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EARLY RESEARCH IN SOILS AND PLANT NUTRITION

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MUCH OF CALIFORNIA'S agricultural success depended upon early research in soils and plant nutrition, with the success built upon hard work and exacting methods. This article mentions some of the work and some of the researchers of the last 100 years at the University of California.

Studies more than fifty years ago by Frank Veihmeyer and Art Hendrickson at Davis showed that tillage other than the minimum required for control of competing weeds was unimportant for moisture conservation. Their work laid the foundation for minimum tillage—in fact for chemical weed control and zero tillage on hundreds of thousands of acres in California's orchards.

Economics helped drive the lesson home. Enterprise efficiency studies initiated by L. W. Fluharty, Extension Specialist in Farm Management, proved the savings. Al Jungerman, Stanislaus County Farm Advisor, demonstrated that reducing annual tillage costs in peach orchards from $33.00 to $7.00 per acre caused no reduction in yield and improved soil tilth.

Further studies have shown that harmful effects of tillage, such as compaction and destruction of large continuous pores, often exceed any possible benefits. Thus the trend toward minimum tillage is nationwide and is being studied as a management practice for many crops.

Salt balance of soils

Early work on the nature of salt-affected soils, both sodic (alkali) and saline, was promoted by Thomas Forsythe Hunt, who came from Pennsylvania to be Dean of Agriculture in California. He said: "One of our most important tasks must be to determine if agriculture can be maintained permanently on irrigated land." This task has become a multi-discipline project.

After E. Hilgard and W. P. Kelley established the chemical nature of salt-affected soils, Kelley and his associates developed the following basic principles of reclaiming salt-affected soils: (1) establish a favorable balance of cations in the base exchange complex of the soil; (2) provide adequate drainage; and (3) leach the salts from the root zone. Kelley was also one of the first to emphasize the need for a "sink" to receive the leached salts.

Soil reclamation

Application of these principles has resulted in the reclamation of thousands of acres of unproductive soils. Kelley's experiments at Kearney Ranch demonstrated that land which had once produced grapes and then had been salted out, could be reclaimed and made to produce good crops of grapes again.

But progress has not been easy, especially on soils of higher clay content. Chemical treatment to reduce sodicity, and water management—both irrigation and drainage methods—are involved. Research on several U.C. campuses has brought about improvement in drainage and leaching practices. The development of a laboratory method of determining gypsum requirement of soils high in exchangeable sodium has helped. We now know how to reclaim the root zone of the soil in most situations.

Unfortunately the most important solution for maintaining *permanent* agriculture on irrigated lands still remains. How can we get all of the salt to a permanent sink where it can be deposited without harm? Natural sinks are the ocean and depressions like the Salton Sea. To reach the sinks, brackish drainage must be conveyed in drains or natural water courses. Unfortunately, much of the salt from irrigated lands is in the temporary sink, the soil below the root zone and above the water table. Here it is a constant threat to pollution of important ground-water supplies, while salt carried in water courses impairs the usefulness of the water.

The growing salt burden in the rivers and in the soil below the root zone is of grave concern not only to farmers and researchers but to pollution control agencies. Salt management has been called "California's most complex water quality problem."

Serendipity

Chance, supplemented by keen observation, often lays the foundation for new and important studies. One sunny afternoon some 40 years ago I was driving along a Southern California road and noticed a strange, yellowish, mottled symptom on orange leaves. Inquiry revealed that it may have been caused by contamination of irrigation water by a spill of borax solution. I asked W. P. Kelley to have a look at the orchard. He recognized the symptom as similar to an undiagnosed one seen on lemon trees irrigated from Sespe Creek. This resulted in extensive studies to determine symptoms of boron toxicity in various crops, as well as boron levels in injured tissues.

Symptoms such as leaf discoloration and scorches were not always evident. At the request of San Benito Farm Advisor Roy D. McCallum, a group of eminent plant physiologists from several U.C. campuses examined a strange die-back of prune trees. A lowly violet in the farmer's yard provided the clue to the mysterious disease, caused by well water with a high boron content. McCallum, with F. M. Eaton of the U.S.D.A., studied the problem extensively and published a bulletin on the boron problem, stimulating the study of boron toxicity for many crops. High boron wells were abandoned, and injured orchards replaced by profitable vegetables. Boron, although an essential element in micro quantities, is now recognized as a hazard and is included in all standard water quality analyses.

Another fortuitous circumstance resulted in discovery of zinc deficiency as a cause of the troublesome mottle leaf of citrus trees. W. H. Chandler had some success in controlling little leaf of peaches in Merced County by applications of iron sulfate. He encouraged J. C. Johnston, Extension Specialist in Subtropical Horticulture, to try iron sulfate on citrus trees. One batch of the material worked, but another did not. Analysis showed that the successful batch contained zinc sulfate as an impurity. Zinc was thus shown to be a deficient micronutrient for both citrus and stone fruit trees, and later became recognized as one of California's most important nutrient deficiencies.

Zinc deficiency is not cured by a

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Santa Rosa (*Prunus salicina*) are more resistant to *Cytospora* than President and other European plum varieties. It appears that the vitamin, myo-inositol, which is more freely available in the bark of the President trees than in the bark of the Japanese plum varieties, may influence development of disease, as *Cytospora* requires this vitamin in combination with thiamin and biotin for optimum growth.

Inoculations of trees with *Cytospora* in March caused cankers which were larger than those caused by inoculations in September when measured after one year. In California, *Cytospora* cankers develop most extensively during the warmest periods of the summer—in sharp contrast to the activity of *Cytospora* in orchards in Idaho, New York, Colorado, and other areas with cold winters, where infections and canker development are more active in the spring months.

Efforts to control the dieback disease of President plums caused by *Cytospora* cankers in California have included sprays of fungicidal materials, use of wound dressings, whitewash of limbs at different times of the year, and various pruning methods. Least effective have been fungicidal sprays such as Bordeaux mixture. Moderately effective were whitewash treatments applied in the early spring months. In an experiment begun in fall 1960, only 8% of the whitewashed trees had developed cankers seven years later, while 20% of the untreated control group had cankers.

Most effective was a modified pruning method developed by M. Gerdts. The method, which strengthens the inner scaffold limbs and partially shades the branches, achieves satisfactory reduction of the disease without loss of fruiting wood from shading of inner branches. The advantages of the method were obvious when ten-year-old short-pruned trees on a ranch in Parlier, California, were compared with trees of the same age pruned according to Gerdts' system. Of the short-pruned trees, 35 out of 37 were affected by sunburn and *Cytospora* cankers. Of those trees pruned by the Gerdts method, 38 out of 41 were free of sunburn damage and none had cankers.

The Gerdts method is shown in photo 4C, where the tree has been pruned to promote numerous interior branches in addition to the normal spreading scaffolds. Lower fruit wood has not been shaded out under this system because the tree has been topped after harvest each year. Without topping, the lower wood probably would shade out. There has been almost no sunburn problem on the tree, and yields have been extremely high. Harvest costs are a little high on the inside of the tree, but the overall cost is about the same. This tree has many more limbs than usually advocated in a typical pruning situation. Although it is difficult to see in the photo, the tree has been roped to prevent further spread.

In a 1971 yield comparison, 13-year-old short-pruned trees yielded an average of 235 lbs per tree, while trees of the same age pruned by the modified method yielded an average of 504 lbs per tree. In August 1974 the figures were 174 and 433, respectively. By that time, the short-pruned trees were severely affected by the dieback disease; some trees had only one or two main scaffolds. New vigorous shoots are being used to fill in the voids, but it is expected that these trees will be removed in two to four years.

Trees pruned with Gerdts' system are now starting to show sunburn near the tops of the scaffolds. Generally there may be one or two sunburned areas per tree on the east or northeast side where the inside of a limb is exposed to the afternoon sun. The sunburn is mainly on small wood (wrist size or smaller), which is being pruned out after harvest. Approximately 50% of the trees in the block with the Gerdts system of pruning had some sunburn by August 1974, and about 5% of the trees had sunburned areas infected by *Cytospora*.

It is often difficult to cure diseased trees by pruning out diseased limbs since this frequently causes increased exposure and sun injury of other limbs. However, if pruning cuts are made, they should be several inches below existing cankers, otherwise the fungus will continue to spread (photo 5) into the remaining limb or branch.

The Gerdts system of pruning (photo 4C) has definitely extended the life of the orchard for an estimated 10 to 12 years, although it is expected that the dieback disease syndrome (sunburn → *Cytospora* → limb removal → decreased yields) will eventually be a major problem. However, in the meantime, production has been increased and orchard life extended to a reasonable or economically acceptable length.

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Early Research

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simple system. Ed Parker of the Citrus Experiment Station developed methods of treating citrus by zinc sprays. Other crops, as Chandler found, were cured by driving metallic zinc into trees, and still others by strong dormant-season sprays.

The study still goes on as a part of multi-campus research, since it is necessary to develop treatment practices crop by crop, not only for zinc but also for other micronutrients. In fact, the newest project of the Kearney Foundation of Soil Sciences will deal with micronutrient deficiencies and their control.

When the Agricultural Experiment Station was established in 1874, much of its work was field studies and extension teaching. Twenty years later the Agricultural Extension began its work, which was limited to meetings, farm calls, demonstrations of known facts and simple tests to determine the local applicability of these facts. Research was a jealously guarded function of the federal and state experiment stations, and was further discouraged by the Federal Extension Service.

The studies reported above, however, were all cooperative efforts of Agricultural Extension and departmental research. This cooperation has grown to the point where most of the field research involving farmer cooperation and some of the research at Experiment Station field stations is done by Extension personnel. University departmental laboratories have been relieved of burdensome routine tests by establishment of Extension regional laboratories at Berkeley, later moved to Davis, and Riverside, as well as 13 county laboratories, conserving the time and facilities of the departments for fundamental research.

Frequent consultation and trips to examine field experiments have kept both Extension and departmental staff members abreast of the times not only with respect to fundamental principles but also with practical application. The many jointly-authored articles appearing in *California Agriculture* attest to the fact that early, sometimes jealous, rivalry has become whole-hearted cooperation. I believe this has made the University of California's total agricultural research system a unique and highly successful service to California and its farmers.

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