

Twenty-three navel orange trees were grown in outdoor solution cultures for a period of 11 years to measure the effect of iron deficiency on fruit production and quality. When the concentration of iron in spring-cycle leaves was below 30 ppm (based on weight of dry leaves) in September, the production of fruit was less than when iron concentration exceeded 30 ppm. As the iron content decreased below this value, fruit production declined progressively and reached essentially zero at 15 ppm of iron. Fruit quality at harvest was not seriously affected except for some loss in color and the fact that iron content of the juice was about proportional to that in the leaves. The decrease in yield was due to fewer fruits being matured. Actual fruit sizes were the same or slightly larger in iron-deficient trees. Twig dieback was observed as a symptom of the degree of iron deficit that caused loss of fruit yield.

# IRON

## *in citrus*

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(1) Part of a moderately iron-deficient orange tree in which chlorotic young leaves became green as the iron content increased. The yellow leaves are part of the newly expanded summer cycle. Photographed in August.

(2) Part of an iron-deficient orange tree in which many leaves failed to develop enough chlorophyll to become self supporting and, therefore, fell prematurely. Twig dieback is typical of this stage of iron deficiency and indicates that fruit production is being lost. Photographed in August.

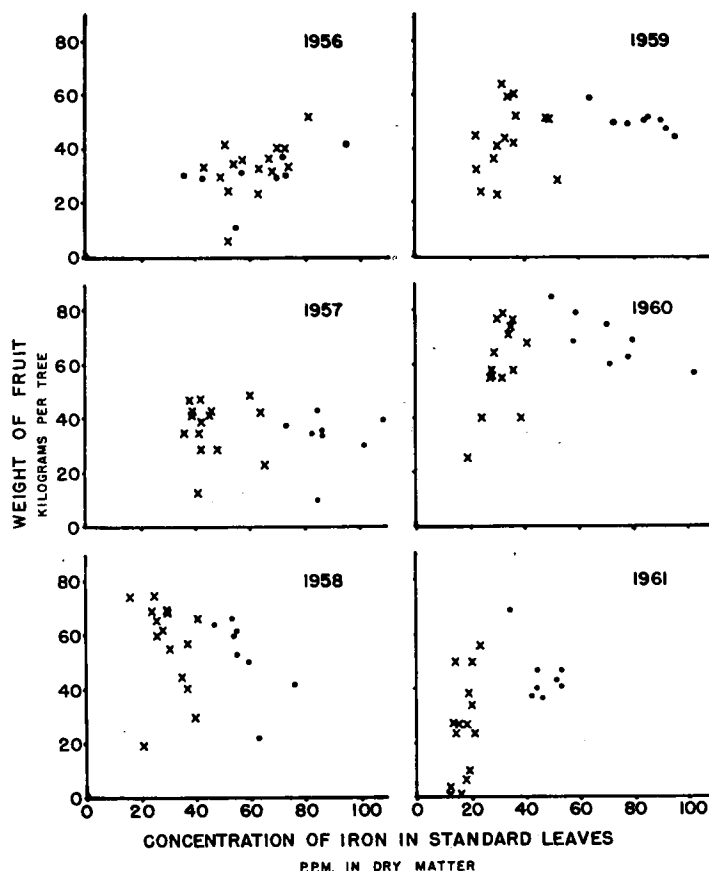
**F**OR MANY YEARS, citrus growers in certain districts have been aware of a nutritional problem widely known as iron chlorosis or lime-induced chlorosis. It may cause the tree to be noticeably pale in color, with young leaves on some limbs quite pale colored for a time and then turning green (see photo 1). In more severe instances, limbs on the whole tree have such yellow leaves that they never fully recover and sometimes drop off, leaving bare twigs that eventually die back (photo 2). In the worst situations, the young tree does not survive long enough to bear fruit (photo 3).

In the more severe cases, it is obvious that fruit production is limited by the chlorosis. In the mild cases, however, it becomes necessary to make careful measurements of fruit yield in many trees showing different degrees of the chlorosis. In these tests, trees were grown in nutrient solutions to allow maximum control over the iron supply.

In 1950, Frost nucellar navels were grafted on one-year-old Troyer seedlings and in 1951 these were transplanted into nutrient solutions in outdoor tanks (4 ft deep and 4 ft in diameter) that were about  $\frac{3}{4}$  buried in the ground. Fifteen



SCATTER DIAGRAMS SHOWING THE RELATION BETWEEN FRUIT YIELD AND IRON CONCENTRATIONS IN STANDARD ORANGE LEAVES FOR THE YEARS 1956 THROUGH 1961.



# production

trees were grown without added iron, although they obviously received some iron from dust that fell in the nutrient solutions. Starting in 1956, eight trees received regular additions of ferrous sulfate three times a week, at the rate of .20 gm per tank, which gave a concentration of .10 ppm iron in the solution. The trees did not absorb all of this iron—much of it precipitated out soon after it was added, making frequent additions necessary. Photo 4 shows this “tank orchard” in 1958. The trees grew at the same rate as in a good soil and required much of the usual orchard care, including winter heating and pest control. In addition, pH of each solution was tested three times a week and adjusted when necessary to keep it in the range from 5.0 to 5.5. Nutrient solutions were removed and replaced with fresh ones at two-month intervals.

A standardized procedure was followed for sampling leaves for chemical analysis. In late September of each year, leaves that developed at blossom time in the spring were picked from non-fruit-bearing

twigs. These were referred to as standard leaves and their chemical composition serves as a measure of the nutrient status of the tree—particularly iron content, in this case. When such leaves were to be tested for iron content, it was necessary to wash them carefully with soap because of the high iron content of dust.

The fruit crop was picked in January each year and sorted according to size. Samples of the 1957 and 1960 fruit crops were analyzed for sugar, total acid, and ascorbic acid, as well as for the mineral elements. The fractions of rind, juice, and pulp were also separated and weighed. The experiment was terminated in 1962 because the trees were becoming too crowded.

The scatter diagrams indicate the effect of decreasing iron levels on fruit production. In 1956, before adding iron, there was no distinction between the two groups of trees either with respect to amount of fruit or to iron concentration in the leaves. In 1957, the iron concentrations found in the two groups were distinctly different but fruit yields were in the same range. Not until 1959 did the low-iron trees begin to line up in a way that suggests a relation between leaf-iron concentration and total weight of fruit. In 1960 and 1961, this trend became clearer. Statistical treatment of the data disclosed that when the iron concentration in standard leaves was 30 ppm or below, fruit yield was less than when leaf iron was above 30 ppm. Yield approached zero when leaf iron dropped below 15 ppm. Thus, we can say that the critical concentration of iron for maximum fruit production was 30 ppm.

Photo 5 shows orange leaves having a range of iron concentration from 11 ppm to 43 ppm. This represents nearly the full range of leaf symptoms that can be shown



(3) Crown of a young lemon tree almost completely killed by iron deficiency.

effectively in black and white photographs. Leaves containing 30 ppm of iron exhibit only a slight chlorosis pattern, but analysis shows that chlorophyll concentration is only half of the maximum found in orange leaves. Thus, moderate iron deficiency limits chlorophyll production without producing a distinct leaf pattern. When the deficiency is severe enough to induce such a pattern in five-month-old spring cycle leaves, fruit yield may be reduced.

The observed loss in fruit yield from iron deficit resulted from smaller numbers of matured fruits. Iron deficiency did not reduce fruit size at harvest—in fact, in some years the average size of fruits was measurably larger in iron-deficient trees.

Tests of fruit quality revealed some differences related to iron nutrition, most of them small enough to be unimportant.

(4) The “tank orchard” of trees growing in nutrient solutions at the Citrus Experiment Station (1958).



The major difference was in the iron content of juice. In 1957, fruit juice from iron-deficient trees contained 83% as much iron as from high-iron trees. In the 1960 crop, the figure was 57%. Other differences found to be statistically significant in the 1960 crop were: low-iron fruits were 46.5% rind, compared with 44.3% in high-iron fruits; and low-iron fruit juice contained 12.8% sugar compared with 13.5%. Flavor and texture were not obviously affected. Color was less intense in iron-deficient fruits.

Measurements of trunk circumference made annually at the same point on each trunk showed that by 1961 the rate of trunk growth in the low-iron trees was about half that of the high-iron trees. Thus, both fruit yield and tree growth were affected by iron deficiencies in the same range.

### Application of results

Obvious differences between solution cultures and soils indicate a need for caution in applying results from one type of culture to the other. One important difference is that in the field, chlorosis is often more severe on one side or in particular limbs than over the tree as a whole. This is assumed to be caused in part by the condition of the particular roots connected to the affected part of the tree. In solution culture, all roots are in about the same environment and iron deficiency tends to affect the whole tree uniformly. Thus, the leaf-analyses and fruit-production figures in this experiment indicate the effects of iron nutrition on the entire tree. In trees that are not uniform in this respect, fruit production varies from one limb to another according to their respective levels of iron nutrition. The fruit deficit, therefore, depends on

what fraction of the tree is deficient in iron.

Use of 30 ppm iron in standard leaves as a critical concentration value for fruit production in navel orange trees does not seem to have any obvious source of error, although experience may show that the figure should be revised slightly upward or downward. The main concern is to be sure it is not misinterpreted. The important point is that leaves that are moderately chlorotic during the period of expansion usually become less chlorotic with age. Spring-cycle leaves that are chlorotic in May or June may be almost uniformly green by September. However, chlorotic summer-cycle leaves may be present on the tree in September and subsequently turn green. If the standard reported here is to be used, judgment should be based on appearance and chemical analysis of spring-cycle leaves in the September condition.

Twig dieback resulting from iron deficit can also be useful in the field as an indicator that tree productivity is reduced. When new leaves are so chlorotic that they never lose the yellow coloration between veins, they commonly drop by midsummer, leaving bare, green twigs that soon die. Fruit-bearing wood is thus lost from the tree.

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## Studies

**W** EED COSTS for the state's 110,000 acres of almond orchards totaled \$1,160,000 in 1964, according to estimates by the California State Chamber of Commerce Weed Control Committee. In the same year, a survey by the Agricultural Extension Service indicated that 88% of almond orchard weeds were annuals and 12% perennials. Most of the cost of control has been for machinery and hand labor necessary to control the weeds in the tree row. Continued disking has also frequently been injurious to both roots and trunks of young trees.

### Several Chemicals

Although several chemicals offer a potential for this type of weed control in almonds, there have been problems in the state over the years because of their toxicity to almond trees. Studies by the University of California since 1959 have shown that a number of herbicides will give economical annual weed control, at rates of 2 to 4 lbs per acre under most orchard conditions. The problem has been essentially one of safety to several tree species. A summary of the phytotoxicity work up to 1963 shows that simazine and diuron were considerably safer than atrazine, but in some trials, simazine at rates up to 4 lbs per acre showed injury to almonds. Atrazine was

(5) Orange leaves showing degrees of chlorosis pattern associated with various iron concentrations in leaves. Iron concentrations in parts per million of dry weight. Chlorophyll concentrations in milligrams per gram of fresh weight.

