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RESPONSE OF IRON CHLOROTIC AVOCADO TREES ON ROCKDALE SOIL TO CERTAIN IRON TREATMENTS

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ABSTRACT

Iron chlorosis of avocado trees on Rockdale soil can be corrected by soil surface applications of NaFeEDDHA, but treatment is relatively expensive. In a search for a more economical treatment, several iron compounds were tested. One of these, $Na_2FeEDTA$, when used in combination with aluminum sulfate, corrected the chlorosis satisfactorily in about 80% of the trees treated with sufficient of the mixture to supply 0.2 pound of Fe per tree. However, there were unexplainable exceptions where there was little improvement. Perhaps it would be feasible to use this mixture for general over-all treatment of iron chlorotic avocado trees on Rockdale soil and later spot-treat with NaFeEDDHA any trees that did not respond satisfactorily.

INTRODUCTION

Within the past 20 years iron chlorosis of avocados growing on Rockdale soil has increased to the point where it is of major concern to growers. With severe cases the trees go out of production and sometimes die. Foliar spray treatments with iron compounds have generally failed to correct the deficiency, and iron compound injections are not practical (6). Soil applications of various iron salts and soil acidifying agents, either alone or in combinations, failed to give satisfactory results until the introduction of chelated iron compounds in the early 1950's. Malcolm (5) and Harkness and Malcolm (2) tried soil applications of several chelated iron compounds on Rockdale soil and found that only Sequestrene 138 (sodium ferric ethylenediamine di-(O-hydroxyphenylacetate) (NaFeEDDHA) consistently corrected the trouble with reasonable dispatch. Several years later, Malo (7) reported that Sequestrene 138 was still the most effective material for correcting iron deficiency of avocados on these limestone soils. Leonard and Stewart (4) secured a little correction of iron chlorosis in citrus on calcareous soil by soil application of FeEDTA at the rate of 30 grams of Fe and aluminum sulfate at 5 and 10 pounds per tree. A modification of this treatment, suggested by Lynch[1] for trial on avocados on Rockdale soil, was soil application of a mixture of 2 parts by weight of $Na_2FeEDTA$ (disodium ferrous ethylenediamine-tetraacetate) chelated iron on vermiculite (5% Fe) to 1 part of aluminum sulfate in amounts supplying considerably more iron and less aluminum sulfate per tree than the earlier trial with the combination. Exploratory trials with this mixture were started in 1967 and expanded in 1968 to include a comparison with several other materials. This report is on these trials through August, 1969.

MATERIALS AND METHODS

The first trial was in a planting of mature 'Lula', 'Pollock', 'Booth 8' and 'Choquette' variety trees. The trees selected for test were reasonably uniformly chlorotic with at least 75% of the foliage of each showing distinct green veination characteristic of iron deficiency. The 2:1 by weight mixture of chelated iron ($Na_2FeEDTA$ 5%Fe) on vermiculite and aluminum sulfate (supplying 0.033 lb Fe/lb of mixture) was applied at 0, 1%, 3, 4%, and 6 pounds per tree to each of 10 single tree plots in randomized block design on July 27, 1967. No effort was made to distribute the different dosages uniformly among the several varieties. The mixture was spread evenly around the trunks of the trees within a circle about 10 feet in diameter. It was not incorporated into the soil by cultivation.

A second trial was started with the same mixture of chelated iron and aluminum sulfate in another grove of mature 'Waldin' and 'Booth 8' variety trees on December 14, 1967. The trees chosen for this test also were reasonably uniformly chlorotic and showed about the same degree of iron chlorosis as in the first test. The chelated iron-aluminum sulfate mixture was applied at 0, 3 and 6 pounds per tree to each of 18 single tree plots in randomized block design, without attention to distributing dosage uniformly between varieties. The mixture was spread evenly within a 10 foot diameter circle around the trunk of each tree. It was not worked into the soil.

A third trial, in which the effectiveness of the $Na_2FeEDTA$ and aluminum sulfate mixture was compared with that of some other materials, was started in a planting of mature 'Lula' and 'Booth 8' variety trees on September 4, 1968. The trees included in these trials were uniformly chlorotic with green veination symptoms typical of iron chlorosis in at least 75% of the leaves of each tree. The materials used (for treatments and rates see Table 3) were $Na_2FeEDTA$aluminum sulfate mixture, NaFeEDDHA, a mixture of $FeSO_4$ and NaFeEDDHA[2], a proprietary 25% chelated iron, $Na_2FeEDTA$ and aluminum sulfate.

Each of these materials was mixed with enough fine granular vermiculite to bring the dosage for each tree up to a volume of 2 gallons. This was spread uniformly about the trunk of each tree in a 10 foot circle. It was not incorporated into the soil. Each material was applied to 10 single tree plots in randomized block design. Six trees in each treatment were of the 'Lula' variety and 4 of 'Booth 8', except for treatments 7 ($Na_2FeEDTA$) and 8 ($Al_2(SO_4)_3$ which were all of 'Booth 8' variety.

The principal measure of effectiveness of the various treatments in all 3 tests was a visual rating of each tree for iron deficiency symptoms. These ratings were made at intervals of approximately every 2 months. The rating scale and applicable description for each unit on the scale are given in Table 1.

Leaf samples from the spring flush of representative trees in the various treatments of the third test were taken in June, 1969, properly washed and analyzed for iron.

Observations were not made on the amount of bloom under the various treatments in the first 2 tests, but were made on the crops after the "June drop". For the third test, a rating was made of amount of bloom on each tree in March, and a rating of the amount of fruit on each tree after the "June drop" was made in July. These ratings were based

on what was considered to be the percentage of the maximum potential bloom and crop for the individual tree.

Table 1. Rating of iron deficiency symptoms in avocado leaves in test No. 1

Date of Observation	Rated by Observer	Rating 1/ Lbs/tree of $Na_2FeEDTA$ and $Al_2(SO_4)_3$ mixture				
		0	1½	3	4½	6
8/27/67	A	5.00	5.00	5.00	5.00	5.00
10/12/67	A	3.50	3.05	2.75	2.00	1.75
10/21/67	B	2.60	2.40	1.80	1.50	1.30
10/22/67	C	3.05	2.95	2.15	2.20	1.75
11/2/67	D	3.70	2.90	3.00	2.00	1.70
11/6/67	E	2.44	2.00	1.20	1.10	0.60
Average A, B, C, D, E		3.06	2.66	2.18	1.76	1.42
2/1/68	A	3.50	2.75	2.30	1.60	1.50
3/29/68	A	4.60	3.80	4.10	3.40	2.40
7/24/68	A	3.00	2.10	2.70	1.90	1.40

1/ Rating scale:

0 Practically all leaves normal green. None with green veination of Fe deficiency.

1 Most leaves normal green, but few with green veination.

2 Some leaves pale green, approximately 10% with green veination.

3 Many leaves pale green, approximately 25% with green veination.

4 Many leaves yellowish green, approximately 50% with green veination.

5 Practically all leaves yellowish green, some with necrotic margins and 75% or more showing green veination.

6 All leaves yellowish green with green veination, many with necrotic margins, and some shoot die-back.

RESULTS AND DISCUSSION

Ratings of iron deficiency symptoms in the first test were made by 5 different observers between October 12 and November 6, 1967. Three additional ratings were made by a single observer through July 26, 1968. These ratings are summarized in Table 1.

It has been observed that iron chlorosis of avocados on Rockdale soil generally is influenced to some extent by soil moisture conditions, increasing with low soil moisture and decreasing with high soil moisture. These trees were not irrigated, but a good rain fell immediately before and during several weeks after the iron was applied. Therefore, it was not surprising that there was some decrease in iron deficiency symptoms early in this test, regardless of treatment. However, within about 11 weeks after treatment, there was a marked decrease in these symptoms on trees receiving iron, especially at the 2 higher rates, as compared with the controls. The ratings by different observers all ran fairly parallel, although at slightly different levels on the rating scale. The over-all improved tree condition was in proportion to the dosage of iron, although there were some exceptions. This improved tree condition remained fairly constant until late spring, when there was an increase in iron deficiency symptoms during a prolonged drought. By late July, after a few weeks of ample rainfall, deficiency symptoms decreased to approximately the levels found 11 weeks after the iron treatments. Deficiency symptoms

increased again in all treatments by late summer.

The iron treatments in the second grove were applied during dry weather. Although the trees were irrigated occasionally, an appreciable decrease in iron deficiency symptoms did not occur until after a period of good rainfall about 7 months after treatment. Then there was a decided decrease in symptoms, regardless of treatment, but trees receiving iron, especially at the higher dosage, rated better in spring and early summer than the controls (Table 2). In late summer, deficiency symptoms increased on trees of all treatments.

Observations made on yields in the first 2 tests showed no relationship between iron chlorosis and yield. Regardless of tree condition, yields were generally light, with many trees bearing no fruit. Drought during bloom probably was the principal controlling influence on yield.

The rating of iron deficiency symptoms on trees under various treatments in the third test ¡from September 4, 1968, through July 15, 1969, I is summarized by varieties, together with the mean for the 2 varieties, in Table 3. This grove was not irrigated, but good rains were reasonably well distributed throughout most of this period, and the response to the treatments probably was as good as could be expected.

The quickest and more nearly complete recovery from chlorosis generally was obtained with NaFeEDDHA. The Na_2FeEDTA-aluminum sulfate mixture was almost as effective as NaFeEDDHA, but leaf color often was not quite as deep green. Also, there were more unexplainable exceptions where the response was poorer with the former treatment than the latter. Usually, the recovery under either treatment was better for 'Lula' than for 'Booth 8' trees, especially for NaFeEDDHA. But there were too few trees of either variety for valid conclusions on a varietal response. There appeared to be some slight improvement under all the other treatments, except for aluminum sulfate alone (treat. 8), but it was never sufficient or consistent enough to be of commercial interest. By July, 1969, iron deficiency symptoms began to increase in the spring flush leaves of some trees under all treatments. This increase appeared to be the least severe, and about equal, on trees under the NaFeEDDHA and the Na_2FeEDTA-aluminum sulfate treatments.

The iron concentration in leaves from trees in this test was in fair agreement with that reported elsewhere. A field survey of avocados in California (1) showed that iron chlorosis was associated with less than 40 ppm Fe in mature leaves and with less than 30 ppm for severe chlorosis. Healthy appearing mature leaves containing 50 to 80 ppm Fe. In Florida (3), yellow leaves were found to contain 35 to 40 ppm Fe and green leaves 40 to 50 ppm. In some early trials with Sequestrene 138 on avocados on Rockdale soil (2), 100 ppm Fe was found in leaves. The iron content of spring flush leaves, taken in June, 1969, from representative trees of the 1968-69 test on Rockdale soil, ranged from 48 to 108 ppm under the NaFeEDDHA treatment. For trees in the Na_2FeEDTAaluminum sulfate treatment the range was 34 to 69 ppm, for the other 5 treatments it was 36 to 51 ppm, and for the controls the range was 30 to 36 ppm Fe. These leaf analyses were fairly consistent with the condition of the individual trees from which the leaves were taken, and with the chlorosis ratings for the various treatments.

Table 2. Rating of iron deficiency symptoms in avocado leaves in test No. 2

Date of Observation	Rating [1] Lbs/tree of $Na_2FeEDTA$ and $Al_2(SO_4)_3$ mixture		
	0	3	6
12/14/67	5.00	5.00	5.00
2/1/68	4.78	4.23	3.61
3/29/68	4.30	3.70	3.10
5/30/68	4.20	3.30	2.10
7/24/68	2.80	2.40	1.50

[1] Rating scale: Same as in Table 1.

In general, bloom in 1969 was good on trees with good color in the third test, but the crop was somewhat on the light side. Bloom and yield ratings made on these trees are summarized in Table 4. A comparison of these data with those in Table 3, which gives the iron chlorosis ratings of these trees, shows a fairly good correlation between a decrease in chlorosis and an increase in bloom and yield. The heaviest bloom, on the average, occurred on trees in the NaFeEDDHA treatment. These trees also rated the highest in yield. The combination of $Na_2FeEDTA$ and aluminum sulfate ranked a close second in bloom and yield. With minor exceptions, all other treatments rated approximately the same as the controls in bloom and yield. An exception was the yield of 'Booth 8' which ranked the same for the combination of iron sulfate and NaFeEDDHA as for treatments 2 and 3. Except for these 2 latter treatments, bloom and yield generally ranked better on 'Booth 8' than on 'Lula' under all treatments, including controls. As with incidence of chlorosis, however, there were too few trees of each variety in the various tests for valid conclusions in this respect.

$Na_2FeEDTA$ normally is recommended for use only on acid soils and had not been found effective on alkaline soils. The mechanism involved in rendering it effective on alkaline soils, when combined with aluminum sulfate, is not known. Certainly the small amount of aluminum sulfate used had little effect on the pH of the entire soil volume in the root zone. Supplemental studies on the effect of aluminum sulfate on the soil reaction of Rockdale soil (as measured by conventional glass electrode method) were made under controlled conditions. It was found that, when used at the same rate as in these experiments (2 lbs/10 ft diam circle) and accompanied by sufficient irrigation to wet the soil to a depth of about 1 foot, the pH dropped from about 8.0 to 7.5 in the 0 to 3 inch zone and to about 7.8 in the 3 to 6 inch zone for about 1 day. Doubling the dosage of aluminum sulfate resulted in about the same change in pH for about 2 weeks. At these dosages, there was little change in soil reaction below about 6 or 7 inches. The effectiveness of the $Na_2FeEDTA$aluminum sulfate mixture in the field appeared to be considerably longer than the measurable change in pH found in this study. It may be speculated that the aluminum sulfate results in a greater and more prolonged lowering of the soil reaction in a micro-zone at the surface of the feeder roots and thus permits absorption of adequate iron from $Na_2FeEDTA$. This pH change in a micro-zone would

not be detected by conventional pH determinations.

Table 3. Rating of iron deficiency symptoms in avocado leaves in test No. 3

Date of Observation	Variety	Rating [1] Treatment Numbers [2] 1	2	3	4	5	6	7	8
9/4/68	'Lula'	5.0	5.0	5.0	5.0	5.0	5.0	--	--
	'Booth 8'	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0	--	--
11/19/68	'Lula'	5.0	2.2	1.0	4.5	4.7	4.2	--	--
	'Booth 8'	4.3	3.5	2.8	4.5	3.3	4.0	3.9	4.8
	Mean	4.7	2.7	1.7	4.5	4.1	4.1	--	--
1/23/69	'Lula'	5.0	2.0	0.3	4.2	5.0	3.5	--	--
	'Booth 8'	4.2	2.2	3.5	5.0	3.0	4.0	3.8	4.8
	Mean	4.7	2.1	1.6	4.5	4.2	3.7	--	--
3/13/69	'Lula'	5.2	1.3	0.5	4.3	5.3	3.7	--	--
	'Booth 8'	4.3	1.7	1.3	4.0	3.3	4.3	4.0	4.5
	Mean	4.8	1.5	0.8	4.2	4.5	3.9	--	--
5/21/69	'Lula'	4.7	1.7	0.8	3.7	3.5	4.2	--	--
	'Booth 8'	4.5	1.7	2.0	4.3	4.0	3.5	3.9	4.1
	Mean	4.6	1.7	1.3	3.9	3.7	3.9	--	--
7/15/69	'Lula'	5.0	1.8	1.7	4.0	4.0	3.5	--	--
	'Booth 8'	5.2	2.2	2.2	3.7	4.2	4.2	3.9	4.2
	Mean	5.1	2.0	1.9	3.9	4.1	3.8	--	--

[1] Rating scale: Same as in Table 1.

[2] Treatments:

1) Control - none
2) $Na_2FeEDTA$ (5% Fe) @ 4 lbs & $Al_2(SO_4)_3$ @ 2 lbs/tree
3) NaFeEDDHA @ 1 lb/tree
4) $FeSO_4$ @ 2 lbs & NaFeEDDHA @ 0.2 lb/tree
5) A proprietary chelated iron (25% Fe) @ 0.4 lb/tree
6) A proprietary chelated iron (25% Fe) @ 0.8 lb/tree
7) $Na_2FeEDTA$ (5% Fe) @ 4 lbs/tree
8) $Al_2(SO_4)_3$ @ 2 lbs/tree

Table 4. Bloom and yield rating of avocado trees in test No. 3

Variety	Treatment Numbers [1] 1	2	3	4	5	6	7	8
	Bloom rating on March 13, 1969 [2]							
'Lula'	1.3	3.3	4.2	1.2	0.8	1.2	--	--
'Booth 8'	1.5	3.0	3.2	1.5	2.0	1.7	1.5	1.3
Mean	1.4	3.2	3.8	1.3	1.3	1.4	--	--
	Yield rating on July 7, 1969 [2]							
'Lula'	1.5	3.0	3.5	1.8	1.2	1.8	--	--
'Booth 8'	1.7	2.5	2.5	2.5	2.0	1.7	1.7	1.3
Mean	1.6	2.8	3.1	2.1	1.5	1.8	--	--

[1] Treatments: See Table 3

[2] Rating scale:

0) no bloom - no fruit
1) 5% of maximum potential
2) 10% of maximum potential
3) 25% of maximum potential
4) 50% of maximum potential
5) 75% of maximum potential
6) 100% of maximum potential

Another possibility was suggested by the observation, when making pH determinations in the supplemental study, that suspended clay and silt particles were effectively precipitated by the aluminum sulfate treatment. The samples (soil: water ratio of 1:2 by vol.) treated with aluminum sulfate became clear overnight after stirring, whereas the control samples remained turbid for at least a few days. The suspended matter in the aluminum sulfate treated samples was absorbed and precipitated in the coagulated gelatinous aluminum hydroxide, which forms from the added aluminum sulfate and calcium hydroxide naturally present in such soil. This effect was appreciable for 6 to 8 weeks, depending upon the dosage of aluminum sulfate. This gel perhaps absorbs and holds iron supplied by the chelate in a form available to the trees for a prolonged period.

The relationship between aluminum sulfate and both soil pH and the duration of precipitate formation indicated that better results in correcting the chlorosis might be secured by increasing the amount of aluminum sulfate applied per tree. At the termination of the third experiment in July, 1969, some of the trees which remained quite chlorotic were treated with mixtures of $Na_2FeEDTA$ (5% Fe on vermiculite) and aluminum sulfate in 1:1 and 2:3 ratios by weight at different rates. Also, a number of chlorotic trees, including the control trees of the third test, were treated with drenches containing 0.5, 1.0 and 1.5 pounds per tree, respectively, of the water-soluble chelated iron (14% Fe), $Na_2FeEDTA$, plus 4 pounds of aluminum sulfate per tree. Other trees received the chelated iron at 1.0 and 1.5 pounds each but without aluminum sulfate. Except for the 2 without aluminum sulfate, the response to all these more recent treatments was about the same, for a given amount of iron, as to the original 2:1 by weight mixture of 5% chelated iron and aluminum sulfate. Without aluminum sulfate the response was negligible. Perhaps the response to the 14% chelated iron-aluminum sulfate drenches may have been a little more rapid than to the dry applications, which were not worked into the soil.

Results with the mixtures of $Na_2FeEDTA$ and aluminum sulfate have been sufficiently favorable to justify further trials, with both the 5% and 14% materials, to determine what combination, dosage and method of application is most effective. Perhaps it would be feasible for growers to make such trials with some such mixture in place of the more expensive NaFeEDDHA for general over-all treatment of iron chlorotic avocado trees on Rockdale soil, and later spot-treat with NaFeEDDHA any trees that might not respond satisfactorily.

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