

and high rainfall experienced during the blooming period. High percentages of parthenocarpic fruit were also produced in many other mango cultivars in the area during this year, as compared to "typical" years (C. W. Campbell, personal communication). On the other hand, the fact that hermaphrodite flowers open earlier in the season (4, 17) may explain the typical distribution of parthenocarpic fruit on the panicle. Apical flowers may have opened earlier and been pollinated but not fertilized due to cold damage to the pollen tube and/or egg apparatus (10). In contrast to other cultivars, mature parthenocarpic fruit of 'Tommy Atkins' did not develop to the full size of the seeded fruit (10). The observation in the field that abscission of parthenocarpic and seeded fruit continued until harvest indicates that other factors, not necessarily related to original reproductive degenerations, may be involved in the induction of abscission. Explants studied under controlled laboratory conditions revealed marked differences in the abscission patterns of seeded and parthenocarpic fruit (Fig. 3). There is an association between ethylene production and increases in abscission rates of seeded fruit; yet, parthenocarpic fruit appears to abscise independently from a rise in ethylene. Moreover, a small fraction (22%) of these fruit did not attain the separation stage even after 95 hr of enclosure. In accordance with the current notions that developing mango seeds are a source of auxin (3), and that a decrease in endogenous auxin promotes abscission (1), it is possible that the experiments with seeded explants reflect a condition which occurs in the field when abscission is preceded by senescence. A decrease in auxin favors an increase in ethylene and events conducive to separation. This contention is supported by the observation that mango fruitlets which were destined to abscise showed an inhibition of growth about 1 wk prior to actual detachment (14). The causal factors involved in such inhibition and subsequent senescence are still unknown, yet consideration has been given to environmental stresses (3, 14, 18).

The situation observed in parthenocarpic fruit is a paradoxical one which suggests that interactions with other factors, perhaps hormonal, are involved in abscission of this type of fruit.

Results and field observations from this study suggest that the mechanism of pre-harvest abscission in mango is not identical in seeded and parthenocarpic fruit, and that seeded fruit may abscise in the field in response to factors different from reproductive degenerations, perhaps environmental stress(es) which may stimulate the synthesis and action of ethylene in the events leading to abscission. Further work in the physiology of abscission in mango, as well as in

the relations between developing parthenocarpic and seeded fruit appear to offer valuable information towards a horticultural manipulation of this process in the field.

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IMPORTANCE OF IRON TO PLANTS GROWN IN ALKALINE SOILS¹

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Abstract. Iron nutrition in cultivated plants grown in calcareous soil in Dade County is discussed along with various strategies used to correct iron chlorosis. A preliminary evaluation of the potential of various chelated iron products in limestone soils is presented. Results suggest that Miller Ferriplus 138 and Geigy Sequestrene Fe 138 are the best suited products for use in these soils.

Iron is an important element required by all plants to

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maintain growth and productivity. Compared to plant requirements for carbon, oxygen, hydrogen, nitrogen, potassium, phosphorus, and sulfur, only a small amount of iron is required to satisfy plant needs. This metallic element functions as a cofactor and catalytic site of a number of important enzymes. Some of these enzymes are utilized in the synthesis of chlorophyll; the green, light-absorbing pigments which are important in photosynthesis. Iron deficiency symptoms include interveinal chlorosis or lack of green pigments in the areas between veins of leaves. Iron chlorosis generally occurs in the youngest leaves. In some deficiency symptoms include interveinal chlorosis, lack of plants such as 'Tahiti' lime (*Citrus latifolia* Tan.) and other citrus species grown on Rockdale soil, only those leaves borne on the last flush of growth show symptoms of iron chlorosis. When a new flush of vegetative growth occurs, the chlorosis symptoms "shift" to the new leaves as leaves from the previous flush become greener. The explanation for this phenomenon is obscure. It may indicate that iron is slowly taken up by the plant but not fast enough to supply the rapidly growing new flush. This possibility, however, does not explain the rapid greening of the previous flush as the new flush enlarges.

Iron chlorosis is a major problem in cultivated plants grown throughout the world. It results when plants are grown in soils which lack sufficient iron or which are of such a nature as to make the iron which is present unavailable to the plant for uptake, especially in areas having limestone or dolomitic soils which are alkaline. Even when salts of iron such as iron sulfate are liberally applied to the soil, plants grown in alkaline conditions are not always able to utilize it. Several factors contribute to this problem. Iron is rapidly complexed under alkaline conditions by readily available hydroxide and carbonate ions to form insoluble iron hydroxide and carbonate complexes (8). It is also rapidly oxidized to form insoluble iron oxide (rust), and the unlimited availability of calcium in calcareous soils and/or magnesium in dolomitic soils competes with iron for uptake into the plant. All of these factors make the percent of soluble iron (II) in soils extremely low. Hence plants are prone to symptoms of iron deficiency when grown in limestone soils such as found in Dade County (4, 12). Other heavy metals such as copper, when present in high enough concentration as a result of fungicidal spraying, will cause iron deficiency symptoms. This is due to competition with iron for uptake sites in roots (3).

Three strategies have been developed to correct iron deficiency symptoms. Foliar sprays have worked well for application of other minor essential elements such as zinc, manganese, and boron. These elements are required by the plant in such low concentrations that the small amounts that enter the leaf surfaces are sufficient to satisfy the needs of the entire plant. Iron, even though it is considered by many to be a minor element, is needed in far greater amounts than can be absorbed through the leaf. Indeed, when iron sprays have been used they appear to enter the leaves only at points of surface damage such as frictional or insect abrasion (11). Recent development of superior, non-toxic surfactants which enhance penetration of iron into stomatal openings of leaves has increased the potential for new approaches to iron nutrition in fruit crops (5, 6).

Another approach has been to formulate iron with acidifying additives such as acid phosphate or sulfur. This strategy can work fairly well in areas with limited calcium carbonate content. The Dade County growing area is composed almost exclusively of calcium carbonate with an alkaline pH between 7.5 and 8.0. Attempts to acidify this soil results in dissolution of the stone or marl and neutralization of the acidifying component. Because of the volume of

rock available, its buffering capacity in the alkaline range is virtually infinite. Therefore, acidifying capacity is rapidly lost as is the availability of the accompanying iron to the plant.

The third approach to iron nutrition has been the use of chelated materials to protect the iron (II) atom from attack by precipitating and oxidizing agents in the soil. Because this strategy has met with the greatest success, it has become the most popular approach to iron nutrition in highly alkaline soils. The remainder of this paper will discuss the importance of metal chelation in alkaline soils, how to recognize potentially effective chelated iron products, and to describe results of preliminary tests of materials conducted on alkaline Rockdale soil in Dade County which suggest possible cost effective products. The inclusion of structural formulas is done to help describe important characteristics of chelating agents.

Chelation is defined as a coordination in which a ring structure is formed between the chelator and metal (8). The greater the number of coordinated bonds that exist in a chelate complex up to 6 (the number of coordination points on iron), the more stable the compound. Natural chelators are common in roots of plants and in organic matter of soil. Both of these sources facilitate uptake of iron by plants. Indeed, one reason why some plants may be more efficient users of iron than others may be because of superior organic chelating substances in their roots (9). The greater the stability of the soluble iron (II) chelate complex the more likely it is to resist precipitation by the prevalent hydroxide and/or carbonate ions thereby maintaining a high concentration in the soil. The logarithm of the stability constants of some common iron chelators used on the market are shown in Table 1 along with definitions as well as product and chemical names. Each unit of difference in these values represents a 10-fold difference in stability; for example, the difference between EDTA and EDDHA is approximately 8 which means EDDHA is 100 million times (10^8) more stable than EDTA.

Table 1. Stability constants^z of some common commercial iron products.

Commercial trade name	Chelating chemical names	Abbreviation	Stability constant (log K)
	lactate	lactate	6.4
Agriplex Fe	citrate-phosphate	citrate	11.85
Hamp Iron 845	N,N-bis(2 hydroxy-5-sulfo-benzyl) glycine	—	—
Sequestrene NaFe Sequestrene AA Versene Iron Chelate	ethylenediamine tetracetic acid	EDTA	25.1
Sequestrene 330 Fe	diethylene triamine pentacetic acid	DTPA	28.6
Sequestrene Fe 138 Ferriplex 138	ethylenediamine di (O-hydroxyphenyl acetic acid)	EDDHA	33.0
Ferriplus 138	ethylenediamine di (O-hydroxymethylphenyl acetic acid)	EDDHMA	—

^zSee reference 2.

The first iron chelate to be tested for agricultural use was iron-EDTA (See Fig. 1a for structure) by Leonard and Stewart (3) at Lake Alfred, Florida. This formulation was used to successfully combat iron chlorosis in acid, sandy soils caused by accumulated use of copper-based fungicides. When this material was tried on limestone soils; however, it was

not effective (10). Development of modifications of this compound soon resulted in a compound which was able to maintain a more stable, protective hold on the iron atom than EDTA. This compound, NaFeDTPA, sold by Geigy as Sequestrene 330 Fe (Fig. 1b) worked well under most soil conditions but not in areas having calcareous or dolomitic soils (10). NaFeEDTA and NaFeDTPA have 6 point attachments for the iron atom giving them good stability. Another modification, the addition of bulky phenyl groups to the molecule enhanced the stability even more because the iron is almost locked into place (Fig. 1c). The bulky groups inhibit the molecule from bending or opening up to release the iron, thus protecting it from the complexing agents in the soil. Geigy Agricultural Chemicals first developed these materials and was instrumental in producing an effective chelated iron product (Sequestrene Fe 138 = HFeEDDHA) which would work well in the calcareous soil conditions of South Dade County (4, 12). One drawback in its use, however, is the high cost of this product which is now approaching \$12.00/lb.

In an effort to better understand these concepts and to test new iron materials on the market which might serve as a less expensive source of iron, several products were tested on a small scale and compared with results produced by Sequestrene Fe 138.

Quantitative results were difficult to obtain because as each new flush emerges, the last flush which was chlorotic rapidly turns green. The new flush then takes on the same or worse chlorosis than the previous flush. This and the natural variation among trees and branches within trees make it difficult to experimentally quantify tree response to iron treatments. Thus, overall tree chlorosis and condition was subjectively noted as described.

The first year's trials were conducted on chlorotic lime trees selected for uniform iron deficiency symptoms in late February of 1981 and observed last in September of the same year. All treatments were distributed in a randomized block design. The materials were applied as a 5-gal drench at rates indicated in Table 2. Leaf color of 12 of the least green leaves on each tree was compared to the range of colors on the Nickerson color fan (7). The applicable colors on the color fan (15 in all) were ranked according to empirically determined leaf chlorophyll content; determined by the method of Arnon (1); for example, color number 1 represents the yellowest leaf found (0.091 mg chlorophyll/g leaf tissue) and 15 represents the greenest (1.25 mg chlorophyll/g leaf tissue). The data represent the average color number of leaves sampled from 10 trees/treatment replicated in randomized blocks. Thus, each datum is an average of 120 leaves.

Eagle iron, a product of Eagle Picher with undetermined formulation, likely depends upon acidification of soil for

Table 2. Effect of iron products and rates on greening of chlorotic 'Tahiti' lime trees.

Treatment	Mean color number
Eagle Iron (4 lb./tree)	6.56 a ^z
Eagle Iron (1 lb./tree)	7.76 ab
Eagle Iron (2 lb./tree)	8.66 abc
Agriplex Fe (1.0 lb./tree)	9.10 abc
Agriplex Fe (0.5 lb./tree)	9.28 bc
Control (H ₂ O)	9.38 bc
Miller Ferriplex 138 (0.5 lb./tree)	10.90 c
Geigy Sequestrene 138 (0.5 lb./tree)	13.92 d

^zMean separation in column by Duncan's multiple range test, 5% level. Color numbers range from 1 (complete lack of chlorophyll) to 15 (darkest green leaves).

effectiveness. Agriplex Fe is a product of RGB laboratories based on a complex of iron phospho-citrate which coordinates with only 3 of the available 6 points on iron. This leaves room for another phospho-citrate molecule on the same iron, but the resulting structure is relatively unstable (Table 1). Miller's Ferriplex 138 and Geigy's Sequestrene Fe 138 were the only products to rapidly increase chlorophyll in the leaves (data not presented). By September, however, the Ferriplex 138 treated trees had begun to develop chlorosis, hence the lack of significant difference between them and controls.

A more subjective evaluation was conducted the following year. Again chlorotic trees were selected and distributed in a randomized block design. The products and rates of application in 5-gal drench as well as results observed 6 months after application in late April, 1982 are shown in Table 3. One of the formulations tested, Hamp-Iron 845, is composed of iron chelated with N,N-bis(2 hydroxy-5-sulfo-benzyl) glycine which coordinates with iron in only 4 of the available 6 points. This leaves the other points on the iron atom to complex with hydroxides. Miller's Ferriplex 138 and Ferriplus 138 reduced chlorosis as rapidly and as well as Sequestrene Fe 138. The Ferriplex 138-treated trees however, were again beginning to become chlorotic by 6 months.

Table 3. Effect of iron products on leaf color of 'Tahiti' line.^z

Product	Replicate						Mean
	1	2	3	4	5	6	
Hamp Iron (2 lb./tree)	3	2	4	4	3	3	3.2
Control (H ₂ O)	4	3	3	5	1	4	3.3
Miller Ferriplex 138 (0.5 lb./tree)	5	3	5	4	4	3	4.0
Miller Ferriplus 138 (0.5 lb./tree)	5	4	5	3	4	4	4.2
Geigy Sequestrene Fe 138 (0.5 lb./tree)	4	5	5	5	4	3	4.3

^zSubjective whole tree evaluation based on following definitions of scores: 1 = severe iron chlorosis extensive in tree; 2 = chlorosis in much of tree; 3 = mild chlorosis in much of tree; 4 = mild chlorosis in small portion of tree; 5 = little to no chlorosis due to iron.

Of all the iron products tested over the past 2 years, only products by Geigy and Miller were successful. Miller's Ferriplex Fe 138 gave immediate response in the trees with rapid and deep greening of chlorotic leaves; however, this material did not have the longevity of Geigy's Sequestrene Fe 138 or Miller's Ferriplus Fe 138. The reason for this difference is clear. The Ferriplex 138 material is composed of approximately 45% *ortho* isomer which is active and the same molecule is Geigy's Sequestrene Fe 138 (Fig. 1c). The remaining 55% is composed predominantly of the *para* isomer (Fig. 1d). This isomer is inactive because the necessary coordinating groups do not align. Thus, less than half of the Miller Ferriplex 138 was active in making iron available. This explains the quick response (because iron was available) and reduced time of effectiveness (it has only half the available active compound). As a result, Miller has begun to market Ferriplus 138 (Fig. 1e) which, with addition of 2 methyl blocking groups, contains a much higher amount of the active compound.

The results of these experiments can only be viewed as preliminary but indicative of the potential of the various iron products tested. Of those tested, the best suited products for South Florida are unquestionably Geigy's Sequestrene Fe 138 and Miller's Ferriplus 138. The increased amount of

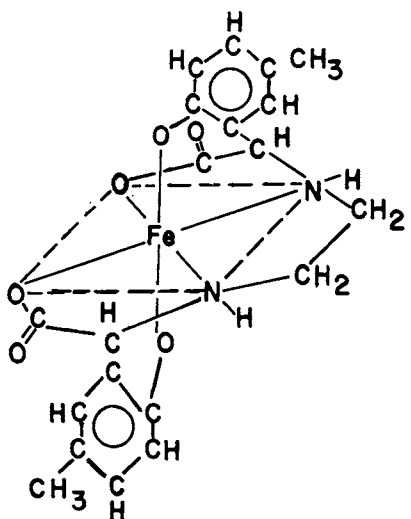
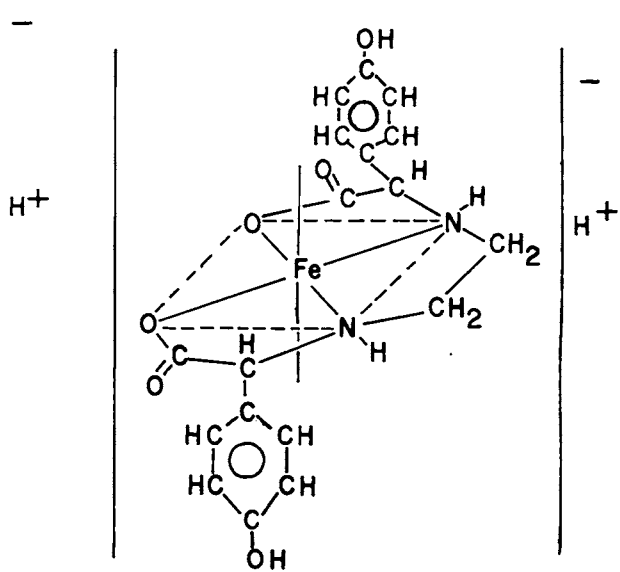
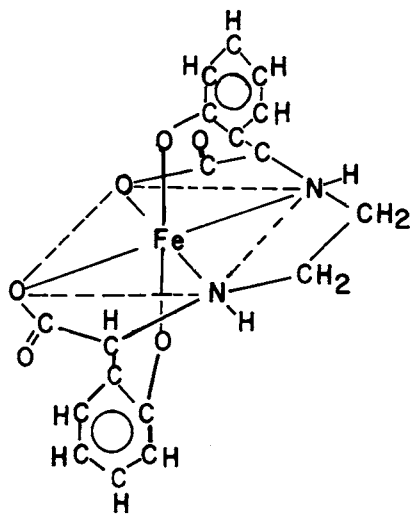
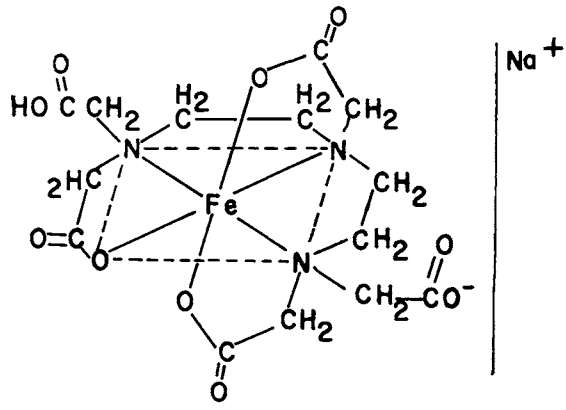
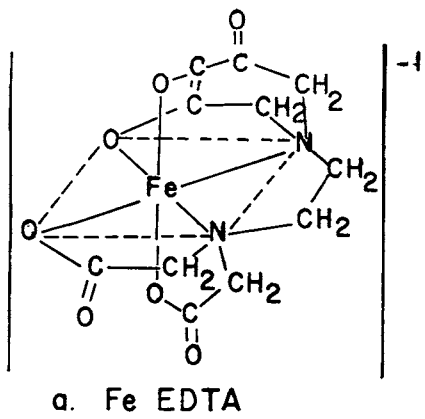


Fig. 1. Chemical structures of agriculturally important iron chelates. See Table 1 for chemical and product name of each.
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the effective compound in Ferriplus 138 is sufficient to give similar longevity as Sequestrene Fe 138; however, grower use and experience should be the most critical judge of cost effectiveness. Presently, Sequestrene Fe 138 retails at approximately \$12.00/lb., whereas the Ferriplus 138 should retail at between \$7.50 and \$8.00/lb. Hopefully, with the new availability of superior iron products on the market, competition will keep the cost of iron nutrition maintenance to a minimum.

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PRUNING, YIELD AND MORPHOLOGY OF 3 RABBITEYE BLUEBERRY CULTIVARS IN FLORIDA¹

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Abstract. 'Woodard', 'Bluegem' and 'Tifblue' rabbiteye blueberry (*Vaccinium ashei* Reade) plants were pruned beginning 7 yr after planting using 4 methods: 1) mechanical topping at 4.5 ft immediately after harvest 2) mechanical topping alternate halves of the bush at 4.5 ft immediately after harvest, 3) selective hand-pruning immediately after harvest, 4) selective hand pruning during dormancy (January). Topping alternate halves produced highest yields in most years for 'Woodard' and 'Bluegem', while other treatments were similar except in 1981 when winter hand-pruning reduced yields. Pruning treatment had little effect on yields of 'Tifblue', although topping at 4.5 ft encouraged excessive vegetative growth. Hand-pruned bushes were more open and upright than mechanically pruned bushes for all cultivars. Fruit distribution was uniform for 'Woodard', greatest in the top two thirds of the bush for 'Bluegem' and lowest in the top one third for 'Tifblue'.

Pruning of bearing highbush blueberries is recommended to balance fruiting with vegetative growth and to stimulate production of new shoots (9). Low-growing shoots, old, nonproductive canes, and weak, twiggy growth are removed routinely by light pruning. Severe pruning generally

induces vigorous vegetative growth and lower production but increases berry size (3, 8). Burning is generally used instead of pruning to regulate growth and fruiting of low-bush blueberry as well as to control weed growth (4, 5, 10).

Rabbiteye blueberry is more vigorous than highbush or lowbush blueberry. Young bushes require little pruning, but bearing plants may require routine removal of deadwood and topping to limit height (1, 2, 7). Pruning methods vary considerably with grower, location and method of harvest (hand or mechanical). Small operations generally prune bushes by hand while larger operations use mechanical methods.

No data is available on pruning of rabbiteye blueberry in Florida. The objective of this study was to compare the effects of 4 commercially used pruning methods on yield, morphology and fruit distribution of 'Woodard', 'Bluegem' and 'Tifblue' rabbiteye blueberries. Cultivar response to pruning treatment was also studied.

Materials and Methods

Forty bushes each of 'Woodard', 'Bluegem' and 'Tifblue' rabbiteye blueberries were selected following harvest in July, 1978. Bushes were planted in 1971 at the University of Florida, Horticultural Unit 3.5 miles north of Gainesville at a 6 x 12 ft spacing. Plants had begun to form a hedgerow and were ca. 6 ft tall. Four pruning treatments were assigned in a completely randomized design with 10 single bush replications per treatment: 1) topping at 4.5 ft immediately following harvest (topping); 2) selective hand-pruning immediately after harvest (hand-summer); 3) selective hand-pruning during January (hand-winter); 4) topping one half of the bush at 4.5 ft immediately following harvest in al-

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