

dividuals. Florida, in our life-time, has stopped producing Boston type lettuce. Apple trees look quaint in parts of Missouri. Vegetable greenhouses are virtually a thing of the past. But the average American is eating more

fruits and vegetables of better quality than he did before we learned the value of large production units and developed our modern methods of handling and shipping fruits and vegetables.

Krome Memorial Section

CHELATES FOR THE CORRECTION OF IRON CHLOROSIS IN SUB-TROPICAL PLANTS

JOHN L. MALCOLM
*Sub-Tropical Experiment Station
Homestead*

Chlorosis is one of the commonest symptoms of mineral deficiency in plants. Most of the causes have been identified and successfully treated. Iron deficiency has been recognized for a long time, but until the announcement of the use of EDTA for the correction of iron deficiency in citrus by Stewart and Leonard (1) there was no very satisfactory method of correcting this condition in plants growing in the field. Experiments reported in this paper have shown that this chelating agent can be used for the correction of iron chlorosis in sub-tropical fruits and ornamentals on alkaline soils, but that a new chelating agent is more active.

Two compounds were tested. These were the sodium salts of ethylenediaminetetraacetic acid, and of N-hydroxyethylethylenediaminetriacetic acid² which will be called EDTA and EEDTA respectively. EDTA is a very effective iron chelating agent in acid soils but its activity diminishes rapidly as the medium becomes more alkaline. EEDTA, on the other hand, remains active throughout the entire range of reaction at which plants can be grown. This is a valuable property since almost all soils in Dade County are moderately to strongly alkaline.

EDTA was the first iron chelating agent tested. By the time work was begun at the Sub-Tropical Experiment Station it was al-

ready known that this compound was not too effective on alkaline soils. For this reason the iron salt of EDTA was first tried as a foliage spray. Leaf burn without correction of the chlorosis was the usual result of this treatment. After this failure soil applications of a dry mixture of EDTA and iron sulfate were tried. Although no damage resulted, there was no benefit either.

At this point we were ready to abandon further tests, when one of our local growers, Mr. John Tower, requested information on the use of iron chelates on mango trees. No information was available but he was supplied with a small quantity of EDTA and iron sulfate. Since previous use of the dry mixture had failed, it was suggested that he first dissolve the salts, allowing the reaction between the EDTA and iron to take place, and then apply the solution as a drench around his trees. He carried out this test and detectable improvement of the trees followed.

Following this experience, a test of the drench method of treatment was made in the slat house on some severely chlorotic *Cordia superba* plants. These plants were growing in paper tubes containing about one gallon of "potting soil." This soil was a mixture of peat, sand, and "red dirt" screened from the Rockdale soil-limestone complex. The pH of the mixture was 7.2. Several of the plants were treated with a drench and received one gram of the mixture of EDTA and iron sulfate, in the proportions recommended by the manufacturer, containing 0.075 gm. of iron. Greening of the treated plants commenced in one week, while the untreated plants remained chlorotic. Since the drench method of application was effective it was adopted as the standard method in all of the following tests.

Florida Agricultural Experiment Station Journal Series, No. 202.

¹Stewart, I. and Leonard, C. D. 1952. Iron Chlorosis . . . Its Possible Causes and Control. Citrus Magazine 14: 22-24.

²Chaberek, S., Jr. and Bersworth, F. C. 1953. New Chelating Agents for Trivalent Iron. Science 118: 280.

A test on the *Cordias* comparing EDTA with and without iron and EEDTA with iron was set up next. The mixture of EDTA and iron sulfate dissolved in water was used at rates of 0.5 and 1.0 gm. per plant, supplying 0.038 and 0.075 gm. of iron per plant. The EDTA without iron was used at the rate of 1.0 gm. per plant. This was sufficient to chelate 0.121 gm. of iron and was tried on the premise that the soil contained sufficient iron for the proper growth of these plants and that the chelating agent could make it available. Since this was our first opportunity to test EEDTA, a dosage series was set up with this new chelating agent. The EEDTA, which was supplied in a solution, was reacted with iron sulfate according to the manufacturer's recommendations. Suitable quantities of this solution were used to supply plants with 0.25, 0.50, 1.00, and 2.00 gm. of this mixture of iron sulfate and the manufacturer's solution of EEDTA; these amounts contained 0.011, 0.022, 0.044, and 0.088 gm. of iron respectively. Some plants were left untreated as checks. Both the EDTA and EEDTA were applied in dilute solutions.

Response was obtained from all treatments. Greening of the youngest leaves commenced within a week on most of them. EDTA with iron sulfate stimulated growth at both rates of application. The plant which received one gram of the mixture never became completely green, although the plants in the previous test which had received the same dose had greened completely and continued to grow well. Plants receiving 0.50 gm. became green. EDTA without iron was also effective. A plant treated with EDTA alone is shown in Figure 1. The check with which it is compared shows



Fig. 1. *Cordia superba* plant treated with EDTA alone compared to check. Photo by J. C. Noonan.)

the stunted growth and interveinal chlorosis typical of iron deficiency.

All of the plants treated with EEDTA improved, but those receiving 0.25 gm. of EEDTA solution and iron sulfate never became completely green. The growth response to this treatment was intermediate between the check and the higher rates of application which all produced equally good results. Figure 2 shows the plants treated with 0.25 and



Fig. 2. *Cordia* plants treated with EEDTA solution and iron sulfate at rates of 0.00, 0.25 and 0.50 gm. per plant. (Photo by J. C. Noonan.)

0.50 gm. of EEDTA solution and iron sulfate compared to the check. These photographs were taken approximately two months after the treatments were applied. Only 0.022 gm. of iron as the EEDTA iron complex was as effective as 0.038 gm. of iron as the EDTA iron complex.

At the same time that the *Cordia* experiment was set up, other plants showing similar symptoms of deficiency were treated with EDTA and iron sulfate at a rate of 1 gm. per plant. Two plants identified only as *Abelia* species were making no growth and their leaves were small and had almost no green pigment between the veins. One of the pair was treated. An ilama budded on pond apple rootstock and an atemoya budded onto pond apple rootstock were also treated. Other plants of both species were left as checks. The treated *Abelia* started to grow about one week after treatment and the leaves turned a normal green color. The untreated plant died back a little. In two months time the treated plant had grown ten times its original size. The untreated plant eventually died. These two

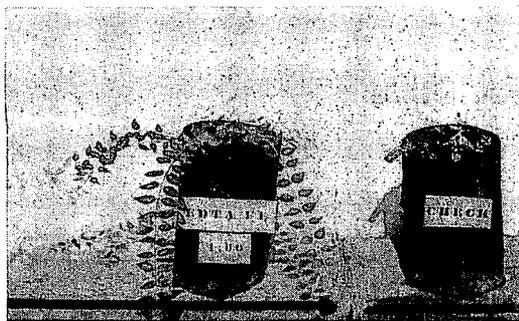


Fig. 3. *Abelia* sp. plant treated with 1 gm. EDTA and iron sulfate mixture compared to check. (Photo by J. C. Noonan.)

plants are compared in Figure 3. The treated ilama showed good leaf color in about a week and grew well while the untreated ones remained sickly. The atemoya on the other hand, showed only slight greening but did grow somewhat better than the checks.

In later trials in the nursery, both ilama and atemoya budded on pond apple rootstock assumed normal leaf color and grew well after soil applications of EEDTA and iron sulfate. The amount used supplied 0.088 gm. of iron in four gallons of soil. The previous test with EDTA on these species supplied 0.075 gm. of iron in one gallon of soil and were only partially successful. Although it supplied much less iron per unit volume of soil, the EEDTA with iron was more effective than the EDTA with iron.

Other plants in the nursery, *Ixora finlaysonia*, *Lagerstroemia thorelli*, *Myrciaria floribunda*, the West Indian or Barbados cherry and lychee, showed symptoms of iron deficiency and were also treated with EEDTA and iron sulfate. The treated plants of this group regained their normal color but so did some of the untreated plants, leaving the results somewhat in doubt. It appeared, however, that the treated plants were the first to recover.

The trials in the slat house and nursery established the usefulness of these chelating agents for the correction of chlorosis in a range of subtropical plants. Both EDTA with iron and EEDTA with iron were effective, when used in adequate amounts, in promoting growth and the development of chlorophyll in the yellow leaves. Although the difference was not outstanding in the nursery, the EEDTA and iron was more effective than the EDTA and iron. In the one experiment in

which it was tried, EDTA alone made the iron already in the soil available to the plant.

The conditions in plantings on the rockland were different from those in the nursery and suggested different procedures. A much larger volume of soil and larger plants were treated outside. The reaction of the soils is more alkaline, up to pH 8.3 where the rock is freshly broken exposing the unweathered limestone. These soils are usually much poorer in organic matter than the potting soil. Liberal applications of fertilizer are used on these plantings causing the plants to outgrow their limited iron supply. Since the EEDTA will effectively complex iron at these higher pH levels and the EDTA will not, only the EEDTA was tested on rockland plantings. Much higher rates of application were used on the rockland than in the nursery.

The first rockland test of EEDTA was on *Ixora macrothyrsa* in a landscape planting. In spite of liberal applications of a complete fertilizer supplemented by a nutritional spray containing copper, manganese, and zinc, these plants remained chlorotic. There was no tip dieback which is often associated with very severe iron deficiency. One plant was treated with a solution of EEDTA and iron containing one gram of iron. The treated plant improved in color in two weeks and was growing normally in four. The untreated check remained the same. Since then the check plant was also treated in the same manner and has recovered.

Among the fruits on the rockland which showed symptoms suggestive of iron deficiency, avocados, carambolas, limes and lychees were treated with EEDTA and iron. Simple tests were used on the avocado, carambolas, and lychees and for the first test on limes. A more elaborate test on limes was set up after a simple spot treatment was successful. All of these iron chelate treatments were applied in a large volume of water, usually five gallons, to the soil under the canopy of the trees.

Positive results were obtained on avocados and lychees and negative results on the carambolas. The avocados were recent transplants on very rocky soil. Other trees in the same planting were growing normally. These trees were generally chlorotic and not growing well. After treatment with EEDTA and iron one of the trees recovered completely, regaining its normal dark green color and the other tree improved. No checks were left in this case.

Tests were made on two groups of lychee trees. One group consisted of three trees which had been in the field for a number of years and had failed to respond to all of the usual treatments. They showed severe dieback and were generally chlorotic with no green color even in the veins of the leaves. Other trees in this planting were already dead. The second group consisted of young trees which were in the field for about one year and were chlorotic but showed little or no dieback. In both plantings there were varieties which were growing quite well under the same conditions. All of the trees which were treated received four grams of chelated iron.

New growth with normal color appeared on two of the old trees and a third improved a little. On the young trees the chlorosis was completely cured. Figure 4 shows a pair of

though the tree was nearly dead at the time, and its few remaining leaves were chlorotic, it responded to the treatment in about ten days. Four months later it was still growing normally. Nearly all of the trees in one section of this same grove showed typical symptoms of iron deficiency. In the extreme cases the leaves were completely yellow. Next came the yellow interveinal areas with dark green veins and the mildest symptoms were slight chlorosis in the interveinal area. Tip dieback was common and much of the fruit was yellow although not nearly mature. Many trees in the grove had been replaced since it was first planted some fifteen years before. Trees of all ages could be found.

A dosage series test was set up on these trees comparing four rates of application of the iron chelate with an untreated check and



Fig. 4. Lychees. Tree in left foreground with tag treated with EEDTA and iron. Tree in right foreground untreated check.

lychee trees which looked the same before treatment. The one with the tag received the iron about eight weeks before the photograph was taken. The other was a check. The carambolas treated with EEDTA and iron were not severely chlorotic before treatment and although they were generally well cared for, no special effort was made to eliminate other possible deficiencies. No benefit was obtained from the treatment.

The lime test was begun with the spot treatment of a single tree. This tree received 1.68 gm. of iron reacted with EEDTA. Al-

a single rate of application of the unreacted chelating agent. The rates of application corresponded to 1, 2, 4, and 8 gm. of iron per tree. The unreacted chelate was applied at a rate equivalent to 2 gm. of iron per tree. All of these materials were applied in a dilute drench under the canopies of the trees. There was plenty of moisture available at the time of treatment. Trees of all sizes received each treatment.

The small trees, three to six feet tall, improved in color and grew better after the treatment. Best results were obtained with

the higher rates of application. On the larger trees, which were from ten to fifteen feet tall, even the highest rate of application of the iron chelate was insufficient to produce any marked benefit. No effect of the unreacted chelate could be observed. It was used at a low rate of application, however, and might work if used in greater amounts.

The results of the exploratory tests using iron chelates for the correction of chlorosis in subtropical plants are summarized in Table 1.

Tests on a rather wide variety of subtropical plants indicate that iron chelates can be used to correct iron chlorosis on alkaline soils. Both EDTA with iron and EEDTA with iron were

Table 1. Results of Tests with Iron Chelating Agents for Correction of Chlorosis in Subtropical Plants.

Scientific Name	Common Name	Soil*	Treatment	Response
<u>Abelia sp.</u>	---	pot	EDTA Fe	Gr Gn **
<u>Annona cherimola</u> x <u>A. squamosa</u>	atemoya	pot	EDTA Fe EEDTA Fe	slight Gr Gn
<u>A. diversifolia</u> Saff.	ilama	pot	EDTA Fe EEDTA Fe	Gr Gn Gr Gn
<u>Averrhoa carambola</u> Linn.	carambola	rock	EEDTA Fe	none
<u>Citrus aurantifolia</u> Swingle	lime	rock	EEDTA Fe EDTA alone	Gr Gn Gr Gn
<u>Cordia superba</u> Cham.	---	pot	EDTA Fe EEDTA Fe	Gr Gn Gr Gn
<u>Gerbera jamesonii</u> Bolus	gerbera daisy	rock	EDTA Fe spray	none burn
<u>Ixora finlaysonia</u> Wall.	---	pot	EEDTA Fe	Gr Gn
<u>Ixora macrothyrsa</u> Moore	---	rock	EEDTA Fe	Gr Gn
<u>Hibiscus sp.</u>	hibiscus	rock	EDTA Fe EEDTA	slight Gn
<u>Lagerstroemia thorelli</u> Gagnep	---	pot	EEDTA Fe	Gn
<u>Litchi chinensis</u> Sonn.	---	pot Rock	EEDTA Fe EEDTA Fe	Gn Gr Gn
<u>Malpighia glabra</u> Linn.	Barbados cherry	pot	EEDTA Fe	Gn
<u>Myrciaria cauliflora</u> Berg.	jaboticaba	pot	EEDTA Fe	Gr Gn
<u>Myrciaria floribunda</u> (West) Berg.	---	pot	EEDTA Fe	Gn
<u>Persea americana</u> Mill.	avocado	rock	EEDTA Fe	Gr Gn
---	mixed grasses	rock	EDTA Fe spray	slight Gr. slight burn

* pot = potting soil of sand, peat and screened Rockdale.
rock = Rockdale soil, usually scarified.

** Gr = increase in growth Gn = greening of chlorotic leaves

used successfully in the slightly alkaline soils used in the nursery. Even the unreacted EDTA corrected iron chlorosis in the nursery when used in sufficient quantity. The most successful chelating agent tested thus far has

been EEDTA, the sodium salt of N-hydroxy-ethylethylenediaminetriacetic acid. Its iron salt corrected chlorosis even in the highly alkaline Rockdale soils. The proper rates of application must now be established.

BELAIR GROVES, SANFORD, PIONEER IN SUB-TROPICAL HORTICULTURAL INTRODUCTIONS

PHILIP J. WESTGATE
Central Florida Experiment Station
Sanford

R. BRUCE LEDIN
Sub-Tropical Experiment Station
Homestead

"Belair, on the Sanford Grant, is so identified with the development of South Florida, has done such good work for it, that some account of its growth and experimental gardens . . . would be of interest." This is the opening statement of an old publication of the last century but it might serve as well for an opening statement of this present paper. The publication (1)—entitled "Some Account of Belair, also of the City of Sanford, Florida, with a Brief Sketch of the Founder," published in Sanford in 1889—brings to light some very interesting history regarding early introductions of sub-tropical horticultural plants into Florida. As shown by the signature on the cover, this publication was at one time the property of S. O. Chase, Sr., early pioneer in Florida agriculture, and cofounder of Chase and Company, Sanford. Belair, located three miles southwest of Sanford, is at present owned by the descendants of Sydney O. and Joshua C. Chase. The original publication was photostated and bound at the University of Florida Bindery, 1948.

General H. S. Sanford, world traveler and at one time Minister to Belgium (1861-1869), first came to Florida in 1869. In the following year he purchased some 23 square miles of land, including Belair. As a result of his contacts in Central and South America, Africa and southern Europe, he was able to import plants and seeds of citrus and many species of tropical and sub-tropical fruits and ornamentals for trial in Florida. By 1889, when this account was published, his collection contained a great number of species, many of which survived

the 1886 freeze. His groves attained national fame and by 1889 had attracted many visitors, including General Grant and President Cleveland, as well as representatives of northern newspapers. The latter wrote glowing accounts of the Sanford Groves. Four of them are printed in his publication.

General Sanford planted his first citrus trees at St. Gertrude, west of Sanford, in 1870, but was forced to move his groves to Belair in 1873 because of poor drainage due to a soil hardpan at the earlier location. These citrus trees, however, were not the first to be planted in the Sanford (Mellonville) area. A group of orange trees planted by Dr. Algernon Speer in 1845, and still standing (1953) in Speer Grove Park, Sanford, was twenty-five years old at the time of General Sanford's first planting.

BELAIR TROPICAL GARDEN OR EXPERIMENTAL TRACT

According to Mr. Donald Houston, Superintendent of Belair Groves, Sanford, 1887 (1), "The Tropical Garden or Experimental Tract is but a short distance from the present residence (of General Sanford). Long before Experimental Stations were thought of, General Sanford instituted the extensive and carefully conducted experiments which, up to the time of the great freeze (1886), promised such important results for other economic plants and trees. These experiments, while largely for his own satisfaction, were designed, more than all, for the benefits of the agricultural interests of the State."

"In January, 1884, he (General Sanford) went before the Committee of Agriculture of the House of Representatives at Washington to urge the establishment of an Acclimation or Experimental Station in Florida, stating that half of the large and unique collection of economic plants in the conservatories of the Agricultural Department could be grown in the