CONCLUSIONS

The authors are aware that the stated objective of this experiment is virtually impossible to accomplish with this or any other experimental design because of the necessity of introducing extra ions to obtain the pH and calcium levels desired. In order to perform the statistical tests, the assumption had to be made that the only variable factors affecting the measured responses were soil pH and added calcium and that the soil amendments used to obtain the different pH and calcium levels were not important. Some of the extraneous factors that were ignored by this assumption were subsoil pH, short term pH fluctuations which may have varied with different treatments, ion balance within the soil, and other factors that may have affected the development of the root system without themselves being detected through leaf analysis. Sodium, and possibly sulfur, were partially responsible for some of the observed responses.

Despite these restrictions, certain conclusions seem valid. The fastest rate of tree growth resulted from the simultaneous increase in both soil pH and added calcium in a proportion of about 100 pounds of added calcium for each one unit increase in soil pH. In acid sandy soils such as the Lakeland fine sand used in this experiment, this simultaneous increase in pH and added calcium can be expected from applications of calcitic limestone. Even when calcium did not appear to be a limiting factor, increased growth resulted from increased pH levels from pH 4 to pH 7. Extremely poor growth generally occurred at the pH 4 level.

The results described in this paper are limited to young citrus trees. It is not known at this time whether the best pH and calcium levels for the growth of young trees are also best for fruit production and fruit quality. This experiment is being continued to evaluate these other effects.

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A COMPARISON OF SOIL AND SPRAY APPLICATIONS OF FOUR MANGANESE SOURCES FOR CONTROL OF MANGANESE DEFICIENCY IN 'VALENCIA' ORANGE TREES

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ABSTRACT

A comparison of the effectiveness of soil and spray applications of 4 different manganese (Mn) sources on control of Mn deficiency in bearing 'Valencia' orange trees growing on Lakeland fine sand was made in a field experiment carried

out over a 5-year period. Average yields and fruit quality were not significantly different.

Soil treatment with either powdered or granular manganese sulfate ($MnSO_4$) applied alone or mixed in fertilizer gave much higher leaf Mn and better control of Mn chlorosis than manganous oxide (MnO) or tribasic $MnSO_4$ applied similarly in equivalent amounts. $MnSO_4$ also gave much higher Mn in feeder roots in the 12-24-inch soil layer than MnO. The residual effects of $MnSO_4$ in controlling Mn deficiency were much greater than those of MnO a year after Mn treatments were discontinued.

Two spray applications per year (postbloom and summer) of 4 Mn sources gave higher leaf Mn and better control of Mn chlorosis than 1 application (postbloom) per year. Mn sprays had very little residual effect in controlling Mn deficiency a year after they were discontinued.

INTRODUCTION

Manganese (Mn) may be applied effectively to Florida citrus groves either to the soil (for acid soils) or in the form of foliar sprays. Current Experiment Station recommendations state a preference for manganese sulfate ($MnSO_4$) for soil application of Mn (6), but include both soluble and insoluble forms of Mn for application as foliar sprays (1). Soil application of Mn for citrus growing on calcareous soils is not recommended; foliar sprays of Mn should be used where supplemental Mn is needed under these conditions.

Mn deficiency usually is much more severe in Florida citrus growing on calcareous soil than in that growing on acid soil. In many groves on acid soils short-lived symptoms of Mn deficiency may appear on one or more of the new flushes of leaves but disappear later without the use of any corrective treatment. Persistent Mn deficiency in citrus growing on acid soil may require soil or spray application of Mn (or both) for correction.

It was the purpose of this study to compare both soil and spray applications of Mn to trees showing moderate Mn deficiency and determine their effects on yield, quality of fruit, and on Mn uptake by the trees.

In 1934, Skinner et al. (8) found that soil applications of $MnSO_4$ to 12 Florida citrus groves gave increased yields of fruit and improved fruit quality in many cases. More than half the groves were in poor condition with declining yields and well-developed chlorosis. Yield increases varied from none to large. Shortly thereafter, Roy (7) reported that soil application of $MnSO_4$ to citrus trees increased leaf Mn within 2 weeks after application, and gave a more intense coloring of rind and juice, and increased firmness and weight of fruit. Since the above work was done at a time when the need for supplemental Mn in Florida citrus groves was just being recognized, it is probable that relatively severe Mn deficiency was present in many of the groves studied.

Peech (5) found most Florida soils used for citrus were very low in total Mn. In a study of Mn leaching, Wander (9) found that 70 per cent of the Mn applied as $MnSO_4$ over a 15-year period in a citrus grove on Lakeland fine sand maintained at pH 5.8 in the surface 6 inches was retained in the top 6 inches. Leonard and Stewart (3) reported high uptake of Mn and rapid correction of Mn chlorosis in orange trees growing on acid soil from soil application of $MnSO_4$, whereas there was no measureable uptake of Mn and no correction of Mn chlorosis from equivalent applications of manganous oxide (MnO) or manganese dioxide (MnO_2).

EXPERIMENTAL METHODS

In the spring of 1963, a field experiment was started in a grove of 10-year-old 'Valencia' orange trees on rough lemon rootstock growing on Lakeland fine sand, to compare the effects on the trees of 4 different sources of Mn applied to the soil and 4 Mn sources applied as foliar sprays. The trees showed symptoms of moderate Mn deficiency. Plots of 4 trees each were established in randomized blocks with 4 replications. During the period of the experiment, the pH of the surface soil was maintained between 6.5 and 7.2 by annual applications of dolomite.

(a) *Soil treatments.*—The Mn sources used for soil application were powdered $MnSO_4$, granular $MnSO_4$, tribasic $MnSO_4$, and MnO. The soil treatments (except tribasic $MnSO_4$) were applied at 2 rates per tree per year—2.5 and 5 pounds of $MnSO_4$ or its equivalent (0.675 and 1.35 pounds Mn respectively) applied alone or mixed with fertilizer of the analysis shown in Table 1. These rates of Mn application are higher than those used in normal grove fertilization in Florida. These high rates were selected to induce high uptake of Mn by the trees from those sources supplying readily-available Mn. This would make it possible to demonstrate clearly by

Table 1. Effect of manganese treatments on manganese content of the leaves of 'Valencia' orange trees growing on Lakeland fine sand.

			Leaf manganese**			
Trt. No.	Source and pounds $MnSO_4$ or equivalent per tree per year	Fertilizer with Mn*	1963 Spring flush ppm	Spring flush 4-year avg. ppm	1969 Spring flush ppm	1969 Summer flush ppm
1	Check	None	19	15 f	14 g	12 i
		Soil treatments				
2	5 $MnSO_4$ powder	None	190	265 a	42 b	26 c,d
3	5 $MnSO_4$ granular	None	209	268 a	44 b	29 b,c
4	5 MnO	None	17	20 f	13 g	13 h,i
5	5 Tribasic $MnSO_4$	None	18	25 f	19 d-g	22 d,e
6	2.5 $MnSO_4$ granular	None	78	95 b	23 c-f	19 e-g
7	2.5 MnO	None	13	15 f	12 g	11 i
8	5 $MnSO_4$ powder	6-3-6-3 (D)	16	60 c,d	31 c	18 e-h
9	5 $MnSO_4$ granular	6-3-6-3 (D)	16	70 c	56 a	26 c,d
10	5 MnO	6-3-6-3 (D)	14	24 f	23 c-f	20 e,f
11	2.5 $MnSO_4$ granular	6-3-6-3 (D)	16	33 e,f	25 c-e	33 b
12	2.5 MnO	6-3-6-3 (D)	15	19 f	19 d-g	23 d,e
13	5 MnO	6-9-6-3 (S)	--	24 f	27 c,d	23 d,e
14	5 $MnSO_4$ powder	6-0-6-3 (S)	--	68 c	60 a	42 a
		Spray treatments				
		No. of sprays				
15	$MnSO_4$	1	25	63 c,d	17 e-g	16 f-l
16	$MnSO_4$	2	91	87 b	18 e-g	18 e-h
17	Tribasic $MnSO_4$	1	26	43 e	15 f,g	13 h,i
18	Tribasic $MnSO_4$	2	63	63 c,d	15 f,g	15 f-i
19	MnO	1	21	26 f	15 f,g	14 g-i
20	MnO	2	54	49 d,e	16 f,g	16 f-i
21	MnEDTA	1	24	21 f	11 g	11 i
22	MnEDTA	2	29	25 f	14 g	16 f-i

*Mn was mixed with fertilizers of analyses shown through 1965; 8-3-8-3 and 8-0-8-3 mixtures were used in 1966 and later. (D) indicates dolomite filler, and (S) indicates sand filler.

**Mean Mn contents of leaves in each column not followed by the same letter or letters differ significantly at P = 0.05.

leaf analysis and Mn chlorosis control any differences in the availability of Mn from the different Mn sources, rates of application, or methods of application (alone or mixed with fertilizer).

The fertilizer mixtures containing Mn were allowed to stand in the bag for 2 to 4 days after mixing before they were applied. When mixed with 6-3-6-3 fertilizer with dolomite filler (first 3 years) or 6-0-6-3 fertilizer with sand filler (second and third years), one-third of each year's Mn treatment was applied in the spring, one-third in the summer and one-third in the fall. Starting in 1966, the fertilizer analyses were changed to 8-3-8-3 (plus Mn and dolomite filler) and 8-0-8-3 (plus Mn and sand filler) and were applied twice a year, spring and fall. All other experimental trees and the buffer trees were given 6-3-6-3 or 8-3-8-3 fertilizer without Mn. The fertilizers were made from ammonium nitrate, muriate of potash, magnesium sulfate (Emjeo) and ordinary superphosphate for mixtures containing PO_4.

(b) *Spray treatments.*—The 4 Mn sources used as foliar sprays were applied once a year (postbloom) and twice a year (postbloom and summer). The Mn sources used for spray application were powdered $MnSO_4$, manganous oxide (MnO), tribasic $MnSO_4$ and manganese ethylenediamine tetraacetate (MnEDTA). The first 3 were applied at the rate of 3 pounds $MnSO_4$ or its equivalent (0.81 pound Mn) per 100 gallons. Hydrated lime at the rate of 0.1 pound per 100 gallons was added to the $MnSO_4$ sprays. The sprays of MnEDTA (containing 12 per cent Mn) were applied at the rate of 1 pound per 100 gallons, or only 0.12 pound Mn per 100 gallons. The much lower Mn concentration was used for MnEDTA to conform to the recommendations of the manufacturer.

Differential Mn treatments (both soil and spray application) were discontinued after 1968. Yields and fruit quality data were obtained in 3 of the 5 years. The effects of the treatments on leaf symptoms of Mn deficiency were evaluated several times in the field. Samples of mature leaves from non-fruiting twigs of the current year's spring flush were taken in late July or August each year. Those samples taken from trees sprayed with Mn during the year sampled were scrubbed with a Dreft solution and rinsed in 5 per cent HCl.

In August, 1969, a year after Mn treatments were discontinued, samples of both the 1969 spring flush and the 1969 summer flush leaves were taken. Also at that time, samples of feeder roots were taken from the 0-6-inch soil layer from the check plots, all the plots given Mn soil treatments, and the plots sprayed with $MnSO_4$ and MnO. Feeder roots were sampled from the 12-24-inch soil layer from the check plots, and those receiving the 5-pound soil treatments with $MnSO_4$ and MnO applied alone. The feeder roots were washed in several different solutions of Dreft and thoroughly rinsed after each washing.

Mn analyses of leaves and roots were made by the tetramethyldiaminodiphenyl methane ("methane base") method (2) and with the atomic absorption spectrophotometer.

Results and Discussion

Yield and fruit quality.—The mean yields and the internal and external quality of the fruit (including fruit size) from the check trees and from the trees receiving the various Mn treatments were not significantly different. This is believed to be due to the fact that the trees in the experimental block showed only moderate Mn deficiency symptoms. Since the mean differences were not significant, yield and fruit quality data are not shown.

Leaf analysis.—(a) *Soil treatments.*—Both granular and powdered $MnSO_4$ applied alone (without mixing in fertilizer) at both rates of application gave much higher leaf Mn values than equivalent amounts of Mn applied as MnO or as tribasic $MnSO_4$, both in 1963 and for the 4-year average (Table 1). Mixtures of $MnSO_4$ with fertilizer resulted in much lower Mn contents of the leaves than $MnSO_4$ applied alone; however, the 4-year average leaf Mn values from the 5-pound rate of $MnSO_4$ with fertilizer were much higher than those obtained with MnO applied alone or mixed with fertilizer. The data indicate that the availability of the Mn in the water-soluble $MnSO_4$ was reduced somewhat by mixing it with fertilizer. However, part of the reduction in leaf Mn from $MnSO_4$ mixed with fertilizer as compared with $MnSO_4$ applied alone once a year was due to the division of each year's Mn treatment into 2 or 3 applications per year. This reduced the amount of Mn applied at any one time as compared with that in treatments applied alone once a year.

On the other hand, the 4-year average showed no significant differences in leaf Mn between the various MnO soil treatments whether applied alone or mixed with fertilizer and regardless of the amount applied. Thus, the relatively low availability of the Mn in MnO was not affected by mixing with fertilizer. The various soil treatments with MnO at the 5-pound rate averaged only 20 to 24 ppm Mn over the 4-year period, while those with $MnSO_4$ at the same rate ranged from a low of 60 ppm when mixed with fertilizer to a high of 268 ppm when applied alone.

Since all Mn treatments were discontinued after 1968, the 1969 leaf analyses provide a measurement of the residual effects of the 1968 and earlier Mn treatments. Five pounds of powdered $MnSO_4$ applied in a no-phosphate fertilizer and 5 pounds of granular $MnSO_4$ in a fertilizer containing phosphate produced the highest Mn in the 1969 spring flush. Similar applications of the 5-pound rate of MnO in fertilizer produced higher leaf Mn in the 1969 spring flush than the 5-pound rate of MnO applied alone; these leaf Mn values were, however, considerably lower than those obtained with $MnSO_4$.

(b) *Spray treatments.*—For each of the 4 Mn sources, leaves from trees given 2 sprays per year contained more Mn than those given only 1 spray. Both 1 and 2 $MnSO_4$ sprays per year produced higher leaf Mn than the other spray materials for the 4-year average. It is probable that the Mn contents reported for sprayed leaves include a small amount of Mn spray residue on the leaf surfaces. It is difficult to remove all of the residue of nutritional sprays from citrus leaves by washing, even with the acid rinse employed here. It is evident that Mn sprays have poor residual effects, since the 1969 spring and summer flush leaves had levels of Mn nearly as low as the check. The 4-year average of 15 ppm Mn in the spring flush leaves of the check trees indicate only moderate Mn deficiency. Leaves from citrus trees on some calcareous soils on Florida's east coast showing severe Mn deficiency symptoms contained only 4 to 7 ppm Mn (4). Such trees produced very little fruit.

Mn-deficiency chlorosis.—(a) *Soil treatments.* Trees given soil treatments with $MnSO_4$ alone showed no Mn chlorosis or very low Mn chlorosis on 2 to 4 of the 16 trees for all 3 ratings shown (Table 2). Application of $MnSO_4$ in fertilizer gave poor results in correcting Mn chlorosis in 1963, the first year of the experiment, but gave excellent results after that. The poor results in 1963 appear to reflect both the reduced availability of the Mn in the fertilizer and also the smaller amounts of Mn applied in these mixtures at one time. Trees given MnO on the soil showed decreases in amount of chlorosis from 1963 to 1969, but in 1969 they still showed much more Mn chlorosis than those given soil treatments with $MnSO_4$.

(b) *Spray treatments.* — Trees given Mn sprays twice a year showed very little Mn chlorosis during the years the sprays were applied except for those given a lower level of Mn in MnEDTA sprays. There was considerable Mn chlorosis on all trees receiving only the postbloom spray each year, and most of it was on the unsprayed summer flush leaves. Mn appears to be poorly translocated from sprayed leaves to newer leaves in later flushes of growth. On the other hand, the summer spray applied to those trees given 2 sprays per year supplied Mn to the summer flush and either reduced or eliminated Mn chlorosis on that flush.

In August 1969, all sprayed plot trees showed considerable Mn chlorosis, nearly all on the 1969 summer flush leaves. There was relatively little difference in the chlorosis between trees given 1 spray and those given 2 sprays of Mn per year during the experiment. This emphasizes the poor residual effects from Mn sprays previously mentioned under leaf analysis. By August 1969, all the Mn-sprayed trees showed more Mn chlorosis than any of the soil treatments except the 5-pound rate of MnO applied alone. Typical 1969 summer flush leaves from several treatments are shown in Figure 1.

Feeder root analysis.—(a) *Soil treatments.*— No significant differences in Mn were found in feeder roots from the 0-6-inch soil layer from trees receiving soil applications of 5 pounds $MnSO_4$ per tree or its equivalent as MnO or tribasic $MnSO_4$ (Table 3). Feeder roots from trees receiving 2.5 pounds $MnSO_4$ per year or its equivalent contained considerably less Mn than those receiving 5 pounds. Very high levels of Mn were found in the feeder roots sampled from the 12-24-inch layer of soil when the trees received 5 pounds of $MnSO_4$ alone, even though the surface soil of these plots had a pH of 7.2. In contrast to this, low levels of Mn were found in similar feeder roots obtained from trees receiving MnO equivalent to 5 pounds $MnSO_4$ (surface soil pH 7.1) and also from the check trees. These very large differences indicate much much deeper soil penetration of Mn applied as

Table 3. Effect of manganese treatments on manganese content of feeder roots of 'Valencia' orange trees growing on Lakeland fine sand.

Trt. No.	Source and pounds $MnSO_4$ or equivalent per tree per year	Fertilizer with Mn*	Mn in feeder roots, 1969** 0-6" ppm	12-24" ppm
1	Check	None	165 j	52 B
		Soil treatments		
2	5 $MnSO_4$ powder	None	2835 a	6365 A
3	5 $MnSO_4$ granular	None	2667 a	
4	5 MnO	None	2400 a-c	120 B
5	5 Basic $MnSO_4$	None	2430 a,b	
6	2.5 $MnSO_4$ granular	None	1237 f-h	
7	2.5 MnO	None	1472 e-g	
8	5 $MnSO_4$ powder	6-3-6-3 (D)	1785 c-f	
9	5 $MnSO_4$ granular	6-3-6-3 (D)	2277 a-d	
10	5 MnO	6-3-6-3 (D)	1752 d-f	
11	2.5 $MnSO_4$ granular	6-3-6-3 (D)	1540 e-g	
12	2.5 MnO	6-3-6-3 (D)	937 g-i	
13	5 MnO	6-0-6-3 (S)	1975 b-e	
14	5 $MnSO_4$ powder	6-0-6-3 (S)	2275 a-d	
		Spray treatments		
		No. of sprays		
15	$MnSO_4$	1	335 i,j	
16	$MnSO_4$	2	575 i,j	
19	MnO	1	380 i,j	
20	MnO	2	680 h-j	

*See first footnote, Table 1.

**Mean Mn content of feeder roots in 0-6-inch soil layer not followed by same letter or letters differ significantly at P = 0.05. In the 12-24-inch soil layer, mean Mn content of feeder roots for Treatment No. 2 differs from those for Treatments 4 and 1 at P = 0.001.

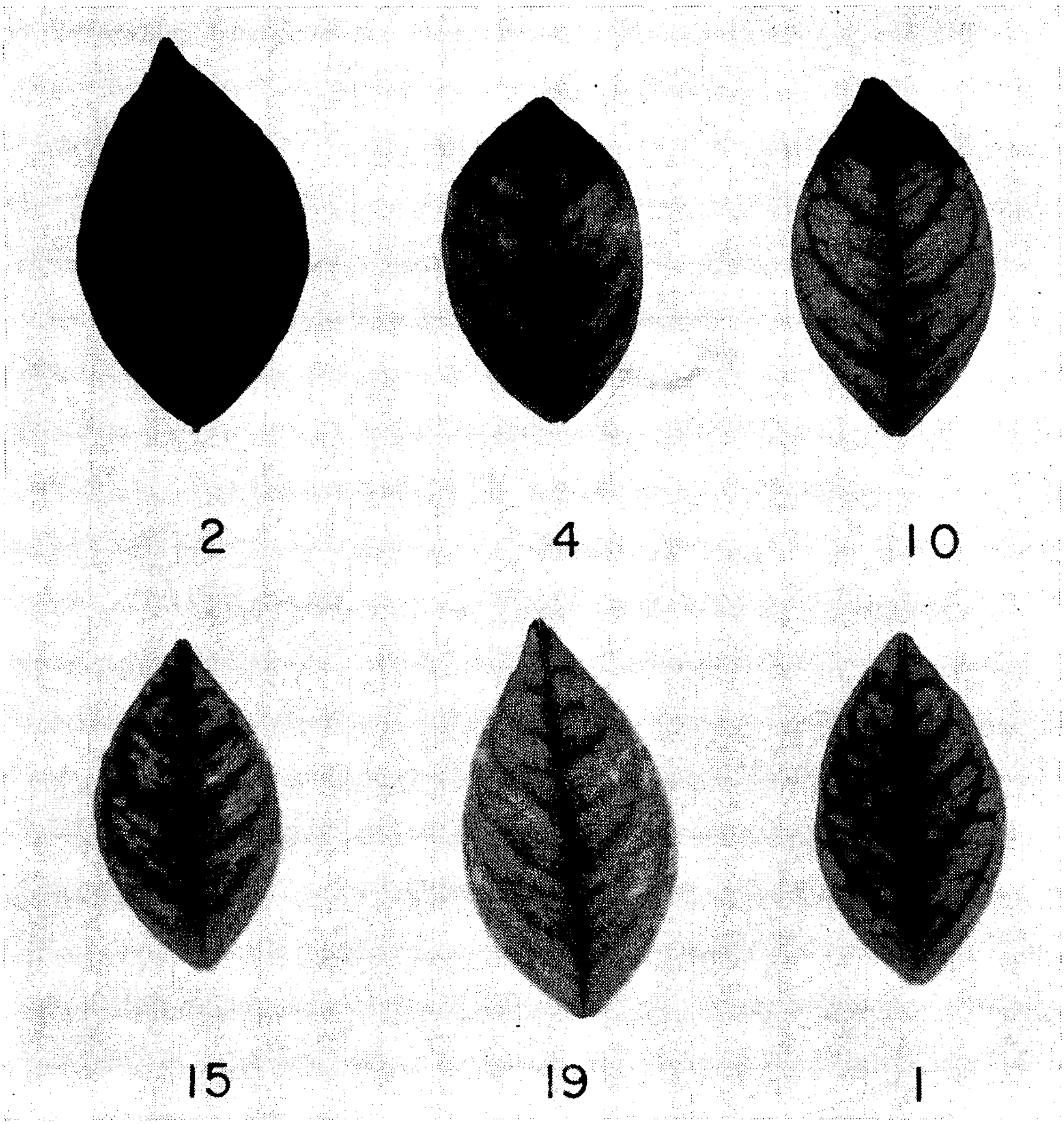

Figure 1.—Typical 1969 summer flush leaves from 'Valencia' orange trees one year after manganese treatments were discontinued. Annual treatments were:

2 = 5 pounds $MnSO_4$ alone to soil.
4 = 5-pound rate of MnO alone to soil.
10 = 5-pound rate of MnO in fertilizer.
15 = Postbloom spray with $MnSO_4$.
19 = Postbloom spray with MnO.
1 = Check, no Mn.

Table 2. Effect of manganese treatments on amount of manganese deficiency chlorosis in 'Valencia' orange trees growing on Lakeland fine sand.

Trt. No.	Source and pounds $MnSO_4$ or equivalent per tree per year	Fertilizer with Mn*	Mn-chlorosis rating** 7-30-63	9-17-64	8-18-69
1	Check	None	3.0	2.5	2.9 a***
		Soil treatments			
2	5 $MnSO_4$ powder	None	0	0	0.2 i
3	5 $MnSO_4$ granular	None	0	0	0 i
4	5 MnO	None	2.7	1.8	1.5 b-f
5	5 Tribasic $MnSO_4$	None	1.6	1.1	0.9 g,h
6	2.5 $MnSO_4$ granular	None	0.2	0.1	0.3 i
7	2.5 MnO	None	2.8	1.9	1.2 f-h
8	5 $MnSO_4$ powder	6-3-6-3 (D)	1.8	0.1	0 i
9	5 $MnSO_4$ granular	6-3-6-3 (D)	2.2	0	0 i
10	5 MnO	6-3-6-3 (D)	2.4	1.1	0.8 h
11	2.5 $MnSO_4$ granular	6-3-6-3 (D)	2.0	0	0.2 i
12	2.5 MnO	6-3-6-3 (D)	2.6	1.4	1.1 f-h
13	5 MnO	6-0-6-3 (S)	---	1.8	0.9 g,h
14	5 $MnSO_4$ powder	6-0-6-3 (S)	---	0.1	0 i
		Spray treatments			
		No. of sprays			
15	$MnSO_4$	1	1.3	1.4	1.8 b-e
16	$MnSO_4$	2	0.3	0	1.5 c-g
17	Tribasic $MnSO_4$	1	1.7	1.4	1.6 b-f
18	Tribasic $MnSO_4$	2	0.3	0	1.3 d-h
19	MnO	1	1.5	1.3	1.9 b,c
20	MnO	2	0.9	0	1.3 e-h
21	MnEDTA	1	2.0	1.8	1.9 b-d
22	MnEDTA	2	1.7	0.9	2.1 b

*See first footnote, Table 1.

**Each tree was rated for amount of Mn deficiency chlorosis on the following scale: 1 = very mild (1 to 3% of leaves chlorotic); 2 = mild (4 to 20% of leaves chlorotic); 3 = moderate (21 to 50% of leaves chlorotic). Each figure is average of 16 trees.

***Mean chlorosis ratings not followed by the same letter or letters differ significantly at $P = 0.05$.

the sulfate than of Mn applied as the oxide. The Water-solubility and consequent deep soil penetration of $MnSO_4$ places this material in a readily available form in contact with many more roots than the relatively insoluble MnO, most of which remains near the soil surface. This rapid movement and quick availability of $MnSO_4$ is reflected in higher levels of leaf manganese and much lower incidence of manganese chlorosis in trees receiving soil applications of $MnSO_4$ than in those given the insoluble MnO.

(b) *Spray treatments.*—Trees receiving Mn sprays had much less Mn in the roots than most of those receiving the soil treatments.

The following conclusions are drawn from the data presented here:

1. $MnSO_4$ supplied much more available Mn than equivalent amounts of MnO in this experiment when both sources were applied to citrus growing on acid to neutral sandy soil.

2. In this experiment, the uptake of Mn from $MnSO_4$ applied to the soil was greater when the $MnSO_4$ was applied alone than when it was applied in a mixed fertilizer.

3. Groves showing chronic Mn deficiency may need 2 Mn sprays per year (postbloom and summer) for good control of Mn chlorosis.

4. The residual effects of the Mn treatments in this experiment a year after the treatments were discontinued, as measured by leaf Mn level and Mn chlorosis control, were greater from soil application than from spray application of this element.

5. In this experiment, yield and quality of fruit were not affected by Mn applications to trees showing only moderate Mn deficiency.

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NITROGEN RATE AND TIME OF APPLICATION ON THE YIELD AND QUALITY OF MARSH GRAPEFRUIT

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ABSTRACT

Ammonium nitrate was applied to Marsh grapefruit (*Citrus paradisi* Macf.) at different rates and timing schedules from 1960 to 1969. Single annual applications were made in January, April, July, and October and a split application in April-October. Rates were 50, 75, 100, 150, and 200-lb N per acre. Yields increased with rate up to the 150-lb level, regardless of time of application. Timing effects on yield were relatively slight at the higher rates. Low rates were less effective in July applications than at other times of the year. Fruit quality was not