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INTRODUCTION

Iron deficiency is one of the most widespread and difficult to correct nutritional disorders in plants and is a serious problem in most Idaho fruit-growing areas. Iron chlorosis, the foliar expression of faulty iron nutrition, may be associated with several different environmental conditions including high soil pH and calcareous soils. The disease is not caused by a deficiency of iron in calcareous soils; rather, the iron is in a form making it unavailable to trees. To complicate matters further, the addition of many different iron compounds to a calcareous soil is of little or no value because the added iron is rapidly "tied up" so that it too becomes unavailable to trees. The treatments reported here, involving a soil injection of the iron chelates DTPA-Fe[2] and EDDHA-Fe[3], show much promise as a corrective measure for iron chlorosis of fruit trees growing on a calcareous soil.

As well as many others, research workers at the University of Idaho have been studying iron chlorosis and its causes for many years. Some of the earliest work using the iron chelate EDTA-Fe (the iron complex of ethylenediamine tetraacetic acid) was reported by Jacobson (4), who studied its use in culture solution, and by Stewart and Leonard who experimented with it on Florida citrus under field conditions (6). Un-

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[2] Monosodium hydrogen ferric diethylenetriamine pentaacetate, containing 14.2% iron as Fe_2O_3.

[3] Sodium ferric ethylenediamine di (o-hydroxphenylacetate), containing 8.5% iron as Fe_2O_3.

Items 2 and 3 were supplied by the Geigy Agricultural Chemicals Division of Geigy Chemical Corporation.

fortunately, EDTA-Fe does not work as well on high pH, calcareous soils as it apparently does in acid soils. Holmes and Brown (3) demonstrated that 2 chelates, DTPA and APCA[1], without added iron, were effective in alleviating iron chlorosis in soybeans grown on 17 different calcareous soils in pots in the greenhouse. Higdon (2) reported that 2 sprays during the first half of the growing season of 2.5 to 3 pounds per acre of DTPA-Fe in 100 to 300 gallons of water gave satisfactory control of iron chlorosis in Anjou pears in Oregon. Higdon reported further that a soil injection of EDTA-Fe or DTPA-Fe corrected iron chlorosis in Anjou pears the year following a spring treatment after effecting "some slight recovery" late in the season of treatment. Smith and Neher (5) corrected iron chlorosis in both young and mature peach trees with DTPA-Fe and APCA-Fe by placing one of these iron chelates in pockets or bands either 4 or 6 inches deep in the soil under the tree.

Trials designed to correct iron chlorosis in Idaho fruit trees have included foliar sprays of iron chelates alone and in combination with wetting agents, urea, glycerol, and chelated manganese and zinc; none of these treatments resulted in a degree of success which would merit their recommendation for use on a commercial basis. Three sprays of DTPA-Fe, 1.5 pounds per 100 gallons of water, plus wetting agent, applied before the end of the first week of June resulted in green spotting of Bartlett pear foliage and, therefore, some correction. Maximum coverage of each tree was assured by spraying until the chelated iron solution dripped from the leaves. However, the response of chlorotic peach trees to 3 sprays of DTPA-Fe, 2 pounds per 100 gallons of water, plus wetting agent, was poor or not measurable.

This is in contrast to the results reported by Bould (1) who effected control of iron chlorosis in peach with 1 spray of 0.1 percent DTPA-Fe on June 29. Our attempts to correct iron chlorosis also included the addition of iron chelates dissolved in 3 gallons of water and sprinkled on the soil surface under the spread of the tree branches. The chelates were then watered into the soil using additional water and a sprinkling can or by spring rains. The response was disappointing, probably because the iron chelate did not enter the root zone.

Working on the pemise that little or no chelated iron was getting to the root zone, a soil-injector was devised and the chelated iron solution injected directly into the root zone.

PROCEDURES

Soil Injection, 1960

The injection of a chelated iron solution into the soil was first tried in 1959 on an exploratory basis. One pound of DTPA-Fe, dissolved in 5 gallons of water, was injected 12 inches into the soil under the spread of the branches of a tree. The results were quite promising so the trial was modified and continued in 1960.

Two iron chelates, DTPA-Fe and EDDHA-Fe, were used on severely

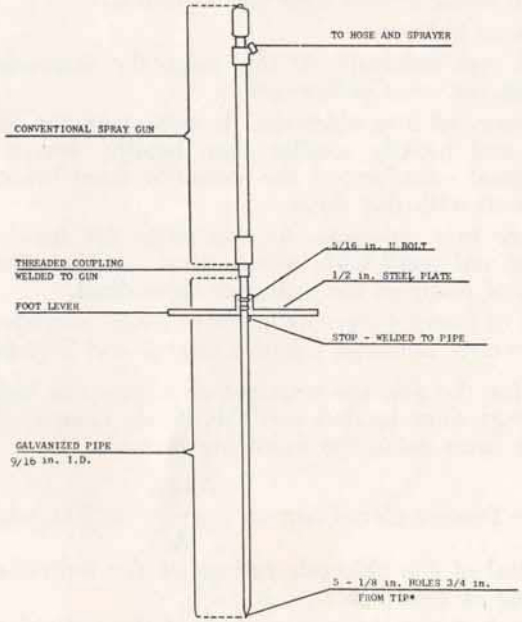
1. An abbreviation sometimes used before the chemical structure of the chelate was known.

chlorotic 15-year-old Hale Haven peach trees. The trees, growing on a calcareous soil in Twin Falls County, had a long history of iron chlorosis. Some of the trees in the block in which the treated trees were growing had died and many of the remaining trees were in poor condition. To treat a tree, 1 pound of one of the aforementioned iron chelates was dissolved in 25 gallons of water and injected into the soil to a depth of 24 inches in a grid at approximately 24-inch intervals inside the drip line. The injector was pressed into the soil by foot and approximately one-half gallon of the chelated iron solution injected per penetration, using a maximum pressure of 400 pounds per square inch. Opening the valve slightly so that little of the solution escaped as the injector was pressed into the soil facilitated penetration. Forty to 50 individual injections into the root zone of each tree were made in 1960. Ten trees were treated with EDDHA-Fe and six trees were treated with DTPA-Fe.

At the time the trees were selected for treatment in 1960, 10 trees in the same orchard and comparable to the trees selected for treatment were designated as checks. The check trees received no treatment which would correct iron chlorosis.

Soil Injection, 1961

Twelve soil injections of EDDHA-Fe per tree were used in 1961 to determine if fewer injections would suffice. The same concentration and amount of iron chelate were used as in 1960. The 12 soil injections were equally spaced in a square with sides 4.5 feet from the trunk of the tree. Seven peach trees, not all of them chlorotic, received injections



*Made by cutting out wedge-shaped pieces an inch or so long in 5 places at the end of the pipe. The resulting serrated tip was then pressed together, welded and ground until pointed and smooth.

12 inches into the soil. With another group of 7 peach trees we planned to inject the iron chelate solution 24 inches into the soil. This was possible with five of the trees. In the soil around two of the trees, we penetrated only 12 to 18 inches because a hardpan was encountered at that level.

The injector was designed for these trials (figure 1), and consisted of a conventional spray gun to which was welded a piece of galvanized iron pipe, 30 inches long with an inside diameter of one-half inch. There were five holes one-eighth inch in diameter bored in the lower, pointed end of the pipe. A 100-gallon sprayer with a capacity of 7 gallons per minute and capable of developing 400 pounds pressure per square inch was used in conjunction with the soil injector.

FOLIAR SPRAY

Although foliar sprays have been disappointing as a means of correcting iron chlorosis in peach trees in our trials, they continue to be appealing because they would be much easier to apply and much more economical. Therefore, EDDHA-Fe, one-half pound per 100 gallons of water, plus a wetting agent, were sprayed on 10 chlorotic peach trees on May 25, 1960. Maximum coverage of each tree was assured by spraying until the chelated iron solution dripped from the leaves.

MEASUREMENT OF THE RESPONSE

The response of the fruit trees to the different treatments was measured by rating the foliage at the time of treatment and at intervals thereafter. The rating system used was as follows:

0—No iron chlorosis.

1—Mild iron chlorosis. At this stage the interveinal portions of the leaves were yellow-green.

3—Pronounced iron chlorosis. At this stage the leaves were yellow and usually smaller than healthy leaves. However, no marginal scorching of the leaves or dead branch tips was associated with this stage.

5—Severe iron chlorosis. At this stage the leaves were yellow-white and small with brown, dead margins. The terminal portions of many of the branches were dead.

Ratings of 2 and 4 were assigned to foliar symptoms intermediate in severity between 1 and 3, and 3 and 5 respectively.

To determine the average response of a group of individually rated trees, the ratings were totaled and this figure compared to the rating totals of other dates using the following formula:

$$\text{Average Percent Correction} = \frac{A - B}{A} \times 100, \text{ where,}$$

A = Total of the chlorosis ratings of the individual trees at the time of treatment.

B = Total of the chlorosis ratings of the individual trees at any given time after treatment.

RESULTS AND DISCUSSION

SOIL INJECTION, 1960

The responses in 1960 and 1961 to the 1960 soil injection treatments are presented in **Table 1**, and **Figure 2** and the cover picture. The trees, treated on May 25, 1960, were checked for the first time on July 12, some seven weeks later. At that time the iron chlorosis had completely disappeared in all the trees receiving a soil injection of iron chelate with only one exception and in this tree the symptoms were mild. At the time of treatment, the terminal portions of many of the branches were dead and we may assume that this die-back would have continued down the branch. Seven weeks after treating, this die-back had been arrested as evidenced by the large green leaves immdiatly below the dead portion (**fig. 2**). In many instances a new terminal shoot which had appeared behind the dead portion was making good growth. The trees were rated again on September 23, 1960, at which time the trees treated with a soil injection of iron chelate were continuing in excellent condition, but symptoms on the check trees were more severe (table 1). The trees seemed to be responding equally well to either chelate 4 months after treatment.

Observation of the trees was continued through 1961 (table 1) and will continue for an indefinite period to determine duration of the response. At the end of the second growing season after treatment, mild iron chlorosis was recorded in two trees treated in 1960 with DTPA-Fe. Trees treated with EDDHA-Fe remained free of iron chlorosis. However, mild foliar symptoms of what appeared to be manganese deficiency were observed on five of these trees on August 15, 1961. Iron chlorosis was more pronounced on the check trees on August 15, 1961, than at any time during the trial.

Figure 2. Representative twigs from check trees (right) and trees receiving a soil injection of one pound EDDHA-Fe (left). The trees were treated on May 25, 1960, and the sample twigs photographed on July 12, 1960.

Soil Injection, 1961

The peach trees treated with 12 soil injections of iron chelate solution 12 or 24 inches into the soil on May 25, 1961, had an Average Percent Correction of 93 percent by June 20, 1961. These results indicate that as few as 12 soil injections per tree of a solution containing 1 pound of EDDHA-Fe in 25 gallons of water will control iron chlorosis. Trials using fewer than 12 injections per tree are planned.

FOLIAR SPRAY

The response of the peach trees to a foliar spray of one-half pound EDDHA-Fe per 100 gallons of water plus wetting agent was positive but did not effect enough of a correction to be commercially practical (**table 1**).

TABLE 1—The average response of 15-year-old Hale Haven peach trees to treatment with iron chelate on May 25, 1960.

TREATMENT	IRON CHLOROSIS RATING					PERCENT CORRECTION*			
	1960			1961		1960		1961	
	May 25	July 12	Sept. 23	June 20	Aug. 15	July 12	Sept. 23	June 20	Aug. 15
Spray—									
½ lb. EDDHA-Fe per 100 gallons	3.1	2.2	2.4			29	23		
Soil Injection—									
I lb. EDDHA-Fe per tree	3.0	0	0	0	0	100	100	100	100
1 lb. DTPA-Fe per tree	3.3	0.2	0.2	0.2	0.6	94	94	94	82
Check—									
(No treatment)	2.6	3.4	3.5	2.9	3.7	—31	—35	—12	—42

*A minus value (as in the check) means that the condition of the trees had deteriorated.

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