

PROMISING METHODS FOR CORRECTING IRON CHLOROSIS IN AVOCADOS-A PRELIMINARY REPORT

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INTRODUCTION

Avocado trees, and many other plants growing in the calcareous soils of South Dade County, have long been known to suffer from deficiencies of iron, zinc, and manganese. The last 2 elements are relatively simple to correct with foliar brays. However, there are, as yet, no economical and practical correction measures for iron chlorosis in avocados. Although chlorosis has been common in the Homestead area ever since avocados were first planted in this area, the condition was not recognized as a problem until the early 1940's (9). In the last 3-4 years iron chlorosis of avocados has become more widespread, and is the cause of much concern among avocado growers because of reduced yields and yellow emit of poor market quality.

Iron, in contrast to zinc and manganese, is quite immobile inside the plant. There is no translocation of iron from old green leaves to new chlorotic ones. The deficiency of iron in leaves is only indirectly associated with their lack of green color. Iron is not a part of the chlorophyll molecule, but iron deficiency leads to a reduction in chlorophyll synthesis in the chloroplasts of the plant. New evidence (7) indicates that iron regulates the synthesis of a type of ribonucleic acid, which is involved in the production of an enzyme which functions in chlorophyll synthesis. Work with iron chelates in avocados (3, 6, 8) has shown that Sequestrene 138 (iron chelate of ethylenediamine di-(o-hydroxy phenylacetic acid) is probably the only commercially available material which has a practical application in correcting iron chlorosis under South Dade conditions. The stability of Sequestrene 138 in highly alkaline soils is well known (8). However, its present high price makes its use economically unfeasible for crops with low to moderate returns. With this in mind it has been the aim of this investigation to find more economical and practical ways to correct iron deficiency in avocado trees.

MATERIALS AND METHODS

The experiments that follow were conducted to test two new chemicals which have been reported as having the ability to increase the penetration of some substances into plant tissue. The first one, Dimethyl sulfoxide (DMSO)³ a byproduct of the wood-pulp industry, is known as an excellent solvent for many organic compounds. Lately DMSO has been found to have the unique ability to penetrate readily and to increase the penetration of other substances into animal and plant tissue (1, 4, 5). The second substance is an experimental anionic surfactant, Sodium dioctylsulfosuccinate (Vatsol OT²), which has been reported to increase the cuticular and stomatal penetration of some substances, including the herbicide Dalapon (2).

Procedure: Four different treatments were used in order to test these substances.

1. *Dips:* Preliminary experiments were first conducted by dipping 5 chlorotic avocado branches in solutions of 1) ferrous sulfate at the rate of 1.5, 2.0 and 2.5 lb/100 gal.; 2) Sequestrene 138 at the rate of 0.25, 0.50, 1.0 and 2.0 lb./100 gal.; and 3) Sequestrene 330 (iron chelate of diethylenetriamine pentaacetic acid) at the rate of 0.25, 0.50, 1.0 and 2.0 lb./100 gal. All treatments contained Vatsol OT, 300 ml/100 gal., and DMSO, 1 gal./100 gal.

2. *Injections:* Chlorotic Lula trees were injected with 1000 ml of solutions of ferrous sulfate or zinc sulfate. The concentrations were: 250 ppm, 500 ppm, 1000 ppm and 1500 ppm. All injections contained 10% of DMSO by volume. The mechanics of the injection process is illustrated in Fig. 1. It is known (8) that in order to obtain uniform distribution of a solution throughout the vascular system of an avocado tree, injections have to be introduced at several points around the trunk. If this is not done, there is usually a channeling of the solution through those vascular bundles that are immediately surrounding the injection hole. This apparently results because of minimal lateral translocation of the solution from the point of injection. Most injections were applied to one side or a large branch of the tree and the other side was used as a control.

3. *Sprays:* Preliminary information obtained by dipping chlorotic branches in various solutions had shown that of the sources of iron used, ferrous sulfate was the most effective and inexpensive. For this reason ferrous sulfate was used for all sprays. All sprays were acidified to pH 3.003.5 with sulfuric acid. The following combinations were designed to compare the iron carrying capacity to both Vatsol OT and DMSO.

a. Two chlorotic trees of unidentified varieties were sprayed with each of the following concentrations of ferrous sulfate: 0.5, 1.0, 1.5, 2.0 and 2.5 lb/100 gal plus 1 gal/100 gal of DMSO. The surfactant Plyac was used at .02% concentration.

b. Five chlorotic Lula trees were sprayed with each of these concentrations of ferrous sulfate: 2.5, 2.0 and 1.5 lb/100 gal. Both DMSO at 1 gal/100 gal and Vatsol OT at 300 ml/100 gal were used.

c. Two groups of five chlorotic trees were sprayed with 2.5 lb and 2.0 lb/100 gal of ferrous sulfate. Vatsol OT was used at same dosages as above; however, DMSO was not used.

d. Five chlorotic Lula trees were sprayed with 2.0 lb/gal of ferrous sulfate. Plyac was used as surfactant.

4. *Soil Treatments:* Soil applications were made with the following materials:

a. Five lb of ferrous sulfate dissolved in 30 gal of water containing 1/2 liter of DMSO were applied to each of five chlorotic Lula trees.

b. Twelve oz of Sequestrene 138 plus 1/2 liter DMSO, dissolved in 30 gal of water, were applied to each of five chlorotic Lula trees.

c. One lb of Sequestrene 138 was broadcasted around each of five chlorotic trees, and drencher with 30 gallons of water.

RESULTS

The results of treatments 1, 3, and 4 are summarized in Tables 1, 2 and 3. Table 1 show that in the branch dipping experiment ferrous sulfate gave better results than Sequestrene 138 and Sequestrene 330 when applied with Vatsol OT and DMSO. Sequestrene 138 and 330 did not penetrate into the leaves of chlorotic branches or if they did, greening was not apparent.

Sprays: Data presented in Table 2, show that acidified sprays of ferrous sulfate containing both DMSO and Vatsol OT, resulted in better chlorophyll synthesis than sprays containing either of these carriers alone or none. However, sprays containing Vatsol OT and no DMSO were superior to those containing DMSO and Plyac. Acidified sprays of ferrous sulfate, without any of the adjuvants, were inferior to all others.

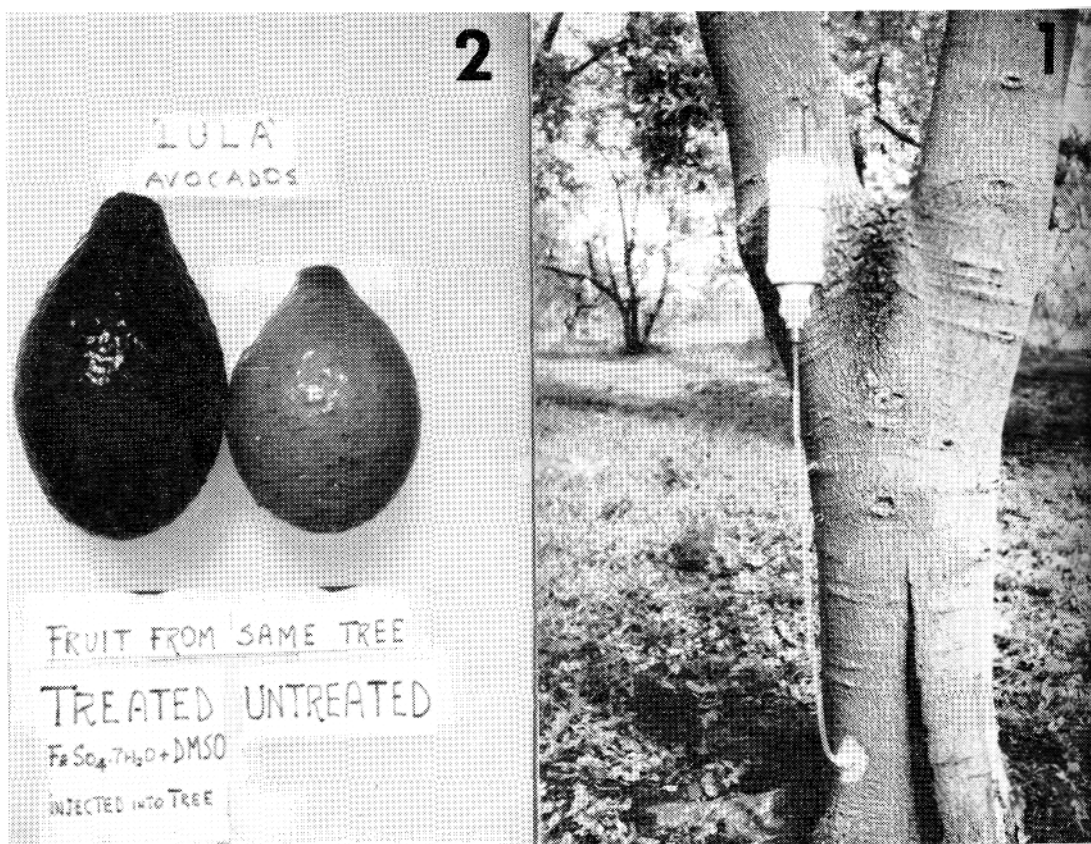


Figure 1.—Trunk of Lula avocado tree being injected with solution of ferrous sulfate plus DMSO.

Figure 2.—Green fruit from "treated" branch was on the average larger than the yellow fruit from "untreated" branch.

Soil Treatments: Table 3, shows that of the 3 materials applied to the soil around chlorotic trees ferrous sulfate plus DMSO rated lowest in chlorophyll production. Table 3, also shows that Sequestrene 138 plus DMSO was somewhat quicker in improving the conditions of the tree than Sequestrene 138 by itself.

Injections: These treatments were perhaps more dramatic than the others in correcting iron chlorosis. All injections of ferrous sulfate plus DMSO, applied to one branch,

resulted in rapid synthesis of chlorophyll in that branch only. There was a sharp contrast in the color of the treated branch and the rest of the plant (Fig.3). All the yellow fruits in treated branches, especially if small and immature when injection was applied, turned to a dark green, and their average size appeared to be larger (Fig. 2). Mature fruit did not benefit from the injections as much, tending to remain somewhat chlorotic. There was no clearly discernible evidence that one concentration was superior to any other in its effect. Some leaf burning observed was more associated with size of tree and branch treated than with concentration of solution injected. All injections without exception were absorbed by the trees. In a few cases, and especially during a prolonged dry period, the solution was absorbed in 20-30 minutes. On the other hand, it took as long as 24 hours when soil moisture was abundant.

None of the 20 injections of zinc sulfate had any noticeable effect on chlorophyll production, although it was clear that the solutions had been absorbed, because they produced a mild burn on the leaves of that branch.

Table 1. Effect of dipping 5 chlorotic avocado branches in solutions containing Vatsol OT (300 ml/100 gal) plus DMSO (1 gal/100 gal) and each of the following sources of iron.

Vatsol OT + DMSO + following sources of iron	Rate in lb/100 gal	Visible changes in chlorotic leaves 3 weeks after treatment.
Ferrous sulfate	1.5	Greening of leaves with slight burning
	2.0	Greening of leaves with burning
	2.5	Greening of leaves with severe burning
Sequestrene 138	0.25	No response
	0.50	Slight spotty greening of leaves
	1.00	Slight spotty greening of leaves
	2.00	Spotty greening with slight burning
Sequestrene 330	0.25	No response
	0.50	Slight spotty greening
	1.00	Slight spotty greening
	2.00	Spotty greening and slight burning

TABLE 2.—Effect of 4 different spray combinations of ferrous sulfate, Vatsol OT and DMSO on chlorotic Lula avocado trees. Vatsol OT and DMSO concentrations, when used, were 300 ml/100 gal, and 1 gal/100 gal respectively. All spray combinations were acidified to pH 3.0-3.5, with sulfuric acid.

Rate of ferrous sulfate (lb/100 gal)	No. of trees sprayed	Response
With DMSO and Vatsol OT		
1.5	5	Irregular greening of leaves, localized at margins, involving 50-70% of leaf surface.
2.0	5	Greening of leaves involving 60-80% of leaf surface although with slight burning.
2.5	5	Greening involving 70-90% of leaf surface in most cases. Severe burning of some leaves.
With Vatsol OT but without DMSO		
2.0	5	Irregular greening of leaves, localized at margins, involving 40-60% of leaf surface. Some leaf burning.
2.5	5	Same as above but with severe leaf burning in some cases.
With DMSO but without Vatsol OT		
0.5	2	No visible effect.
1.0	2	Slight spotty greening of leaves.
1.5	2	Slight greening. Larger spots than above.
2.00	2	Greening with larger coalescing spots. Some leaf burning.
2.5	2	Greening with large coalescing spots. Some severe leaf burning.
Without either DMSO or Vatsol OT		
2.0	5	Spotty greening of leaves. Some burning.

DISCUSSION

Ferrous sulfate, a very inexpensive source of iron, is a very inefficient one when used for nutritional sprays or soil applications for most crops growing in calcareous soils. When iron sulfate is sprayed on chlorotic avocado trees, the result is a few green spots

usually around small leaf wounds instead of the desired uniform greening of the leaves. It is generally believed that substances that increase the acidity inside leaves permit greater iron absorption and translocation from foliar sprays (8). For this reason all spray applications in these experiments were acidified with sulfuric acid.

The data presented indicate that Vatsol OT and DMSO, when applied together, increase the penetration of iron. They promoted higher chlorophyll synthesis in chlorotic avocados than either material used alone, or when only ferrous sulfate was used in an acidified solution. It was not entirely surprising that Sequestrene 138 and 330 did not penetrate chlorotic leaves. This has also been the experience of other investigators (8). On the other hand, Sequestrene 138 is perhaps the best iron chelate for the application to calcareous soils (8). The data from these experiments have shown that although the absorption of this chelate from the soil is satisfactory, it can be improved with DMSO. A few preliminary tests not reported in this paper showed that Sequestrene 330 and DMSO applied independently to chlorotic trees did not have any effect on chlorophyll synthesis.

The injection of ferrous sulfate plus DMSO into chlorotic trees, although perhaps not practical for avocado growers, has good possibilities as a diagnostic tool in mineral nutrition research. In these experiments, it was established that the chlorosis of the trees studied was corrected by injections of iron, but it was not corrected by injections of zinc.

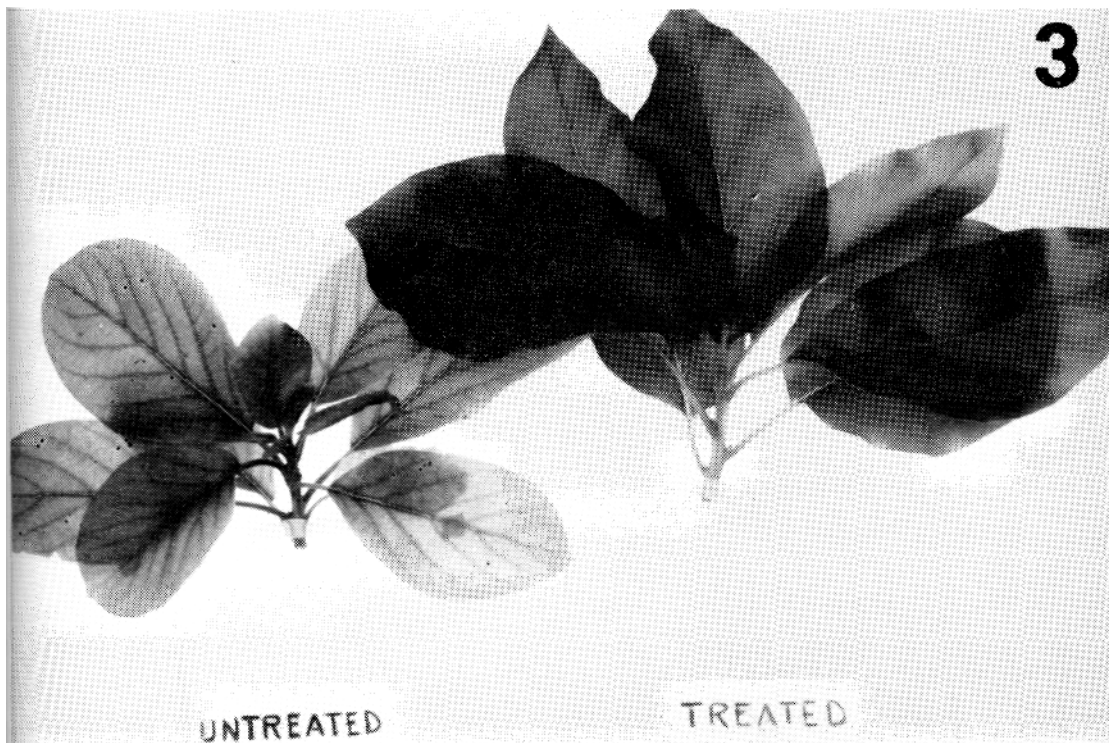


Figure 3.—Leaves from “treated” and “untreated” branches. “Treated” branch was injected with solution of ferrous sulfate plus DMSO.

Table 3. Effect of soil applications on chlorotic Lula avocados. Individual trees were drenched with 30 gallons of water immediately after treatment.

Material applied and amount/tree	No. of trees	Effect on trees
Ferrous sulfate 5 lb + $\frac{1}{2}$ liter DMSO per tree	5	Very little greening in new growth after 3 weeks.
Sequestrene 138 12 oz + $\frac{1}{2}$ liter DMSO per tree	5	Greening of leaves was observed within a weeks' time. Chlorotic condition of trees had disappeared within 3 weeks
Sequestrene 138 1 lb per tree	5	Greening of leaves was slower than above. Chlorotic condition of trees had not disappeared entirely after 3 weeks.

SUMMARY

- Four separate experiments were conducted to correct iron chlorosis in avocado trees.
- The micronutrient carrying ability of Dimethyl sulfoxide (DMSO) and Sodium dioctylsulfosuccinate (Vatsol OT) was tested. DMSO, in conjunction with an iron source, was used in sprays, soil applications and trunk injections. Vatsol OT was only used in foliar application.
- Chlorotic branches were dipped in solutions containing DMSO, Vatsol OT and each of these sources of iron: ferrous sulfate, Sequestrene 138, and Sequestrene 330. The solution containing ferrous sulfate was the only one that resulted in greening of leaves. It was concluded that this chemical penetrates effectively the leaves of chlorotic avocados when used with DMSO and Vatsol OT.
- Acidified ferrous sulfate sprays on chlorotic trees resulted in greater chlorophyll synthesis when both DMSO and Vatsol OT were included in the spray than when either was used by itself.
- Sequestrene 138 applied by itself to the soil around chlorotic avocado trees improved the condition of the trees substantially. However, it had a greater effect when applied with DMSO.
- Solutions of ferrous sulfate or zinc sulfate plus DMSO, injected into the trunk of chlorotic trees, were taken up rapidly. Injections of solutions of ferrous sulfate, but not zinc sulfate, corrected the chlorosis.
- It was concluded that DMSO and Vatsol OT increased the penetration of iron in foliar sprays. Of the materials used with DMSO and Vatsol OT, ferrous sulfate was best for foliar sprays. Sequestrene 138 was best for soil applications when used with and without DMSO.

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²Sub-Tropical Experiment Station, Homestead, Florida.

³Provided by Crown Zellerbach Co., Camas, Washington.

⁴Provided by American Cyanamid Company, Princeton, New Jersey.

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