Cultural practices

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Since the Citrus Experiment Station began in 1907, a major concern has been development of more efficient fertilizer practices. Early experiments by CES scientists, primarily in the orchards of cooperating growers, showed that on most, but not all, California soils, citrus trees do not respond to potassium and phosphorus application. Substantial amounts of nitrogen, however, have been required annually to maintain good vigor and yield. Later (after World War I), it was found that animal and green manures could be replaced as nitrogen sources by chemical sources, which, among other advantages, were more efficiently used by the tree and became progressively cheaper per unit of nitrogen.

In the last 30 years, the development of automated pressure irrigation systems (sprinkler, drip, micro-jet, and the like) have made it possible to plant orchards on virgin hillside soils. Such soils are generally lower in native fertility than those in most older orchards planted on relatively flat valley floors and irrigated by traditional gravity systems (such as basin and furrow).

Research has shown that many hillside orchards require potassium fertilization. Such soils tend to have a lower inherent available potassium content and also lack the accumulated residue of potassium from repeated fertilization with the potassium-rich organic manures that were commonly applied to early California orchards on valley floor soils.

Also, it was found that fertilizers, especially nitrogen sources, might have important side effects on tilth of many soils, which could depress or even override the yield benefits of nitrogen as a nutrient. For example, repeated applications of sodium salts of nitrogen have a cumulative effect on water penetration, which gradually depresses yields because of soil moisture deficits not easily remedied by revising irrigation practices.

One widespread problem that led to the establishment of the CES was the disorder called "little leaf," which was associated with low vigor, poor yield, and distinctive leaf symptoms (small, narrow, yellowed leaves). University of California scientists played a key role in demonstrating that the disorder was caused by a deficiency of zinc, a nutrient essential in minute amounts for normal growth. They showed that it could be effectively and economically controlled by periodically spraying the foliage with dilute solutions of zinc salts. This micronutrient deficiency was prevalent in citrus regions of the world, and today zinc sprays are an integral part of the cultural program in most well-managed orchards.

Research at the CES also contributed important information on causes and control of other micronutrient deficiencies, such as manganese, copper, iron, and boron. Studies showed that heavy fertilization with potassium salts eventually induces a magnesium deficiency in California citrus orchards, as in other citrus regions. Indeed, results obtained in California and elsewhere clearly demonstrate strong cumulative reciprocal relations among applied nutrient elements, and show that persistent use of unneeded fertilizers almost always leads to undesirable side effects over a period of years.

As a result of CES studies, the effects of mineral nutrition on fruit quality are better understood. Extensive orchard and solution culture experiments isolated the effects of deficiencies and excesses of both macro- and micro-nutrients on juice composition, fruit size, and juice percentage, as well as on peel color, texture, thickness, and susceptibility to certain rind disorders. For example, a potassium deficiency is associated with small fruit size; a high juice percentage low in acid; thin, smooth, well-colored peel; and a tendency toward excessive rind splitting. Very high levels of potassium are associated with large fruit having thick, coarse-textured, poorly colored peel, and a low juice content high in acidity. These effects of high potassium are accentuated by high nitrogen levels.

Analysis of leaves to diagnose deficiencies and excesses has become a primary guide in the development of efficient fertilizer practices in many important citrus regions of the world. It has been especially valuable in avoiding the excessive use of unneeded fertilizers in orchards. Also, use of leaf analysis in research has greatly reduced the need for large numbers of expensive, ponderous orchard experiments. Again, CES scientists played a key role in developing this valuable technique.

Possible pollution of underground water with chemicals used in fertilization, especially nitrates, has become of concern in the last decade with regard to human health. CES research has shown that such pollution can be avoided or greatly reduced by leaf analysis combined with leaf application of a part of the required nitrogen in the form of urea.

As a result of the efforts of CES scientists and

An early disorder of citrus called "little leaf" was corrected after U.C. scientists traced it to a deficiency of zinc.

others, few well-managed citrus orchards in California suffer yield restraints from faulty fertilization, whereas before World War II, most orchards produced below potential because of poor fertilizer practices.

Weed control

After World War I, heavy, tractor-drawn equipment for orchard cultural operations became increasingly common. By the 1930s, CES investigators observed that in most orchards the frequent traffic of such heavy equipment caused a gradual deterioration in soil structure. Frequent mechanical cultivation for weed control was especially harmful. The result was reduced water penetration, impaired root development, and related effects that reduced tree vigor and productivity.

In the 1940s, experimentation began with light petroleum oils for weed control as an alternative for mechanical cultivation. After World War II, CES started intensified research on the use of oils and other chemicals being developed as herbicides. These investigations clearly showed that a "clean culture" or "nontillage" system of soil management using chemical herbicides would be practical in most California citrus orchards. In addition, they demonstrated its advantages over mechanical weed control in cost and improved soil tilth, as well as in reduced water use, frost hazard, and soil erosion.

By the mid-1960s, almost all California citrus growers had converted from mechanical to chemical weed control—the first to adopt the nontillage system of soil management on a wide scale. This system has since spread to many other orchard crops around the world, and even to such annual row crops as corn, cotton, and many others.

Plant growth regulators

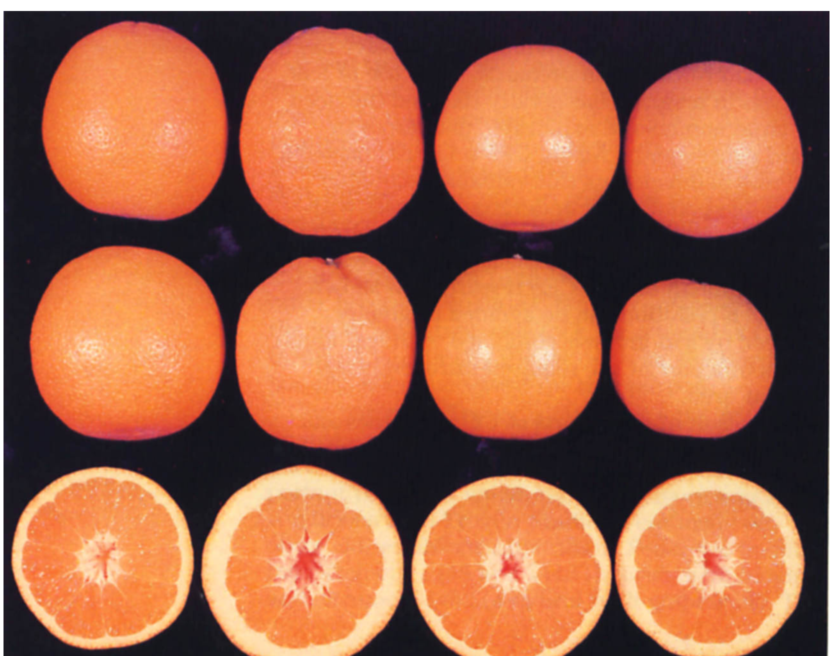
By the end of World War II, plant scientists in laboratories all over the world had shown that certain organic chemicals called growth regulators, when applied in minute concentrations, could profoundly influence growth and other processes in plants. CES played a significant role in applying this basic knowledge to practical citrus culture.

An early 1950s application was the development of a technology for using preharvest sprays of 2,4-dichlorophenoxyacetic acid (2,4-D) and related compounds to delay and reduce abcission (drop) of mature fruit of most citrus varieties grown in California. Another important effect of such "stop drop" spray treatment is the delay of degenerative changes that accompany abcission and reduce fresh market or processing quality of fruit. In addition, 2,4-D is used to some extent to improve fruit size of Valencia oranges and grapefruit by dilute sprays applied to very young fruitlets. Also, 2,4-D is sometimes added to oil pesticide sprays to lessen leaf drop caused by the oil.

Another growth regulator, gibberellic acid (GA_3), now commonly used in many citrus growing regions, was pioneered in the 1960s by CES scientists. In California, preharvest GA_3 treatments are now widely used to delay rind degeneration of navel oranges. By greatly reducing such disorders as rind staining, water spot, and sticky rind afflicting navel oranges held on the tree past the midpoint of physiological maturity, GA_3 significantly lengthens the effective harvest season, improving returns to growers and quality of fruit to consumers. GA_3 is also used to some extent, especially in coastal regions of California, to delay fruit maturity of lemons. Late fall applications of GA_3 shift the major flowering period so that more fruits mature during the summer when demand is at its peak. Research in California with GA_3 led to its use in Florida to improve fruit set of the Orlando tangelo (a mandarin-grapefruit hybrid not grown commercially in California), and to delay rind degeneration of seedless grapefruit varieties, a problem in Florida's climate.

The naturally occurring (endogenous) growth regulators have been little studied, but the work that has been done indicates they are related to fruiting behavior. This is a promising field for future work.

Effects of fertilization on quality of Valencia oranges on phosphorus-deficient soil. From left: no fertilizer, nitrogen alone, phosphorus alone, nitrogen and phosphorus.



Effects of climate

Growers early-on observed striking differences in season of maturity and quality of fruit produced in the several California regions suitable for citrus culture. For example, Valencia oranges mature about 11 months after flowering in the hot desert climate of the Coachella Valley, and may be stored on the tree about three months after reaching acceptable harvest maturity. In the cool, more humid coastal climate of the Oxnard Plain, 13 to 14 months are required to reach harvest maturity, and the fruit may be stored on the tree another five or six months before unacceptable deterioration and loss occur. Many growers and marketing people attributed such differences to climatic diversity rather than to differences in soils or cultural practices. But definitive information was lacking, and there was much controversy.

Studies at CES after World War II confirmed that climatic diversity was indeed the major cause of the differences observed. The shape of the cumulative seasonal net radiation curve is more closely related to the form of fruit and rate of maturation than are other more conventional indices of seasonal heat. Net radiation is a closer reflection of the ambient thermal energy level (temperature) of plant tissues than is ambient air temperature. Correlative studies in orchards in various climatic regions and with fruiting trees in controlled temperature greenhouses indicated that differences in the ambient energy level during various stages of fruit development were the primary cause of the observed differences, and thus could not be appreciably modified by orchard management.

Other studies have shown that heat stress in the hottest desert regions of California and the Southwest can be a significant yield restraint. Unseasonably hot weather during the fruit-setting period may cause heavy crop reduction, especially in navel and satsuma varieties. Heat damage to leaves when air temperatures exceed 104° F (40° C) may impair photosynthetic capacity, cause leaf drop, and reduce yields. The number of days per season when air temperatures exceed 104° F is a measure of the heat damage potential to citrus foliage, but windiness may be an aggravating factor.

Effect of climate on quality of Redblush grapefruit. All were harvested during last week in January from genetically identical trees of the same age receiving similar cultural treatment. Two fruits on left are from two cool coastal valley locations; two on right from hot to very hot, arid interior valley climates. High temperatures produce large, early-maturing fruit and stimulate the pink pigmentation.

Other cultural practices

Planting distances: There are no fixed planting distances; they vary with scion variety and rootstock. Considerable study by CES scientists and others indicates a 20- by 20-foot to 25- by 25-foot spacing may be about right for a mature orchard. Closer spacing produces more fruit per acre until the trees begin to crowd, after which shading out occurs, and the trees must be thinned to maintain yields. Hedgerow planting is sometimes used, but there are disadvantages.

Pruning: An important finding of research on pruning has been that citrus does not respond as do other fruit trees, such as apple or peach. Pruning is not required to maintain fruit yield. Usually, spacing is not sufficient, however, and pruning is required to keep the trees relatively small, permitting more efficient spray application and cheaper fruit harvest. This is especially true for lemons. Because of labor costs, most pruning is now done by mechanical toppers and hedgers.

Fruit thinning: The number of fruit per tree and fruit size are usually inversely correlated. Because small fruit size is sometimes a problem with the Valencia orange and some mandarins, considerable work has been done on the effects of thinning. Results have not been consistent; hence, thinning has not become a common practice. Hand-thinning is expensive and as yet, there is no chemical thinner that will do a consistent job. It has been shown that alternate bearing in Valencia can be reversed by the removal of all young fruit in July of the "on" year.

Typical nontillage California citrus orchard, where herbicides replaced mechanical cultivation by the mid 1960s.

Alternate bearing and time of harvest: Since CES was established, its scientists have studied, but not yet solved, the problem of alternate bearing, especially in late-harvested Valencia orange. Early harvest can reduce the intensity of alternate bearing but is not practical because of marketing problems. Recent research indicates that in some cases the depletion of carbohydrates results in the "off" year. In other situations, the naturally occurring growth regulators appear to be involved. Work along these lines may produce an answer to the problem.