.11	.11
	d	1.62	1.08	2.16	1.21	.14	.14
1952 - To date(2)	a	.90	.60	1.10	.66	.08	.08
	b	1.20	.84	1.52	.91	.11	.11
	c	1.80	1.20	2.20	1.32	.16	.16
	d	2.44	1.44	2.92	1.78	.22	.22

(1) Estimated anticipated production 4 boxes per tree per year.
(2) " " " 6 " " " " " " .
(3) Applied as three applications, 1/3 poundage applied at each application. 10-0-10-7-1-1 mixture applied in spring, 6-6-8-4 1/2-1/2-1/2 applied in summer and fall.

Table 3. Dates of Fertilizer Application for Fertilizer Experiment.

Year	Season	Date of Application
1948	Fall	November 10
1949	Spring	March 7
1949	Summer	June 23
1949	Fall	December 3
1950	Spring	March 9
1950	Summer	May 18
1950	Fall	December 21
1951	Spring	March 3
1951	Summer	June 20
1951	Fall	November 24
1952	Spring	February 16
1952	Summer	June 5
1952	Fall	December 3
1953	Spring	February 27
1953	Summer	June 16

amount of nitrogen was increased the other constituents in the mixture were also supplied proportionally in larger amounts.

Fertilizer was applied with a mechanical distributor and all other cultural and production operations were uniform for all plots and in keeping with good grove management practices. The actual date of each fertilizer application is listed in Table 3.

The previous known fertilizer history of this block is presented in Table 4, showing the time of application and the pounds and analysis used. Dolomite has been used for control of pH. The actual time and rate of application was variable but sufficient quantities were used to maintain the pH at a level between 5.5 and 6.0 (see Table 5).

Soil samples were taken from the 0-6" depth of each plot. Each composite sample consisted of 24 cores per plot. pH measurements were made using a 1 to 1 soil water ratio and glass electrode equipment. Analyses for extractable calcium, magnesium, potassium, manganese and phosphorus were made using a solution of sodium acetate buffered at pH 4.8 and following methods essentially as outlined by Peech and English (2) except for using a photoelectric colorimeter for color measurements.

Leaf samples were collected as spring flush leaves from nonfruiting stems with 30 leaves per tree composited into a single sample from each plot. Leaves were washed with a detergent and rinsed with deionized water before drying and grinding. Nitrogen content was measured by the Kjeldahl procedure (semi-micro), phosphorus by the modified Truog method (1), magnesium by the 8-hydroxyquinoline procedure (5) and potassum and calcium using a Perkin-Elmer Model 52A Flame Photometer.

Fruit samples were collected for analyses throughout the season until harvest. Juice was extracted with a F.M.C. In-Line extractor and measurements were made of total soluble solids, titratable acid, vitamin C, percent of juice by weight and volume of juice per fruit.

Table 4. Fertilization Schedule Previous to Beginning of the Present Experiments.

Year	Time and Rate of Previous Fertilizer Applications					
	Pounds	Spring	Pounds	Summer	Pounds	Fall
1943			5	4-6-8-2-1/2-1/2	5	4-6-8-2-1/2-1
1944	3	8-0-8-6-1-1	7	4-6-8-2-1-1	8	4-6-8-2-1-1
1945	5	8-0-8-6-1-1	10	4-6-8-2-1-1	10	4-6-8-2-1-1
1946	5	10-0-10-7-1-1	10	5-6-8-2-1-1	10	5-6-8-3-1-1
1947	5	10-0-10-7-1-1	8	5-6-8-3-1-1	8	5-6-8-3-1-1
1948	3	10-0-10-7-1-1	5	6-6-8-4 1/2-1/2-1	7	6-6-8-4 1/2-1/2-1/2
1949	5	6-6-8-4 1/2-1/2-1				

Results

Soil analysis data as reported in Table 5 warrants further explanation. Analysis of the first soil samples taken from the spring, summer, fall time of application plots revealed a definite dissimilarity between the soils of duplicate plots. Differences in analyses between exchangeable calcium and magnesium and in soil reaction were most apparent. Upon inquiry it was learned that the soil of one of the replicates had been formerly used as a building site and that considerable quantities of limestone and plaster had been worked into the soil after the buildings were demolished. For this reason the results of analyses of these samples have been kept separate in Table 5 and not reported as treatment averages. Two groups of soil analyses data (from 1950 and 1953 samples) are presented to show any significant changes which may have resulted either from changing the rate or time of application of the fertilizer mixture. There are no marked differences apparent between these two groups of analyses. The most consistent difference is a slightly higher pH and calcium content in the 1953 samples whereas magnesium and manganese are slightly lower.

The leaf analysis data show that the time of application of fertilizer resulted in no particular change in leaf composition (Table 6). The leaves from trees receiving the spring-summer treatment contained the highest percentage of nitrogen, potassium and magnesium. This, however, would be expected since these trees received their entire year's supply of fertilizer prior to sampling. The trees receiv-

Table 5. Average Chemical Analyses of Soils Sampled at Two Separated Times from the Time and Rate of Fertilization Plots.

Treatment Designation	pH(1)	Sampled April 13, 1950 Lbs. per Acre Six Inches Exchangeable Bases				
		Ca	Mg	K	Mn	P
Time						
Spring-Summer-Fall	6.90(2) 5.90	1130(2) 375	98(2) 55	45 38	25 22	39 21
Spring-Summer	6.2	480	71	20	26	23
Spring-Fall	5.8	300	86	29	34	30
Summer-Fall	5.7	280	41	29	19	25
Rate						
a	5.65 5.85	350	57	41	23	31
b	5.80 5.90	330	56	24	15	33
c	5.90 6.00	355	65	37	28	54
d	6.90 5.90	750	77	42	24	30

Sampled September 9, 1953

Time						
	6.98(2)	1600(2)	114(2)	37	10	33
Spring-Summer-Fall	6.08	564	65	48	10	26
Spring-Summer	5.93	536	61	40	10	55
Spring-Fall	5.58	490	42	36	18	31
Summer-Fall	6.12	550	55	58	10	30
Rate						
	6.13					
a	6.65	495	44	31	14	22
	5.48					
b	6.18	440	32	20	12	24
	6.04					
c	5.68	485	41	24	22	25
	6.98					
d	6.08	1082	90	43	10	30

(1) pH values recorded separately for individual plots.
(2) This plot located on former building site resulting in soil containing quantities of limestone and plaster.

ing the low fertilizer rates (a and b) produced leaves appreciably lower in nitrogen content (3).

Average characteristics of the juice of fruit from trees receiving the timing and rate of application treatments are presented in Tables 7 and 8. Only data for the past two seasons are presented due to limited space. The rate of application of fertilizer has not appreciably affected the quality of fruit although some trends have been associated with the time of application of the fertilizer mixture. The internal fruit quality has been slightly better as reflected by the soluble solids, acid and vitamin C content where the fertilizer has been applied in two applications, spring and fall. The effect of fertilizer timing upon fruit quality has not been pronounced but the spring-fall timing treatment has resulted in fruit of slightly better quality during the entire period of the experiment. During any single year this difference has not always been statistically significant (Table 7).

Yield records have been taken for individual trees each year since the experiment started, Tables 9 and 10. It is apparent that the yield has been affected to a considerable extent by variations in the timing and rate of application even though the soil, leaf and fruit analyses were not greatly affected by these treatments. The spring-summer application resulted in the highest yield of all timing treatments and this averaged over one box per tree higher than the next highest treatment. There was no significant difference in average yield over the four year period between the other timing treatments.

The rate of application of fertilizer has also affected the yield of Hamlin oranges considerably. The highest yield for the four year period was obtained from trees that received the rate arbitrarily designated as c (Table 10)

Table 6. Chemical Analyses of Hamlin Orange Leaves from Trees Receiving Variable Time and Rate of Fertilization Treatments.[1]

Treatment	Percentage Composition (Dry Weight)				
	N	P	K	Ca	Mg
Time					
Spring-Summer-Fall	2.37	.123	1.52	5.09	.293
Spring-Summer	2.75	.134	1.65	4.37	.297
Spring-Fall	2.38	.141	1.54	4.44	.256
Summer-Fall	2.63	.132	1.63	4.87	.275
Rate					
a	2.17	.130	1.65	4.75	.268
b	2.09	.129	1.65	4.78	.236
c	2.40	.127	1.55	4.44	.285
d	2.37	.123	1.52	5.09	.293

Sample collected Sept. 9, 1953

[1]The authors wish to express thanks to Dr. Robert Koo for his help with some of the analytical work reported above.

Table 7. Average Juice Characteristics of Hamlin Oranges as Affected by Time of Application of Fertilizer Mixture.

Treatment	Season	Percentage		Acid	Ratio	Mgs. Vitamin C/100 Mls.
		Juice by Weight	Soluble Solids			
Spring, Summer, Fall	1951-52	50.6	8.71	1.06	8.60	58.1
	1952-53	49.4	9.10	0.96	9.67	63.9
Spring, Summer	1951-52	52.8	8.63	1.05	8.52	56.3
	1952-53	50.4	9.30	1.05	9.07	64.5
Spring, Fall	1951-52	48.5**	9.16	1.19	8.06	63.3
	1952-53	50.7	9.18	1.01	9.21	67.1
Summer, Fall	1951-52	52.4	8.80	1.09	8.45	58.6
	1952-53	52.4	9.07	0.95	9.73	61.1

**Significantly different at the 1% level.

Table 8. Average Juice Characteristics of Hamlin Oranges as Affected by Rate of Application of Fertilizer Mixture.

Rate	Season	Percentage			Ratio	Mgs. Vitamin C/100 Mls.
		Juice by Weight	Soluble Solids	Acid		
a	1951-52	50.4	9.09	1.11	8.30	68.4
	1952-53	45.3	9.15	0.87	10.78	68.0
b	1951-52	51.6	9.08	1.10	8.64	67.5
	1952-53	48.6	9.19	0.92	10.26	67.1
c	1951-52	52.1	9.09	1.10	8.60	66.6
	1952-53	49.6	9.17	0.98	9.63	64.7
d	1951-52	50.6	8.71	1.06	8.60	58.1
	1952-53	49.4	9.10	0.96	9.67	63.9

Table 9. Effect of Time of Application of Fertilizer on the Average Number of Boxes of Fruit Produced per Tree.

Year	Treatment			
	Spring Summer Fall	Spring Summer	Spring Fall	Summer Fall
1949-50	3.45	4.06	3.67	3.64
1950-51	2.13	3.06	1.88	3.85
1951-52	6.40	8.79	6.17	5.88
1952-53	4.24	5.00	2.64	4.07
4 yr. avg.	4.24	5.56	3.74	4.42

L. S. D. - 1% Level = 1.26 Boxes
5% " = 0.95 "

and this difference of approximately one box per tree was significant. Increasing the poundage above this level has not resulted in increased yields, while at lower rates (a and b) the yield was significantly reduced.

Discussion

The trends in the yield data regarding the effect of time and rate of application of fertilizer show that these variables may markedly affect production. Except on a theoretical basis it is not possible at this time to account for the superiority of the spring-summer timing treatment or the c fertilizer rate of application. It was stated previously that the rate designations as given were arbitrary based on expected yield and do not represent the values based on actual yield. The values based on actual yields have been calculated, and are presented in Table 11 expressed as average pounds of fertilizer ingredients supplied per box of fruit produced for the period of the experiment. There is no correlation between the amount of any one ingredient supplied per box per year and the yield of fruit, however, the yield appears to be correlated with the total pounds of fertilizer supplied, with the

Table 10. Effect of Rate of Application of Fertilizer on the Average Number of Boxes of Fruit Produced per Tree.

Year	Rate Designation			
	a	b	c	d
1949-50(1)	4.03	3.32	3.25	3.45
1950-51	2.73	4.26	5.38	2.13
1951-52	5.77	6.89	7.22	6.40
1952-53	1.55	3.03	4.32	4.24
3 Year Average	3.26	4.59	5.58	4.55

L.S.D. - 1% = 1.21 Boxes
5% = 0.92 "

(1) Yield of trees previous to start of experiment.

Table 11. Approximate Pounds of Fertilizer Ingredients Supplied per Year per Box of Fruit Produced.

Treatment	N	P_2O_5	K_2O	MgO	MnO	CuO
Time						
Spring-Summer-Fall	.45	.30	.60	.33	.04	.04
Spring-Summer	.35	.23	.46	.26	.03	.03
Spring-Fall	.51	.34	.67	.38	.04	.04
Summer-Fall	.42	.28	.56	.31	.036	.035
Rate						
a	.20	.13	.25	.15	.018	.018
b	.20	.13	.24	.14	.018	.018
c	.25	.17	.31	.19	.022	.022
d	.44	.28	.57	.33	.039	.039

yield increasing as the supply of fertilizer increased up to a point beyond which no increase was obtained and some decrease in yield resulted. These data also serve to focus attention to the importance of timing of the fertilizer application. That timing affected the yield is apparent by the fact that a highly significant increase in production was obtained when the fertilizer was applied as a spring-summer application. However, the average yield of trees receiving this treatment was no larger than the average yield of trees receiving the "c" rate treatment in which 25 percent less fertilizer was supplied. The cost of the increased fertilizer used in the spring-summer timing treatment is greater than the additional distribution cost of the rate "c" treatment and the latter must be considered the more efficient.

Because the timing treatments were not replicated and since a single variety is represented these data are not sufficient evidence for changing general recommendations. However, as a result of these studies more comprehensive experiments have been established to see if the suggested trends will hold for other varieties.

Summary

The results of a timing and rate of application of fertilizer experiment are presented. Timing periods included spring-summer-fall, spring-summer, spring-fall, and summer-fall. Rates of application were designated as a, b, c and d and represented the amount of mixed fertilizer containing .15, .20, .30 and .40 pounds of nitrogen per box of anticipated yield with other elements in proportion. Significant increases in production were found to result from the spring-summer timing period. The highest yielding trees in the rate experiment received the rate "c" treatment. When rates of fertilizer above and below this amount were applied the yields decreased. There was little or no correlation between soil or leaf analyses and the yield data. Fruit quality as determined by juice analysis was not significantly changed by any of the fertilizer timing or rate experiments although there was a trend

toward higher quality from spring-fall applications.

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THE EFFECT OF BORAX AND LEAD ARSENATE SPRAYS ON THE TOTAL ACID AND MATURITY OF MARSH GRAPEFRUIT

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Recognized symptoms of boron deficiency, such as gumming, lumpiness and hard misshapen fruit appear occasionally on grapefruit in Florida (1). Such fruit is undesirable from the standpoint of production; therefore, some growers apply borax to grapefruit trees in the dormant or post-bloom spray, or as a component in the fertilizer. However, a recent survey indicates a tendency to supply too much boron in some groves in Florida (12).

Morris (5, 6) first described boron deficiency symptoms of Valencia late oranges in groves in Southern Rhodesia. He found that trees with boron deficiency produced low yields of oranges with a high amount of hard fruit. In addition, normal oranges grown on boron-deficient trees were low in soluble solids, acid, and juice contents. Reitz (8) found no apparent differences in fruit maturity or quality factors as a result of borax spray treatments. In sand cultures using soluble arsenic, Roy (9) produced grapefruit with boron-deficiency symptoms, even with apparently high boron levels in the leaves.

Use of lead arsenate in maturity sprays on grapefruit to reduce acidity and promote early legal maturity is common practice in Florida. However, these sprays often produce grapefruit with symptoms similar to boron deficiency. Sometimes these appear even though apparently adequate levels of boron are present in the leaves. It is not known definitely whether arsenic produces symptoms similar to boron deficiency or whether it is antagonistic to boron. When both lead arsenate and borax are used, boron deficiency of grapefruit may still occur, but in a less degree than fruit with no borax applications (2). Apparently there are still other unknown factors involved.

Under Florida maturity law, legally mature fruit must contain adequate juice and soluble solids contents, and must have the proper ratio of soluble solids to acid. Furthermore, this ratio must be maintained throughout the fruit season. For this reason, moderate rates of lead arsenate are used on grapefruit for early legal maturity, while low amounts are sprayed to insure passing ratios of the fruit in midseason.

Although lead arsenate sprays generally hasten legal maturity, there are certain other practices which delay it. For example, excessive use of potash in the fertilizer program raises the acid content of grapefruit (10), while improper timing of oil sprays lowers the soluble solids (11). Copper sprays (3), alone or in combination with lead arsenate, tend to raise the acidity of the juice and thus delay legal maturity. Experiments conducted for the past three years at the Citrus Experiment Station indicate that grapefruit from trees sprayed with borax matured somewhat later than fruit from unsprayed trees. The reason for the delay in maturity was found to be an increase in the acid content, which occurred even though no boron-deficiency symptoms of the leaves were apparent.

The purpose of this paper is to show the effect of borax spray on the total acid content and legal maturity of Marsh grapefruit. The grower is also interested in knowing the effect of borax on legal maturity when used in conjunction with lead arsenate sprays.

Experimental

The experiment was carried out during 1950-53 on mature Marsh grapefruit trees

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