Citrus Trees in Water Cultures

information derived from studies using nutrient solutions as tools of research is of inestimable value to citrus industry

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Certain types of basic information about soil-plant relations are indispensable for a sound basis for soil management. However, soils are an extremely complex body—consisting of almost endless numbers of chemical compounds and minerals, aqueous solutions, gas, and microorganisms—and are continuously changing.

A soil is never quite the same two days in succession—water is moving, temperatures are adjusting, air is flowing, chemicals are reacting, bacteria and fungi are at work—so it is difficult, and in some cases impossible, for a research worker to obtain information that is essential.

The use of water cultures—a method of growing plants without soil—is one way to get around some of the complexities in soils. Everything the soil normally does for the plant—support, water, mineral nutrients, and oxygen for the roots—is accomplished in some other appropriate way.

Solution cultures were first used about a hundred years ago, but equipment and methods have improved steadily. Some of the kinds of information which have been derived from water culture research are: *1,* Determination of the minimum levels of each nutrient required for best plant growth; *2,* Determination of the plant's seasonal absorption of nutrients; *3,* Identification of the visual symptomatology associated with deficiencies and excesses of mineral nutrients; *4,* Determination of the effects of variable levels of nutrients on fruit quality; *5,* Determination of the effects of variable

Nutrient adjustment of solution culture.

nutrient supply on yield; *6,* Interrelations of controlled climatic factors on tree behavior as related to variable nutrient supply; *7,* Studies of the interaction of different elements; *8,* Development of tissue analysis techniques for diagnosing nutrient status and requirement; *9,* Relation of nutrition to disease resistance; *10,* Relation of nutrition to insect infection; and *11,* Rates of transpiration in relation to climate and nutrition.

The nutrient solution itself is a very dilute solution of certain salts in water. The choice of salts used is controlled primarily by the elements required by plants, and the exact composition of the nutrient solution depends on the kind of experiment. Those added in definite quantities are: calcium, magnesium, potassium, nitrogen, phosphorus, sulfur, boron, iron, manganese and sometimes zinc. The need of the trees for copper, molybdenum, and chlorine, as well as for any other elements not now recognized as being essential, is usually satisfied by supplies already present as contaminants in the other salts, in the tanks or in the water.

In one long term experiment, a group of orange trees were grown for six years in solutions of graduated potash content. The trees grew well on maintained concentrations of potassium as low as two ppm—parts per million. Visual symptoms useful in the diagnosis of potash deficiencies in the field were produced and catalogued. Low potash made for small fruit sizes. High potash, on the other hand, made for increased fruit sizes, increased rind thickness, increased toughness of rind; and if the potash excess were extreme, fruit quality was seriously impaired. All of these findings were subsequently confirmed by field experiments. The studies also supplied basic data for determining potassium status of citrus trees by leaf analysis.

A comparable experiment with phosphorus was carried out for nine years, again producing results which clarified the influence—of variable phosphate supplied—on yield, fruit quality, tree performance, visual symptoms, and the leaf content associated with acute and subacute deficiencies.

In another experiment carried out with bearing orange trees the weekly absorption of nitrate for three consecutive years was determined. There was some absorption all year, but the two months of least withdrawal were January and February,

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Water culture layout showing concrete containers in foreground and a group of 6-year-old citrus trees in background with pipe framework which acts as both support for trees and carries compressed air for nutrient solution aeration.

CULTURES

Continued from preceding page

the months when soil temperature is at a minimum. Beginning about the middle of March there was a rapid rise in absorption rate, continuing then on a high plane until about the middle of December when—with cooling soil temperature—the rate began to decrease. These results suggested that the nitrogen absorbed in the fall and early winter built up a store in the tree which was then used to support the blossom and fruit setting in the spring.

A supplemental experiment is currently underway to determine the relative importance of seasonal nitrogen supply. In this experiment a group of orange trees receiving nitrogen continuously is being compared with other groups where nitrogen is withdrawn for four months and then restored. In one group, nitrogen is withdrawn in May, immediately following bloom; in a second group, it is withdrawn in September; in a third, in January. The trees in which nitrogen is withdrawn in May show extreme nitrogen deficiency by the end of the four-month withdrawal period; but despite the symptomatology, there has been to date, after some five years, no evidence of decreased yield or fruit size. It is evident that the citrus tree can store sufficient nitrogen to tide it over a considerable period of nitrogen starvation and that even incipient nitrogen deficiency at the blossom and fruit set period does not decrease fruit set. Just how severely nitrogen deficient a tree must be at this period to decrease fruit set has still to be determined. All of this work is yielding important data by which practical nitrogen fertilization can more easily be guided.

Other experiments currently underway involve calcium and iron. When environmental control equipment is on hand, a study will be made of the interrelations of various recurring climatic extremes and nutrition to determine whether the ill effects of climate can be offset by proper nutrition.

Equipment developed for growing fruit-bearing citrus trees—over long periods—consists of a tank for the nutrient solution in which the roots are immersed, an overhead framework of pipe for supporting the tree, and facilities for constant aeration of the solution.

The tank is made by setting a 4′ length of 4′ diameter concrete pipe on end, about 2′ into the ground. A concrete bottom is poured in after the pipe is in place. The tank is made waterproof by painting the inside with a commercial asphaltum preparation that is nontoxic to plants.

A circular cover for the tank—formed of reinforced concrete, cast in two halves—keeps the nutrient solution clean by preventing leaves, twigs, insects, and dirt from falling into the tank. The cover also shuts out light and thus prevents growth of algae in the solution. Furthermore, it provides an anchor for the tree to reduce the tendency to shift sideways. A lid in two sections makes it possible to uncover half the tank for planting or removing trees, changing nutrient solutions, and so forth.

The overhead framework of pipe serves two purposes; each tree is suspended from the frame by heavy wires; and, the pipe carries compressed air which is bubbled continuously through the nutrient solution to supply oxygen to the roots, a necessary condition for growing citrus.

When certain types of experiments require water of high degree of purity, ordinary tap water—suitable for some studies—is passed through a de-ionizer to remove salts in the water by a process similar to that of a water softener. De-ionized water is always used for replacing water lost from the tank by evaporation because the lime and other salts in tap water would eventually cause undesirable changes in nutrient concentration and balance.

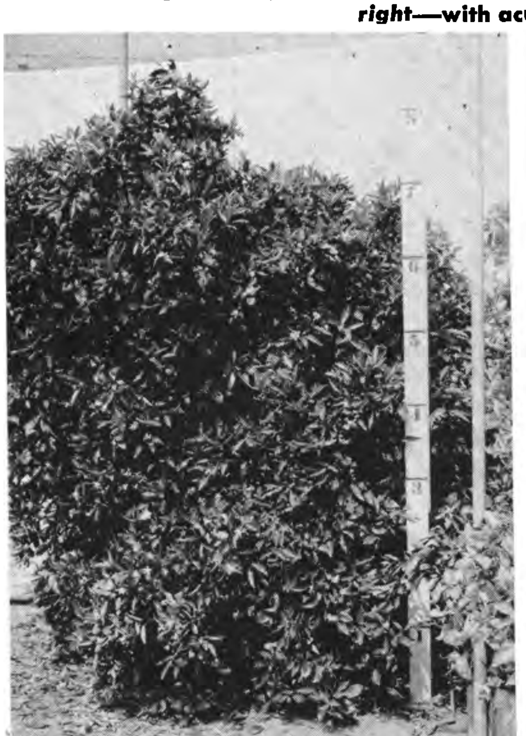
A complete nutrient solution found satisfactory might contain about 0.5% calcium nitrate, 0.2% magnesium nitrate, 0.2% potassium sulfate, 0.01% potassium phosphate, and traces—0.1–0.5 ppm—of boron as boric acid and of iron, manganese, and zinc in the form of sulfates or chlorides.

The actual concentrations used are always a compromise. The tree could obtain enough of any of these elements from much more dilute solutions. However, it would be difficult to maintain such low concentrations. As a practical device, the quantities used are somewhat larger than the minimum requirements. On the other hand, excessive amounts result in reduced growth and fruit production. Therefore—as a compromise—the buffering or leveling effect of the soil is eliminated by a most careful control of total nutrient concentrations.

While pH—relative acidity and alkalinity produced by hydrogen ion concentration with the rating of seven as neutral—of a nutrient solution in the range from acidity of pH4 to alkalinity of pH9 does not seriously affect the ability of the plant to absorb mineral nutrients, it does affect their solubility and certain other factors. In the case of citrus trees, difficulties are encountered with certain molds that cause root rot if the pH of the nutrient solution goes much above 5.0. Unless the experiment requires a different value, the pH is maintained in the range from 4.0–4.5.

In general practice, nutrient solutions are removed about every two months and replaced with fresh solutions. Sometimes it is necessary every week or two to replace the nitrates and phosphates that have been taken up by the tree. The techniques of nutrient control are in general conditioned by the type of experiment involved.

Orange trees grown for seven years in water culture. *Left*—with full nutrition; *right*—with acute potash deficiency.



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