A PRELIMINARY REPORT ON THE REQUIREMENTS OF YOUNG VALENCIA TREES FOR ZINC, MANGANESE, AND COPPER WHEN FERTILIZED AT TWO DIFFERENT RATES

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In the spring of 1949, a small block of newly set Valencia trees near Lake Placid was made available for experimental work.* The trees were on rough lemon root stock and were planted on sandy soil typical of the Lakewood series encountered at Lake Placid. After being set out in the grove, they were not sprayed or fertilized prior to the inauguration of the experiment reported here.

The experiment was designed to study the zinc, manganese, and copper requirements of young citrus trees. Originally, neutral materials were compared with the sulfates, but this aspect of the experiment was discontinued in 1952. Each of the three metals was tested at 0, 1 and 3 pounds of the sulfate per 100 gallons of spray, or at the equivalent metallic content if neutral materials were used.

Since all three rates for the three materials were to be tested, there were 27 different treatments. Single trees were used for each treatment so that, within a plot, each of the 27 trees had a different treatment. There were 216 trees in the experiment with the zinc-manganese-copper treatments replicated eight times. The trees were sprayed with sulfur, oil, and DN as needed.

Although fertilizer formulae have differed from time to time, they have averaged about an 8-4-8-5 throughout the 4½ years. Originally, half of the experiment received twice as much fertilizer as the other half. In 1951, this was changed so that the high level was about half again as much as the lower level. Table 1 shows the pounds of nitrogen applied per tree in each of the first five years.

* Without the cooperation of Lykes Brothers Groves this work would have been impossible. The authors particularly wish to express their deep appreciation for the sincere help of Mr. Robert C. Wooten. His generosity and cooperation permitted this project to be set up and to be operated with the burden of the expense donated by Lykes Brothers Groves. This experiment was started while the senior author was employed by the Citrus Experiment Station.

TABLE 1

Pounds of Nitrogen Applied Per Year Per Tree

	Fertilizer Level	
Year	High	Low
1949	.14	.07
1950	.80	.40
1951	.72	.47
1952	1.32	.88
1953	1.91	1.31

Since 1949, seven copper, zinc, or manganese sprays have been applied (June, Oct., 1949; Jan., May, 1950; Apr., 1951; May, 1952; and May, 1953). The trees are now so large that they will be too close together for sprays to be used another year. It is planned to start soil treatments in 1954.

A total of approximately 10 gallons of spray has been applied per tree during the five spray seasons. This represents 1/10 of a pound of zinc, manganese, or copper sulfate per tree at 1 lb./100 gals. and 0.3 lb. at 3 lbs. per 100 gallons. Approximately half of this total amount was applied in 1953. Zinc, manganese, and copper have not been supplied in the fertilizer.

Results and Discussion

Results are still preliminary. Until yield rates have been established, it will be impossible to fully evaluate the experiment. However, growth characteristics and deficiency symptoms suggest some tentative conclusions.

Trunk Diameter: The rate of growth is a primary consideration when studying the necessity for a nutritional program. In this experiment growth was measured by determining the diameter of each tree at a point just above the bud union. This area was marked with a painted white band. These were first measured after the trees were set and similar determinations have been made in the spring of each succeeding year. Table 2 presents these data.

The major effect on diameter has resulted from the amount of fertilizer applied. Regardless of initial size, by 1951, in all of the comparisons shown in Table 2, the greater diameter was always found on the high fertilizer level. The magnitude of this difference appears to be increasing with each year.

Neither zinc nor manganese have had any effect on trunk diameter through the first four growing years. In the case of copper, there is a tendency toward increased size with increasing amounts of copper. This is somewhat questionable because of the variation within the copper treatments.

Yield: Sufficient fruit was set in 1952 and 1953 to give preliminary information on yields. Individual fruits were counted on each tree in March 1953. (See Table 3). The 1953-54 crop was counted in October 1953. (See Table 4). Zinc and manganese had no effect on the number of fruits per tree. In the case of copper, there appears to be a reduction in the number of fruits produced on the no copper treatment as compared with 1 or 3 pounds per 100 gallons. This was true on both the high and low levels of fertilization for both years.

Fertilizer rate had an influence on the number of fruit. This was true with all treatments. There was a much greater percentile difference in the 1952-53 crop than the 1953-54 one. It is possible that increased yields will completely

Table 2

Diameter of Trees in mm. as affected by Fertilizer Level and Zn, Mn, or Cu.*

	Year	Pounds of Sulfate per 100 gallons								
		0			1			3		
		Fert. Level			Fert. Level			Fert. Level		
		High	Low	Avg.	High	Low	Avg.	High	Low	Avg
	1949	26	27	27	25	26	26	25	26	26
	1950	32	33	33	33	32	33	32	32	32
Zinc	1951	58	57	58	56	54	55	55	54	55
	1952	85	83	84	83	80	82	85	80	83
	1953	118	117	118	117	112	115	119	111	115
	1949	25	26	26	25	26	26	26	26	26
	1950	32	32	32	32	32	32	34	31	33
Manganese	1951	56	55	56	56	54	55	58	55	57
	1952	86	81	84	84	79	82	85	82	84
	1953	117	114	116	118	112	115	117	115	116
	1949	26	26	26	26	26	26	25	27	26
	1950	33	32	33	33	32	33	33	32	33
Copper	1951	55	54	55	58	57	58	59	55	57
	1952	85	79	82	83	81	82	86	83	85
	1953	118	112	115	117	115	116	119	116	118

* Each figure represents an average of 36 trees.

justify the increased rate of fertilization, but this is not obvious as yet. If fertilizer is figured at 2½ cents per pound, it has cost approximately 93 cents per tree for fertilizer for the low level, and 149 cents for the high level for the first five years. During this same period the trees on the low rate have produced an average of 94 oranges as compared with 118 on the high level.

Metal Deficiency Symptoms

Periodically the trees have been examined for symptoms of zinc, manganese, and copper deficiency. Typical symptoms for all three of these materials have been noted. However, on several occasions symptoms typical of a given deficiency have not been correlated with the rates of application of the metal. This fact has caused considerable confusion in an attempt to evaluate the leaf symptoms as they have been noted. In the discussion below, typical deficiency symptoms are listed and evaluated. At the same time, a discussion of the symptoms which cannot be catalogued is made, and information other than data collected in this experiment is also included. This latter discussion may offer a partial explanation for similar situations which arise in commercial grove practice.

Copper Deficiency: No symptoms of copper deficiency were noted until the fall of 1952. Prior to that time, neither multiple growth nor split fruit had shown any relation to copper usage. Ammoniated fruit was first seen in November 1952, when symptoms were noted on 15 trees, of which 13 were on the high level of fertilization. The ammoniation on one tree on the low fertilizer level was questionable, and it had received copper at 1 pound per 100 gallons. All others were on the 0 copper level. In October 1953, ammoniation was beginning to be evident on the fruit, but it was still too soon to analyze the final

Table 3

Number of Fruit Per Tree When Counted In the Spring of 1953. *

	ZINC			MANGANESE			COPPER			
Lbs. S04/100 Gal.	0	1	3	0	1	3	0	1	3	Average
Low Level of Fertilizer	53	32	34	43	44	32	37	39	43	
	55	40	56	43	60	49	34	59	58	
	42	63	43	63	32	53	53	55	40	
	35	45	55	43	51	40	31	43	60	
Average	46	45	47	48	46	43	39	49	50	46
High Level of Fertilizer	62	67	55	64	41	80	58	63	64	
	69	91	76	65	81	91	75	89	72	
	64	65	61	80	58	53	49	56	87	
	65	87	60	72	63	77	62	93	57	
Average	65	78	63	70	61	75	61	75	70	69
Average of 2 Series	56	61	55	59	54	59	50	62	60	57

* Each Figure Represents An Average For 9 Trees.

Table 4

Number of Fruit Per Tree When Counted in October 1953. *

	ZINC			MANGANESE			COPPER			
Lbs. SO4/100 Gal.	0	1	3	0	1	3	0	1	3	Average
Low Level of Fertilizer	143	103	134	128	121	131	111	143	125	
	110	138	151	142	126	133	124	128	152	
	166	159	142	160	130	177	153	174	140	
	115	182	155	148	155	149	135	155	162	
Average	134	146	146	145	133	148	131	150	145	142
High Level of Fertilizer	152	156	162	143	166	162	159	155	156	
	182	178	187	197	180	170	169	187	191	
	159	138	144	151	139	151	125	142	174	
	190	167	185	170	186	183	154	174	210	
Average	171	159	170	165	168	167	152	164	183	167
Average of 2 Series	153	153	158	155	151	158	142	157	164	155

* Each Figure Represents An Average For 9 Trees.

extent of this condition. As this is written no die-back has been evidenced in the plots, split fruit has not been correlated with lack of copper, and neither multiple nor S-shaped growth has been associated specifically with low copper. There has been a reduction in yield on the zero copper plots.

Zinc Deficiency: In January 1950, one year after planting, four trees were observed with some leaf symptoms which appeared to be typical of zinc deficiency. Three of these received no zinc, copper or manganese. The fourth tree received zinc at 1 pound per 100 gallons.

In February 1951, there were 5 trees with typical zinc deficient leaves. Of these, none received zinc and only one was on the low fertilizer level. In March 1952, 38 trees showed deficiency symptoms. These symptoms were related to the low zinc levels and there was a slight tendency to be related to high copper and manganese. Half of the trees were on the low fertilizer level.

In November 1952, a careful check of leaf symptoms was made. Typical leaves from each tree were selected and then an attempt was made to separate the various patterns and to relate them to treatment. Those that were typical of zinc deficiency appeared related to low zinc and to a lesser extent to high manganese or copper. Twenty-one trees had zinc deficiency symptoms on the high fertilizer level and 16 on the low.

In September 1953, symptoms of zinc deficiency were found on 85 trees. Most of these patterns were found on summer flush foliage. Of the trees involved, 39 were on the low level of fertilization and 46 were on the high. Forty-nine of the trees with symptoms had received no zinc, 26 received zinc at 1 pound of the sulfate per 100 gallons, and 10 received 3 pounds per 100 gallons. There was a tendency for zinc deficiency to be related to increased rates of manganese and copper applications.

In April 1951, and again in May 1953, considerable leaf pattern was present on the spring flush growth. At both times, most of the pattern would ordinarily have been considered as typical of zinc deficiency, but some of the leaves showed green veining similar to iron deficiency, and others were apparently typical of manganese deficiency.

Although in 1953, there was a slight relationship between leaf pattern and the amount of zinc used, trees which had received the heaviest zinc applications had almost as much pattern as did those which had never been sprayed with zinc. Other than this tendency there was no relationship to rates of application of zinc, manganese, or copper, but there was more pattern on the high level of fertilization. This association with rate of fertilization was true in both years.

No adequate explanation for these deficiency symptoms is possible at the present time. However, the appearance in 1953 was preceded by almost complete defoliation during the winter months. This problem is discussed further in a paragraph below.

Manganese Deficiency: Throughout the 4½ years some leaves have been noted which were apparently typical of manganese deficiency. Table 5 shows the relationship of manganese like symptoms to manganese application. In only July 1952 and Sept. 1953 were leaf symptoms typical of manganese related to the rate of application. Thus, as noted for zinc above, leaf pattern apparently typical of a given deficiency could not always be related to the rate of application of that material.

TABLE 5

Number trees showing symptoms similar to Mn deficiency as related to amount of Mn applied

	Lbs. of Mn/100 Gals. 0	1	3
March 1952	0	2	3
July 1952	6	4	2
Nov. 1952	11	16	11
May 1953	31	29	27
Sept. 1953*	55	17	3

* Analyses by Dr. C. D. Leonard (Cit. Exp. Sta.) showed that leaves with Mn pattern were low in Mn.

Possible Iron Deficiency: As early as April 1950, it was noted that one of the two trees in an area where trash had been burned showed spring growth leaves with a pattern which is now thought to be typical of iron deficiency. This tree had received the equivalent of 1 pound of manganese sulfate per 100 gallons and no copper or zinc. The other tree in the burned area, but with no leaf symptoms, had received 1 lb. of zinc, no manganese, and 3 pounds of copper. At the present time the pH in this burned area is 7.4, while that around most of the trees is 5.4. This difference was probably even greater at the time of this initial observation.

In almost all of the examinations of leaf symptoms discussed in preceding sections, some leaves with fine green veins were noted, and these were found almost exclusively on young foliage. In February 1953, because of the presence of these symptoms, three of the four 27 tree plots on both levels of fertilization were treated with EDTA* in the form of 2 ounces of the sodium salt of the iron chelate (8% Fe) of EDTA, or the equivalent amount of EDTA as the calcium salt of the calcium chelate, or as the tetra-sodium salt of EDTA. On June 12, the trees were graded according to the severity of the leaf symptoms. In this examination it was found that the two plots which received no EDTA had more severe deficiency symptoms than the other six plots. In fact, there was almost twice as much pattern on the control plots as elsewhere. There was an average of only 3½ trees with no pattern in the untreated plots as compared with more than 10 on the treated ones. Although much of the pattern was typical of zinc or manganese deficiency, it was reduced by the use of EDTA. Therefore, it would appear that the leaf patterns which cannot be adequately associated with the use of zinc, manganese, or copper may be related to iron, or at least to some element whose uptake is facilitated by the use of EDTA. Similarly, in the analysis of leaf symptoms in Sept. 1953, zinc deficiency was almost twice as pronounced in the two plots which received no EDTA as elsewhere.

This suggests that the recognition of deficiency based solely on leaf symptoms may be misleading. Thus, in 1951 and 1953 considerable pattern was found on spring flush growth which could not be related to zinc or manganese treatment. In both years these patterns had largely disappeared by late summer, and in 1953, the overall pattern was reduced by the use of EDTA.

So called manganese deficiency symptoms are commonly found on arsenated grapefruit trees and on trees which have suffered severe defoliation. In the former instance these ap-

* Ethylene diamine tetra-acetic acid.

parently manganese deficient leaves are often preceded by leaves with fine green veins.

During the past two years the authors have found this so-called manganese pattern to be very common on several varieties of citrus on sweet orange root stock. In many places the pattern is present in spite of the fact that manganese has been supplied in spray form during the last two years.

In 1948, the senior author had some leaves analyzed for manganese content.* These leaves had symptoms typical of both zinc and manganese deficiency. All were found to have a manganese content of 5-15 ppm. These values were low regardless of the nature of the apparent deficiency. This further suggests that leaf symptoms are brought on by a complex set of circumstances and that often several elements may be below normal levels. It logically follows that sprays of zinc and/or manganese will not always correct such conditions. This is a problem which deserves considerably more study.

Application of Results to Young Groves

The results reported here suggest that young trees need very little zinc, manganese, or copper during the first four years after planting. However, there is no evidence to show that the larger amounts used were in any way harmful during these early years. It has been suggested (1) that a desirable level of copper in grove soils is about 50 pounds per acre. No such figures are available for manganese, and information on zinc is still further lacking and confused. It appears logical, however, to slowly build up reserves of these materials in the tree and in the soil.

Table 6 shows the actual amount of zinc, manganese, or copper which was applied in spray form during the first four years. This is compared with the amount of the metal which would have been applied if each application of fertilizer had included 0.25 of a unit expressed as the oxide. Had the material been applied in the fertilizer the low fertilization rate would have been fairly comparable to the 3 lbs./100 gallons level. The 1lb./100 gallons rate appeared to be reasonably adequate and this represents much lower amounts that would have been applied in the fertilizer.

* Analyzed by A. E. Willson, formerly Asst. Biochemist, Citrus Expt. Sta.

TABLE 6
The Pounds of Metallic Zinc, Manganese, or Copper Actually Applied as Sprays as Compared with the Amount Which Would Have Been Applied in Fertilizer if .25% Based on the Oxide Had Been Used in Each Mixture for Four Years

	Lbs. of Metal Applied As Spray		Lbs. of Metal Which Would have been Applied at .25% in all Fertilizer Mixtures	
	1 lb. of SO4/100 gals.	3 lbs. of SO4/100 gals.	High	Low
Zinc	.020	.060	.076	.047
Manganese	.013	.039	.074	.045
Copper	.014	.041	.069	.042

These experiments have no data on the adequacy of soil applications and recommendations along this line must be tentative and subject to revision. At the present time the authors are suggesting that manganese and copper be included in all young tree fertilizer mixtures at .25 or .30 unit expressed as the oxide. These are arbitrary figures, but by following this procedure, at the end of 10 years, at least 25 pounds of metallic copper or manganese will have been applied per acre. If an occasional nutritional spray is included, the amount will increase. On the basis of field experience these levels are probably adequate during that period.

It is possible that soil applications should be supplemented by at least one spray during the first year or two. Whether or not young groves can be maintained with soil applications of zinc has never been fully explored, and zinc sprays remain in order until more information is available. On the basis of these experiments there seems little justification for the application of more than one nutritional spray per year at rates equivalent to 3 pounds of zinc, manganese, or copper sulfate. Reduction in the number of nutritional sprays will probably be beneficial in terms of insect control.

Rates of fertilizer application yield some pertinent information. It would appear that the higher level applied in these experiments may ultimately be justified in terms of yield.

Summary and Conclusions

1. Valencia trees on rough lemon root stock were set out on virgin soil near Lake Placid in the spring of 1949. Since that time, copper, zinc, and manganese have been applied as sprays at rates of 0, 1, and 3 pounds of the sulfate or the metallic equivalent of a neutral material per 100 gallons. Single tree treat-

ments were used with 4 replicates on each of two fertilizer levels.

2. At the end of four years, trunk diameter was not influenced by the amount of zinc or manganese applied. There appeared to be increased diameters with increased amounts of copper. The high level of fertilizer gave increased diameters as compared with the low level of application.

3. The number of fruit produced per tree in the 1952-53 and the 1953-54 seasons was not influenced by the rates of zinc or manganese used. Where no copper had been applied, some fruit was ammoniated and there were less fruits per tree. High fertilizer levels increased the number of fruits.

4. Some zinc deficiency symptoms have been present on foliage since the first year, but no really deleterious results on yield or growth have been noted as yet.

5. Several leaf patterns have been present which cannot be correlated with the use of zinc, manganese, or copper. An application of EDTA reduced some of these symptoms.

6. It is suggested that young trees require no more than one nutritional spray per year at the equivalent rate of 3 pounds of the sulfate of zinc, manganese, or copper. It is further suggested that manganese and copper be included at about .25 of a unit expressed as the oxide in all fertilizer mixtures applied on young trees for the first 7-10 years. As much fertilizer as was used at the high fertilization level in this experiment will probably be justified in young groves.

LITERATURE CITED

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OBSERVATIONS ON CITRUS BLIGHT

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Blight is among the oldest described citrus diseases in Florida being antedated only by foot-rot, a fungus (*Phytophthora* sp.) disease, and exanthema (copper deficiency). It has also been called orange blight, limb blight, go-back, wilt, dry wilt, leaf wilt, leaf curl, roadside decline, root-rot, and Plant City disease. According to Rhoads (4) Manville alluded to blight in 1883, but older settlers doubtless knew of the disease for a number of years before that. In 1891 Underwood (9) was sent to Florida by the U. S. Department of Agriculture to make a preliminary study of citrus diseases, and the following year Swingle and Webber (8) were sent to work on citrus diseases, especially blight in Florida. After their report was published in 1896 very little further work was done until Rhoads (4) took up the problem in 1923.

Economic Importance

Underwood (9) considered blight "the most dangerous disease that has yet appeared among the orange groves" and urged an immediate study to determine its cause and cure. Swingle and Webber (8) noted that in some localities 1 to 10 percent of the trees were annually stricken with blight. They estimated the annual loss to be about $150,000. According to Fawcett (1) the loss from blight in 1909 was probably in excess of that figure.

Between 1910 and the present time, a great change occurred in the Florida citrus industry which caused blight to be largely obscured. Thousands of acres of new land were planted with the new rough lemon (*Citrus limon*) rootstock, with the result that citrus production was approximately doubled every 10 years between 1910 and 1950. These newer plantings increased at such a rate and dominated the citrus picture to such an extent that blight seemed to decrease, and in 1918 Stevens (6) reported that blight was much less important than formerly. However, the number of trees attacked annually by blight did not decrease at any time.

In time blight began to show up in the newer rough lemon rooted plantings as the trees matured and became susceptible. To many growers it was a new disease which they sometimes called root rot. In 1947 Suit and DuCharme (7) reported that root rot (blight) was the second most frequently encountered disease (20 percent) in their survey of 204 sick groves. Foot rot was first (27 percent) and spreading decline was third (13 percent). Seven other causes of decline, ranging from water damage to drought injury were