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Use of Chelates for Correcting Iron Chlorosis in Avocados Growing in Calcareous Soils in Cyprus

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SUMMARY

Lime induced chlorosis is a serious problem with avocado grown on calcareous soils in Cyprus. Five Fe sources at three levels each were used for solving the problem. Sequestrene 138 at all three rates was the most effective for the control of Fe chlorosis. Trees treated with Sequestrene 138 recovered completely from any symptoms of chlorosis and both growth and yield were higher than with other treatments and the control.

INTRODUCTION

Chlorosis of avocado is a serious problem under certain conditions. It is most common on calcareous soils, and as a result it is often referred to as "lime-induced chlorosis." Such chlorosis is more critical to avocados on a worldwide scale than to any other fruit crop (Malo, 1976).

In Cyprus, and especially in the south-west coastal part of the island where climatic conditions are favorable for avocados and good quality water is available, the soils are mostly alkaline. Also, the rootstocks which have so far been used are varieties from the Mexican race which are sensitive to "lime-induced chlorosis." So iron deficiency chlorosis is a common phenomenon and a major problem in avocado orchards in the above area. Interveinal chlorosis develops on leaves on affected trees, followed by a complete yellowing of the leaves. In severe cases, the leaves die and drop prematurely and the trees decline.

The best method to avoid lime-induced chlorosis would be to avoid planting avocados on highly calcareous soils, or to use rootstocks which are resistant to lime-induced chlorosis. Such rootstocks belong to the West Indian race (Bergh, 1975 and Kadman and Ben-Ya'acov, 1982).

The only means to control chlorosis in already established orchards is soil application of Fe-chelates, since applications by foliar sprays have not been successful on a commercial scale and iron compound injections are not practical (Kadman and Lahav, 1971). 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.

There are many chelates available, but few are really effective under alkaline or calcareous conditions. The purpose of this experimental work was to test a number of Fe-sources at different rates for control of chlorosis in avocados.

MATERIALS AND METHODS

Variety, location, and cultural practices

Trees of the Hass variety, 10 years old, on Mexican race rootstock grown at Kouklia Government Farm of the Department of Agriculture, were used.

The soil was a well drained sandy-clay loam with a $CaCO_3$ content of 35% and a pH of 8.2 (measured on a 1:2.5 soil:water suspension). The specific conductivity of a saturated soil extract at 25°C was 0.8, 1.1, and 2.0 mmhos/cm at depths of 30, 60, and 90 cm, respectively.

The irrigation water used had a pH of 7.3 and an electrical conductivity of 0.8 mmhos/cm. It contained on average 665 ppm of total soluble salts, including 62 ppm Cl, 60 ppm Na, 78 ppm Ca, 27 ppm Mg, 82 ppm SO_4, and 337 ppm HCO_3. Usually, 20 cubic meters of water per tree were applied during the irrigation season at a frequency of one application per week.

Annual applications of ammoniun sulphate, triple superphosphate, an potassium sulfate were applied at the rate of 3.0 kg, 0.5 kg, and 1.0 kg per tree, respectively. Soil application of Chelene (Fe-chelate) at the rate of 100 g per tree was used in spring 1980.

The degree of chlorosis of each tree was recorded in February 1981 (Table 1). A scale from 1 to 11 was used to evaluate the degree of chlorosis of tree canopy. According to the degree of chlorosis, the trees were separated into the following four categories (see following page):

The treatments were applied to single-tree plots in a completely ran-domed design with 9 replications. There were three replications with severely chlorotic trees and two each with moderately chlorotic, slightly chlorotic, and healthy trees.

The Fe compounds were applied in two split applications, one in early May and the other in early June of the years 1981 and 1982. This time of the year is the flushing period of avocado in Cyprus. The application was done in six holes inside the drip line of each tree and incorporated into the soil. Trees were irrigated with microjet sprinklers immediately after treatment.

The principal measure of effectiveness of the various treatments was a visual rating of each tree for iron deficiency symptoms. This was done by two observers at intervals of approximately every two months. The rating scale was from 1 to 11, as previously described.

Category	**Rating Scale**	**Description of Leaf Symptoms**
Healthy trees	1-2	Practically all leaves normal green. None with green veination of Fe deficiency.
Slightly chlorotic trees	3-5	Some leaves pale green, approximately 10% with green veination.
Moderately chlorotic trees	6-8	Many leaves pale or yellowish green, approximately 50% with green veination.
Severely chlorotic trees	9-11	Practically all leaves yellowish green, more than 75% showing green veination, many with necrotic margins, and shoots die-back.

Leaf samples were taken in September 1981 and analyzed for iron concentration. The crop was harvested in February and the yield of each experimental tree was recorded in kgrs. Also in October, the trunk circumference of each tree was measured at a fixed point 15 cm above the bud union.

Treatments and experimental design
Five Fe sources were tested at three levels. Equivalent amounts of Fe were applied with all sources at each rate. The Fe sources and their rates were as follows:

Fe-source	*% Fe*	*Rate of Fe-source grams/tree*		
Sequestrene 138 Fe-EDDHA	6%	150	300	450
Ferrostrene Fe-EDDHA	6%	150	300	450
Chelene Fe-EDDHA	6.8%	130	260	390
TEXAS Fe-DTPA	5%	180	360	540
$FeSO_4$-$7H_20$	20%	45	90	135

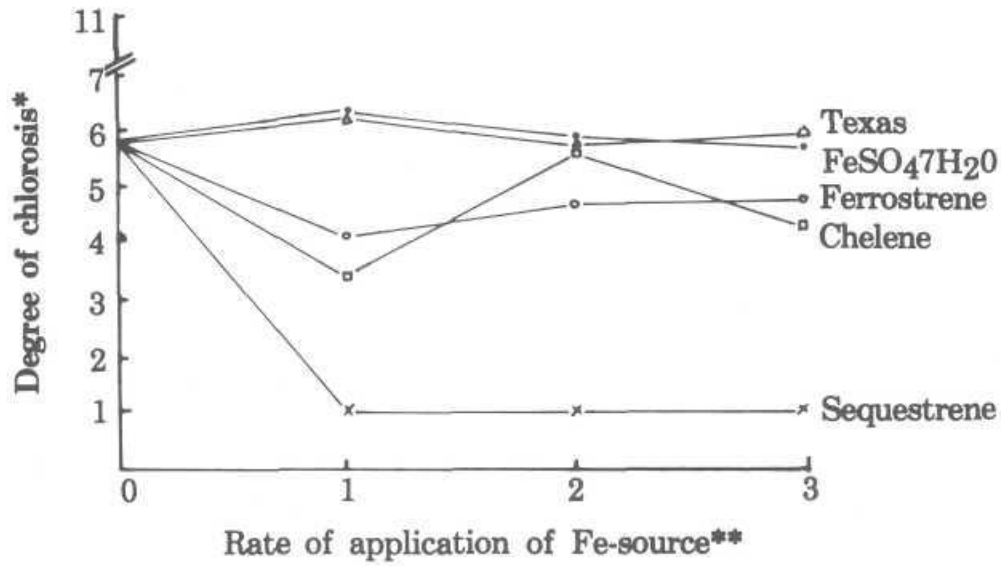
RESULTS AND DISCUSSION

Records taken in February 1981 show the degree of chlorosis of the experimental trees before any treatment (Table 1). Ratings of iron deficiency symptoms after treatment were made between August 1981 and February 1983 (Table 1).

It has been observed that within about two months after treatment (August 1981) there was a marked decrease in iron deficiency symptoms on all trees regardless of treatment, but trees receiving iron rated better than the control (Table 1.)

The quickest and more nearly complete recovery from chlorosis was obtained with Sequestrene 138. This improved tree condition remained fairly constant for trees receiving Sequestrene 138, whereas control and trees receiving the other Fe-sources did not show the same picture. In autumn and winter, iron deficiency symptoms increased on these trees.

In all recording dates, Sequestrene 138 gave the best results at all three rates. Even trees receiving the lowest rate of Sequestrene 138 completely recovered from chlorosis (Table 1, Figure 1).



*Values are means of nine trees.
Recording date is February 1983.

1-2 Healthy trees
3-5 Slightly chlorotic
6-8 Moderately chlorotic
9-11 Severely chlorotic

**	1	2	3
Sequestrene	150g	300g	450g
Ferrostrene	150g	300g	450g
Fe-DTPA	180g	360g	540g
Chelene	130g	260g	390g
$FeSO_4 \cdot 7H_20$	45g	90g	135g

FIGURE 1. *Effect of different Fe-sources on chlorotic avocado trees.*

Trees receiving other Fe-sources continued to have the iron chlorosis symptoms, and in the second year of the experiment are without any remarkable improvement. Almost no significant differences were found between the degree of chlorosis of these trees and the control.

Table 1. Mean degree of chlorosis of Hass avocado trees receiving different Fe-sources of three different rates.

Treatments	February 1981	August 1981	October 1981	December 1981	February 1982	August 1982	October 1982	December 1982	February 1983
Sequestrene 138 - 150g	6.1a*	1.7ab	1.1ab	1.3a	1.6a	1.0a	1.0a	1.0a	1.0a
Sequestrene 138 - 300g	6.3a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a
Sequestrene 138 - 450g	6.5a	1.4a	1.0a	1.1a	1.2a	1.0a	1.0a	1.0a	1.0a
Ferrostrene - 150g	6.0a	2.2abc	2.1abcd	4.2b	5.0b	4.1b	3.3ab	3.6ab	4. 1ab
Ferrostrene - 300g	6.2a	2.1abc	2.3abcd	3.6ab	5.2b	3.4b	3.7ab	3.7ab	4.6b
Ferrostrene - 450g	6.2a	1.4a	1.7abc	2.3ab	3.0ab	3.8b	4. 1ab	4.2ab	4.7b
Texas - 180g	5.9a	3.3bc	3.6cd	5.2b	6.6b	5.1b	5.3b	5.4b	6.2b
Texas - 360g	5.9a	2.0abc	2.9abcd	4.2b	5.4b	4.9b	4.7b	4.4b	5.7b
Texas - 540g	5.9a	2.5abc	2.7abcd	5.0b	6.3b	5.0b	5.2b	5.1b	5.9b
Chelene - 130g	5.9a	1.7ab	2.1abcd	3.0ab	3.8ab	4.6b	3.6ab	3.3ab	3.4ab
Chelene - 260g	6.0a	1.9ab	2.2abcd	4.4b	5.3b	4.3b	4.7b	4.8b	5.6b
Chelene - 390g	6.2a	1.9ab	2.3abcd	4.2b	5.3b	3.6b	3.0ab	3.2ab	4.2ab
$FeSO_4 \bullet 7H_20$ - 45g	6.2a	2.7abc	2.8abcd	5.1b	6.2b	5.6b	5.2b	5.0b	6.3b
$FeSO_4 \bullet 7H_20$ - 90g	5.9a	2.8abc	3.2bcd	4.9b	6.2b	4.8b	4.8b	5.2b	5.7b
$FeS0_4 \bullet 7H_20$ - 135g	5.9a	1.6a	2.0abcd	2.8ab	4. 1ab	4.2b	5.1b	6.3b	5.6b
Control	6.1a	3.7c	4.0d	5.1b	6.5b	5.2b	4.6b	4.9b	5.8b
S.E.		0.524	0.628	0.884	1.061	0.885	1.059	1.018	1.063
C.V. %		74.26	81.47	73.78	69.81	65.04	83.19	78.52	71.65

* See rating scale in Material and Methods. Values are means of nine trees. Means in the same column with the same letter are not significantly different (P<0.05).

Application of treatments was done in May and June 1981 and 1982.

The degree of chlorosis of the individual trees in each replication during the last recording date of February 1983 is shown in Table 2. Observing this table, it is obvious that there is a high variability of the degree of chlorosis between trees. Except from the treatments of Sequestrene 138 where all trees were healthy, in all other treatments and the control there were trees from all four categories: healthy, slightly, moderately, and severely chlorotic. The same picture was in all recording dates. (Table 2).

Table 2. Degree of chlorosis of individual avocado trees, Hass variety, receiving different Fe-sources at three rates. [Recording date: February 1983].

	Repl.								
Treatments	1	2	3	4	5	6	7	8	9
Sequestrene 138 - 150g	1*	1	1	1	1	1	1	1	1
Sequestrene 138 - 300g	1	1	1	1	1	1	1	1	1
Sequestrene 138 - 450g	1	1	1	1	1	1	1	1	1
Ferrostrene - 150g	4	3	1	10	3	2	9	1	4
Ferrostrene - 300g	1	8	9	1	4	8	3	4	3
Ferrostrene - 450g	1	1	2	1	8	9	9	7	4
Texas - 180g	8	1	4	3	8	1	10	10	11
Texas -360g	1	7	3	5	3	1	10	11	10
Texas -540g	5	1	1	9	5	11	10	10	1
Chelene - 130g	1	2	4	2	1	1	8	9	3
Chelene - 260g	3	1	9	9	4	3	10	3	8
Chelene - 390g	1	1	9	1	1	9	4	8	4
$FeSO_4 \cdot 7H_20$ - 45g	4	1	5	1	8	9	10	10	9
$FeSO_4 \cdot 7H_20$ - 90g	4	7	3	5	1	6	5	10	10
$FeSO_4 \cdot 7H_20$ - 135g	1	6	2	1	10	8	3	9	10
Control	9	6	4	3	9	6	3	2	10

* See rating scale in Material and Methods.

The results of this experiment showed that the most effective chelate to cure chlorotic avocado trees under alkaline or calcareous conditions is the ferric chelate of ethylenediamine di-(o-hydroxyphenyl acetic acid), or FeEDDHA, known commercially as Sequestrene 138. This product has been used experimentally and commercially since about 1955 and has proved to have a higher stability under calcareous conditions than any other chelate (Harkness and Malcolm, 1957; Kadman, 1962; Kadman and Lahav, 1971; and Kadman and Lahav, 1982).

Although trees receiving Sequestrene 138 had completely recovered from iron chlorosis symptoms and all leaves were normal green, leaf analysis for iron did not show any significant differences between treatments (Table 3). The iron concentration, expressed on dry weight basis, ranged from 72 ppm to 94 ppm (Table 3).

Table 3. The effect of different Fe sources on growth and yield of Hass avocado trees and on iron concentration of their leaves.

Treatments	Increase in trunk circumference-cm*	Cumulative yield 1981-1982 kgrs/tree	Fe, ppm Dry weight basis
Sequestrene 138 - 150g	8.1	51.2	82
Sequestrene 138 - 300g	7.5	53.1	89
Sequestrene 138 - 450g	8.2	60.9	82
Ferrostrene - 150g	5.2	36.7	94
Ferrostrene - 300g	6.5	42.8	76
Ferrostrene - 450g	5.7	43.5	86
Texas - 180g	5.4	33.9	74
Texas -360g	6.3	36.1	85
Texas -540g	5.3	28.6	*81*
Chelene - 130g	5.7	28.2	91
Chelene - 260g	5.9	34.7	72
Chelene - 390g	5.0	43.1	79
$FeSO_4 \cdot 7H_20$ - 45g	5.5	19.7	77
$FeSO_4 \cdot 7H_20$ - 90g	5.1	31.3	82
$FeSO_4 \cdot 7H_20$ - 135g	6.0	37.3	79
Control	4.6	23.5	78

No significant differences were found among treatments.
* The increase in trunk circumference is referred to the period April 5, 1981 through July 12, 1982.

The increases in growth of the experimental trees as indicated by the trunk circumference, are given in Table 3. Although there were no significant differences between treatments, trees receiving Sequestrene 138 had considerably more growth than the control and trees receiving other Fe-sources. This improved tree growth was not in proportion to the dosage of Sequestrene 138, but the growth was improved at all three dosages.

Cumulative yield for 1981-1982 is shown in Table 3. Yield of trees receiving Sequestrene 138 was much higher than the yield of trees receiving other Fe-sources. The yield of trees receiving Sequestrene 138 was almost double compared to the yield of trees receiving other Fe-sources and the control. Despite that, no significant differences were found among treatments and this was due to the high coefficient of variation, which was 88%.

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