Citrus Section

EFFECTS OF RATE AND FREQUENCY OF FERTILIZER APPLICATIONS ON GROWTH, YIELD AND QUALITY FACTORS OF YOUNG 'VALENCIA' ORANGE TREES

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ABSTRACT

Three fertilization rates and 3 application frequencies were combined factorially to give 9 treatment combinations used on both outside and inside rows of young 'Valencia' orange trees on rough lemon rootstock planted on a 4-row bed on Felda soil. Application frequencies were 3, 4 and 5 times a year and the 3 rates of fertilization were approximately ½, equal to, and 1½ times the current recommendations for similar age trees. Highest consistent growth and yield responses were obtained on inside rows with medium fertilization rate and lowest application frequency, while trees planted where appreciable topsoil had been removed on outside rows responded most favorably to medium frequent applications and highest fertilizer rate. A significantly greater number of trees showed young tree decline symptoms in low fertility plots than higher fertility plots on the interior two rows of the 4-row bed. It is suggested that results of this experiment may be applicable to young citrus trees planted in groves under both optimum and marginal soil conditions in the flatwoods and marshes.

INTRODUCTION

Very little information based on results from replicated field experiments is available on fertilizer practices for young trees planted on lowland and calcareous soils in the flatwoods and marshes. Rapid expansion of the citrus industry into more marginal soils in poorly drained areas has been accomplished without the benefit of experimental data regarding efficiency of fertilizer use and without the evaluation of problems which may be different from those of the established citrus growing areas. In a series of experiments on well-drained acid soils, Rasmussen and Smith (4) evaluated young citrus tree fertilizer practices and on the basis of their findings made significant modifications to earlier recommendations in Bulletin 536 (7) and Bulletin 536A (8). These recommendations with some modifications appear fairly sufficient for young citrus trees on the finer textured lowland and calcareous soils as in the Indian River area. However, fertilizer recommendations for Florida citrus given in Bulletin 536B (9) were devised primarily for average sandy, well drained soils low in organic matter, such as the Lakeland and Blanton sands.

The primary objective of the experiment reported here was to test current recommendations regarding frequency and rate of fertilization of young trees under conditions of fine textured lowland soil, close tree plantings, and 4-row bed design. An additional objective was to investigate and if possible eliminate soil fertility differences related to poor tree growth on outside rows of a 4-row bed system.

EXPERIMENTAL PROCEDURE

This study was initiated in January, 1963 in The Coca Cola Company, Foods Division, Holman Cloud grove near Fort Pierce, Florida. The trees, 'Valencia' oranges on rough lemon rootstock, were planted in 1961 on beds consisting of 4-rows spaced 27 feet apart with trees 15 feet apart in the rows. The soil type in the experimental area is Felda fine sand. Measurements of pH made

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on soil sampled from several locations in the experimental area showed that pH of the top 12 inches of soil ranged from 6.5 to 8.3. The surface soil horizon in the experimental area varies in color from gray to dark gray with subsurface layers grading into much lighter gray to white sand. The soil contains appreciable amounts of sandy clay loam at depths of 28 to 42 inches. The sandy clay loam layer is usually underlain by highly pervious marine shell at depths of 42 inches or more.

Ditch spoil composed of a mixture of these soil layers was graded into the surface soil during the 4-row bed construction. The crown of the 4-row citrus bed in the Cloud grove was graded approximately 1 to 1.5 feet higher than the bed area immediately adjacent to the ditch berm on the sides of the bed. During the grading procedure to obtain the bed crown the dark gray surface soil (A_1 horizon) was partially to completely removed from the outside row planting areas. Shifting the surface by grading markedly improved the soil quality for the interior rows, but exposed white, coarse, leached, sandy layers in the area on which the two outside tree rows were later planted.

Three fertilization rates (R_1, R_2 and R_3) and 3 application frequencies (F_3, F_4 and F_5 were combined factorially to give 9 possible treatment combinations. Fertilizer rate treatments consisted of a medium fertilizer rate (R_2) which was approximately equal to the average recommendation for similar age trees in Bulletin 536B (9) and rates R_1 and R_3 which were ½ and 1½ times the average recommendation, respectively. Fertilizer application frequencies were 3, 4 and 5 times per year for the F_3, F_4 and F_5 treatments, respectively. Treatments were randomized in four replicate blocks. The experiment was duplicated on the outside and on the inside rows of a single 4-row bed containing approximately 4.3 acres including ditches. Each plot consisted of 4 'Valencia' orange trees with single buffer trees on each end of the plot. Approximate dates of application are presented in Table 1. The amounts of fertilizer applied for each of the 3 rates during the 6-year period are shown in Table 2. The fertilizer ratio was 8-4-8-6-0.25-0.25 for the first 2 years and was changed to 12-6-12-9 with the first application in 1965.

Systematic field observations of tree condition were made 2 or 3 times each year. Even more frequent observations were taken when it became evident that a large number of trees in this grove were showing young tree decline symptoms similar to citrus blight (5). Soil was sampled in May, 1969 at 6-inch increments down to 72 inches from both declining and healthy trees for pH and other determinations. Spring flush leaves from non-bearing twigs were sampled for mineral element analyses in early November, 1964. Yield was obtained when the crop was harvested commercially, which generally was in late spring each year. Fruit quality measurements were made each year, primarily in March. Trunk circumference measurements were taken in March, 1963 and again in November, 1968, while tree height and canopy diameter were measured only in June, 1969. Tree canopy area was calculated from the height and tree diameter data.

Data obtained in the study were analyzed statistically as a 3 x 3 factorial. Duncan's (3) multiple range test was applied to the data to detect individual differences among the 9 treatment combinations.

Table 1. Dates of application of fertilizer frequency and rate treatments.

Treatment symbols	Fertilizer rate	Frequency of application	Dates of application
R_1F_3	Low	3	2/15, 4/15, 11/15
R_2F_3	Medium	3	2/15, 4/15, 11/15
R_3F_3	High	3	2/15, 4/15, 11/15
R_1F_4	Low	4	2/15,4/15, 8/15, 11/15
R_2F_4	Medium	4	2/15,4/15, 8/15, 11/15
R_3F_4	High	4	2/15,4/15, 8/15, 11/15
R_1F_5	Low	5	2/15, 4/15, 6/15, 8/15, 11/15
R_2F_5	Medium	5	2/15, 4/15, 6/15, 8/15, 11/15
R_3F_5	High	5	2/15, 4/15, 6/15, 8/15, 11/15

Table 2. Amounts of fertilizer applied per tree and per acre per year.

Seasons	Fertilizer rate	Pounds per year											
		N		P_2O_5		K_2O		MgO		CuO		MnO	
		Per tree	Per acre	Per tree	Per acre	Per tree	Per acre	Per tree	Per acre	Per tree	Per acre	Per tree	Per acre
1963-65	R_1	.24	19.15	.12	9.58	.24	19.15	.18	14.36	.0075	.60	.0075	.60
	R_2	.48	38.30	.24	19.15	.48	38.30	.36	28.73	.0150	.90	.0150	.90
	R_3	.72	57.46	.36	28.73	.72	57.46	.54	43.09	.0225	1.80	.0225	1.80
1965-69	R_1	.63	50.0	.31	25.0	.63	50.0	.47	37.5	0	0	0	0
	R_2	1.25	100.0	.63	50.0	1.25	100.0	.94	75.0	0	0	0	0
	R_3	1.88	150.0	.94	75.0	1.88	150.0	1.41	112.5	0	0	0	0

Irrigation, pest control, nutritional spraying and other grove management practices were carried out by The Coca Cola Company, Foods Division and were considered to be adequate.

Results

Tree Condition and Growth—The fertilization rate and frequency treatments on inside rows had no statistically significant or practical effects on increase in trunk circumference, tree foliage diameter and tree canopy area (Table 3). Significant differences in height were detected among the R_2F_3, R_1F_5 and R_2F_5 treatment combinations on inside rows.

Increasing fertilizer rate on outside rows increased trunk circumference, tree height, tree foliage diameter, and tree canopy area, but these increases were not always significant. The treatment combination which tended to give the maximum growth increases for the trees on outside rows was the high fertilization rate applied with medium frequency (R_3F_4), but the F_4 frequency was not always statistically distinguishable from the lowest application frequency for all these growth effects (Table 3). It is interesting to note that the R_3F_4 combination gave by far the largest square feet of tree canopy area. This area compared quite favorably with the largest canopy area attained for trees on the inside rows (Table 3).

Trees receiving the R_2 and R_3 fertilization rates were distinctly greener and denser in foliage than trees receiving the R_1 rate in both inside and outside rows, although this condition was more striking in the outside rows. In the early years of the experiment, trees in outside rows receiving the R_1 fertilization rate were thin and yellow in foliage, and the leaves generally showed N and Mg deficiency symptoms.

Table 4 shows a breakdown by treatment of the incidence of young tree decline symptoms in the fertility plots on inside and outside rows. These data reveal a trend for more young tree decline symptoms on trees on the inside rows. Trees in R_1 plots appeared to be affected most frequently. The average effect of rate disregarding frequency was a significantly greater number of trees showing young tree decline symptoms in plots receiving the R_1 fertilization rate than in plots receiving the R_2 and R_3 rates (data not presented).

Table 3. Effects of fertilizer rate and frequency treatments on height, diameter, canopy area and trunk circumference of young 'Valencia' orange trees.

Application frequency	Inside rows, Fertilizer rate R_1	Inside rows, Fertilizer rate R_2	Inside rows, Fertilizer rate R_3	Outside rows, Fertilizer rate R_1	Outside rows, Fertilizer rate R_2	Outside rows, Fertilizer rate R_3
			Height, ft.			
F3	12.0^{abc}*	12.7^{a}	12.6^{ab}	10.9^{bc}	11.0^{bc}	11.7^{b}
F4	11.8^{abc}	11.8^{abc}	11.8^{abc}	9.8^{c}	10.6^{bc}	13.0^{a}
F5	11.2^{c}	13.0^{a}	11.3^{bc}	10.7^{bc}	11.4^{b}	11.0^{bc}
			Diameter, ft.			
F3	14.4**	15.3	14.3	11.7^{bc}	12.3^{abc}	13.1^{ab}
F4	14.4	14.3	14.6	10.5^{c}	11.9^{bc}	14.1^{a}
F5	13.4	15.4	14.2	11.9^{bc}	12.4^{abc}	11.7^{c}
			Canopy area, sq. ft.			
F3	403	454	416	293^{e}	313^{cd}	359^{b}
F4	397	394	406	237^{f}	291^{e}	421^{a}
F5	352	467	378	297^{de}	326^{c}	294^{de}
			Trunk circumference increase 1963-68, inches.			
F3	16.4	17.1	16.3	13.3^{abc}	12.8^{bc}	15.8^{ab}
F4	16.0	15.4	16.0	10.8^{c}	11.7^{c}	16.5^{a}
F5	14.1	17.0	14.4	12.8^{bc}	13.5^{abc}	13.9^{abc}

* Means for individual years and bed position followed by the same letter do not differ at P=0.05.

** Columns and rows of means without letters are not statistically significant.

Table 4. Number of trees showing young tree decline symptoms in fertilizer frequency and rate plots on November 12, 1968.

Application frequency	Inside rows, Fertilization rate			Outside rows, Fertilization rate		
	R_1	R_2	R_3	R_1	R_2	R_3
			Number of trees			
F3	4^{ab}	0^{b}	2^{ab}	0	0	0
F4	6^{a}	2^{ab}	1^{b}	4	0	0
F5	4^{ab}	1^{b}	2^{ab}	1	0	1

See footnotes of Table 3.

Yield—Table 5 shows that increasing frequency of fertilizer applications had no practical effect on fruit yields on inside rows. In fact, frequency treatments were significant only in the 1964-65 season when more frequent fertilizer applications at the R_3 rate tended to decrease yields. Fertilization rate treatments on inside rows gave statistically different yields 3 years out of 5. There was a significant interaction between frequency and rate treatments on inside rows only in the 1966-67 season. The highest yielding treatment combination the first 3 years for inside rows was R_3F_3. In the last 2 years of the experiment the R_2F_3 treatment combination gave highest yields. Fertilization rate responses on inside rows followed a curvilinear trend as yield per tree leveled out or often decreased at the R_3 rate.

Table 5. Effects of fertilizer rate and frequency treatments on yield of young 'Valencia' orange trees on rough lemon rootstock planted in inside and outside rows of a 4-row bed.

Application frequency	Inside rows, Fertilizer rate			Outside rows, Fertilizer rate		
	R_1	R_2	R_3	R_1	R_2	R_3
			BOXES/TREE			
			1964-65			
F3	$.42^{b*}$	$.77^{ab}$	$.96^{a}$	$.09^{b}$	$.22^{ab}$	$.21^{b}$
F4	$.45^{b}$	$.55^{b}$	$.47^{b}$	$.11^{b}$	$.20^{b}$	$.39^{a}$
F5	$.32^{bc}$	$.55^{b}$	$.54^{b}$	$.15^{b}$	$.18^{b}$	$.26^{ab}$
			1965-66			
F3	.58**	.85	1.11	$.12^{bc}$	$.30^{b}$	$.56^{ab}$
F4	.89	.68	.92	$.19^{b}$	$.49^{b}$	$.92^{a}$
F5	.90	.96	.83	$.34^{b}$	$.58^{ab}$	$.48^{b}$
			1966-67			
F3	1.79^{cd}	2.60^{ab}	2.90^{a}	1.00^{cd}	1.32^{bcd}	1.76^{b}
F4	2.06^{bcd}	2.09^{bcd}	2.26^{abc}	$.83^{d}$	1.65^{bc}	2.63^{a}
F5	1.45^{d}	2.62^{ab}	2.12^{bc}	1.24^{bcd}	1.77^{b}	1.66^{bc}
			1967-68			
F3	1.76^{b}	2.67^{a}	2.42^{ab}	1.67^{abcd}	1.73^{abcd}	2.08^{abc}
F4	1.76^{b}	2.14^{ab}	2.33^{ab}	1.22^{d}	1.48^{cd}	2.36^{a}
F5	1.78^{b}	2.23^{ab}	2.20^{ab}	1.52^{bcd}	2.19^{ab}	1.80^{abcd}
			1968-69			
F3	2.22	2.82	2.49	1.16^{bc}	2.02^{ab}	2.15^{ab}
F4	2.42	1.94	1.62	1.14^{bc}	1.53^{abc}	2.31^{a}
F5	1.96	2.57	2.46	1.34^{abc}	$.96^{c}$	1.69^{abc}

See footnotes of Table 3

Table 6. Effects of fertilizer rate and frequency treatments on fruit weight and juice quality factors. Data represent 5 year averages.

Application frequency	Inside rows Fertilization rate R1	R2	R3	Outside rows Fertilization rate R1	R2	R3
			Juice (%)			
F3	54.98	55.08	55.80	55.00	55.76	55.16
F4	54.62	55.16	54.86	56.00	55.94	55.78
F5	54.94	54.96	54.24	54.92	55.42	56.42
			Brix (%)			
F3	11.56[a]	11.04[b]	10.76[d]	11.70[b]	11.38[c]	10.50[f]
F4	11.66[a]	11.02[b]	10.88[c]	11.84[a]	11.28[cd]	11.24[d]
F5	11.60[a]	10.94[bc]	10.88[c]	11.86[a]	10.90[e]	11.26[d]
			Acid (%)			
F3	.91[abc]	.87[cd]	.85[d]	.94[a]	.88[bcd]	.80[e]
F4	.92[ab]	.89[bcd]	.92[ab]	.92[abc]	.86[d]	.89[abcd]
F5	.94[a]	.89[bcd]	.88[bcd]	.93[ab]	.87[cd]	.87[cd]
			Brix-to-acid ratio			
F3	13.2	13.2	13.2	12.7	13.1	13.5
F4	13.1	12.9	12.3	13.1	13.2	12.9
F5	12.8	12.9	13.0	12.9	12.7	13.2
			Fruit weight (grams)			
F3	176.6[e]	200.6[c]	206.4[bc]	209.6[abc]	219.8[abc]	226.0[a]
F4	178.0[e]	204.0[bc]	213.8[ab]	204.6[c]	219.6[abc]	217.4[abc]
F5	185.2[e]	203.4[bc]	223.8[a]	206.0[bc]	223.8[ab]	218.6[abc]

See footnote of Table 3.

Fruit yields were significantly different due to rate in all seasons on outside rows. There were significant interactions between frequency and rate treatments on outside rows in the last 3 seasons presented in Table 5. The consistently highest yielding treatment combination for outside rows was R_3F_4. The data show a trend in certain years for sizeable yield increases on outside rows with increasing fertilization rates at both F_3 and F_4 application frequencies, but at the F_5 frequency, there was no significant differances yields due to rate for any of the 5 years. In fact, on the average increasing number of fertilizer applications above 4 per year tended to lower yields on both inside and outside rows.

Fruit Quality—The data shown in Table 6 are averages of quality analyses determined once each year over the 5 year period, 1964 through 1969. Years were used as replications for statistical purposes and were significant statistically for percent acid and fruit weight determinations on inside rows and for degrees Brix and percent acid on outside rows. Significance of years means that quality differed considerably in different seasons. Most of the overall effect on juice quality can be ascribed to the fertilizer rate treatments, however more frequent applications on the average increased soluble solids in fruit from outside rows. The treatment combination giving heaviest fruit on inside rows was R_3F_5, which apparently was due to an interaction of the frequency and rate treatments. The average effect of increasing fertilizer rate on both inside and outside rows was to decrease soluble solids per fruit, decrease fruit acid slightly and produce a heavier fruit (Table 6). Brix-to-acid ratios and percent fruit juice by weight were not influenced significantly by any of the treatments.

Leaf and Soil Analysis—Rate and frequency treatments did not significantly influence leaf N, Ca and Mg on inside rows as shown in Table 7. Increasing fertilizer rate significantly increased leaf P on inside rows at the F_4 and F_5 frequencies. Leaves from outside rows generally had larger amounts of N, Ca and Mg with increasing fertilizer rates. Leaf K content in trees on outside rows generally decreased as rate of fertilization increased. Interaction between rate

Table 8. Representative pH values determined on soil sampled from varying depths at the dripline of healthy and declining 'Valencia' orange trees.

Depth inches from - to	Soil pH Healthy trees Tree A	Tree B	Declining trees Tree A	Tree B
0 - 6	7.3	8.6	7.5	8.0
6 - 12	7.3	8.2	7.3	8.0
12 - 18	6.5	8.5	7.2	8.1
18 - 24	4.2	4.5	5.5	6.6
24 - 30	3.6	4.6	3.4	6.5
30 - 36	3.6	7.6	3.5	6.3
36 - 42	3.4	8.1	3.2	6.7
42 - 48	4.0	8.0	6.7	7.3
48 - 54	7.5	7.7	7.4	7.6
54 - 60	7.8	7.9	8.0	7.8

and frequency was present in the leaf P data indicating the effects of rate and frequency were not independent in influencing leaf P content.

Values of pH obtained from soil sampled at varying depths from the dripline of both declining and apparently healthy trees are presented in Table 8. No consistent differences in pH between the declining and healthy tree locations were obtained. Extremely low pH values were encountered frequently under both declining and healthy trees. Soil from these low pH layers was usually of sandy loam texture. The soil has a light blue color with reddish mottled streaks which generally indicates chemically reduced conditions, with some evidence for slight oxidation.

Discussion

Fertilizer requirements appear different for the 2 center rows of young 'Valencia' trees than for the outer 2 rows on a 4-row citrus bed. Rate-frequency combination R_3F_4 gave largest consistent growth and yield responses on outside rows. The R_2F_3 treatment combination accomplished the same function on inside rows. Overall, the fertilization rate treatments appeared to be of primary consideration, while frequency treatments were decidedly of secondary importance, especially on inside rows. Plots receiving fertilizer applications in June (F_5 treatment) usually had less growth and yield than plots receiving the same rates, but less frequently and in drier periods. These results are in agreement with a number of workers (1, 6, 10, 11) who have shown that time of application is of little importance provided that fertilizer applications are made during the drier seasons of the year.

The differential tree response to fertilizer, depending on location on the 4-row bed appears to be the result of differences in soil properties existing between the 2 locations. Field observations of the experimental area reveal that soil on which the center rows were planted is deeper, contains more fine textured material, including organic matter, than soil in outer row areas which is white, highly leached and often nearly devoid of organic matter. Extra fertilizer applied more often on outer rows apparently partly compensates for the loss of topsoil. However, growers should keep in mind the additional expense of the higher rates and more frequent applications which were necessary to obtain favorable responses for outside rows.

The results of these experiments show that current recommendations in Bulletin 536B (9) were adequate and practical for young 'Valencia' trees in center rows growing under better soil conditions. Maximum response at this bed location was usually obtained at R_2F_3 rate-frequency combination which is similar to that recommended for similar age trees in Bulletin 536B. The results indicate that additional yield and growth responses were obtained under outside row conditions at fertilizer rates and frequencies higher than currently recommended in Bulletin 536B.

Inferences may be drawn from the results of these experiments to other young groves planted on soils with similar properties. Citrus trees planted on white sandy soils in lowland areas comparable to the outside rows used in this experiment may respond to higher and more frequent applications than are recommended in Bulletin 536B. Whether the extra care necessary to produce these responses is economical will have to be decided in individual situations.

The experiment is being continued to assess the relative rate at which trees in the fertilizer plots show young tree decline symptoms. The influence of the highly acid layers (Table 8) in the soil profile as a possible contributor to the young tree decline is being investigated by soil and plant analyses. The highly acid soil layers quite possibly may be identical to the soil condition described by Coleman and Thomas (2) as "cat clay." These workers found that certain coastal soils derived from marine parent materials and recently drained from swampland upon oxidation develop highly acid layers by conversion of sulfides accumulated in the profile to sulfates.

Summary

Nine fertilizer frequency and rate treatment combinations applied over a 6 year period gave

wide ranges in growth, tree condition and fruit production of young 'Valencia' trees on rough lemon rootstock. The treatment combination of medium fertilization rate and low application frequency appeared satisfactory for trees planted under soil conditions existing on interior rows of the 4-row citrus bed. Medium frequent applications and high fertilizer rate gave favorable results on exterior rows where appreciable top soil had been removed. Declining growth and yield responses to more than 4 applications per year apparently was the result of applying fertilizer during the rainy season when leaching losses are high. Young tree decline symptoms were significantly greater in low fertility plots on the interior 2 rows of the 4-row bed. Results from this experiment can be extrapolated to young citrus trees planted in groves on both optimum and marginal soil conditions in the flatwoods and marshes.

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EFFECTS OF SOIL pH AND CALCIUM ON THE GROWTH AND MINERAL UPTAKE OF YOUNG CITRUS TREES

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ABSTRACT

A soil pH—added calcium factorial experiment was started in 1964 in a 2-year-old block of 'Valencia' oranges on rough lemon rootstock located on newly cleared Lakeland fine sand. The treatments consisted of annual soil applications of sulfur, gypsum, soda ash (sodium carbonate), and calcitic limestone applied alone or in combinations to provide 4 levels of soil pH (4.0, 5.0, 6.0, and 7.0), 4 levels of added calcium (0, 100, 200, and 400 pounds calcium per acre per year), and all possible combinations for a total of 16 treatments.

Striking differences in tree growth due to treatment were observed by October, 1967. Maximum growth occurred at the highest pH level and maximum rate of added calcium. This treatment consisted of liming the soil to pH 7.0 with calcitic limestone and supplementing the limestone with gypsum to provide a total of 400 pounds added calcium per acre per year. In general, the fastest rate of growth resulted from the simultaneous increase in both soil pH and added

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