Fifth in a centennial series . . .

U.C. RIVERSIDE:

Outstanding achievements in agricultural research

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THE CITRUS EXPERIMENT STATION (CES) was officially created by the regents of the University of California in February 1907, following appropriation of $30,000 by the legislature in 1905. The appropriation established a plant pathology laboratory at Whittier and the CES at Riverside. During the next nearly 60 years the station grew steadily, to meet the rapidly increasing research needs of an expanding agriculture in the southern portion of the state, and of the citrus industry in the central valley.

While citrus has always received major research attention at the station, its program has broadened greatly over the years to include some aspects of practically every southern California commercial crop, including poultry and livestock. Because of the breadth of its research program, the regents in 1961 changed the name of the Citrus Experiment Station to the "Citrus Research Center and Agricultural Experiment Station" (CRC-AES). Concerning this change, the regents said: "The change in name is to indicate the broader scope of activity, but retains the word 'citrus' in the title, since the excellence of the citrus research program has gained worldwide recognition and the station will continue to be the world's leading citrus research center." From the beginning, the station's administration has encouraged problem-solving research. Basic research has been conducted as needed; when funds have been available, information required to solve specific problems has been developed.

Because of limited space, many important research projects have not been included here which have nevertheless contributed much to the solution of major agricultural problems.

The fledgling CES was concerned with soil management, fertilization, irrigation requirements, and rootstock-scion relationships, in order to increase citrus production and improve fruit quality. A citrus variety collection for plant breeding was begun soon after the station's founding, and is now the largest and most comprehensive citrus collection in the world. This collection has been invaluable as a source of germ plasm for genetic and plant breeding research on varietal and rootstock improvement and on new varieties.

Among the most serious problems confronting the citrus industry in the early 1900s was the mottle-leaf malady. It was one of the many reasons for establishing the CES. Mottle-leaf causes reduction in leaf chlorophyll with consequent decreased tree vigor, resulting in production of fewer and poorer quality fruit. In the early 1930s university researchers not on the CES staff found that this disorder was due to zinc deficiency, which could be corrected by sprays containing zinc. CES staff members played the major role in putting to practical use this breakthrough, which solved the mottle-leaf problem.

In addition to the zinc nutritional work, extensive laboratory and field research has been done at CES on other nutritional elements for citrus: nitrogen, phosphorus, potassium, copper, iron, manganese, magnesium, boron, and others. Symptoms of deficiencies and excesses of these elements have been diagnosed and evaluated. This information provided the basis for establishing standards for the optimum amount of each major element. Leaf tissue analysis methods were developed to determine the nutritional status of trees in the field, and this information guides current fertilizer practices. Today the leaf analysis technique is used to determine the nutritional needs of approximately 50% of California's citrus trees. It has resulted in the use of significantly less nitrogen fertilizer per acre without impairing fruit quality or yield.

The nutritional programs for avocados, potatoes, and melons, based on tissue analyses, were also developed. These programs are widely used to great advantage by commercial growers.

The most important result of the citrus genetic and plant breeding research has been the development of the nucellar embryo phenomenon to provide virus-free bud lines of oranges, tangerines, lemons, and grapefruit, and also virus-free rootstocks. The rootstock studies led to development of Troyer citrange, the most valuable rootstock in California for all citrus species and varieties, with the exception of lemons, for which *Citrus macrophylla* is the most popular. Trees from nucellar bud lines (i.e., scions and the two rootstocks mentioned) constitute about 75% of the more than 180,000 acres of citrus planted in this state since 1959.

Other genetic and plant breeding research includes the many potential new varieties of avocado now under evaluation. The most promising new variety released is the Teague, which matures early in the season. Station research has demonstrated that cross-pollination is essential for best production of avocados and, therefore, that nearby colonies of honeybees are needed during the blossoming period.

Fig breeding research has produced many new varieties, some of which may have commercial value. The Conadria variety, released in the late 1950s, is a commercial success. The Tena variety, now under commercial evaluation, looks very promising.

Turfgrass research on plant breeding and culture has resulted in the introduction and widespread use of the Santa Ana hybrid Bermudagrass variety, which has a high degree of tolerance to air pollution and salinity. Also, a superior variety of dichondra was developed, UCR No. 1, which is becoming increasingly popular. Irrigation and fertilization management practices have been developed for several varieties of turfgrass in various locations.

Sesame seed, a superior source of edible oil and protein, is not produced in the U.S. because commercially-available varieties shatter the seed at maturity and cannot be harvested with machines. Genetic and plant breeding research has ultimately resulted in nonshattering varieties that can be harvested mechanically. Further plant breeding research is under way to obtain higher yielding nonshattering varieties, and the prospects now appear promising for development of a new California crop that is in demand by food industries.

Jojoba, a woody perennial plant native to the semiarid or desert areas of the Southwest, has been under study for the past decade. Its seeds contain a unique liquid wax that has many potential uses, chief of which is a substitute for oil from the sperm whale (an endangered species). Wild plants selected for high seed yield, high wax content in the seed, and large seed size have been growing under different fertilization, irrigation, and pruning treatments to determine potential yields and production costs under cultivation. If these treatments, coupled with yield increments through plant breeding, demonstrate that jojoba can be grown profitably, a new agricultural resource will become available for the large semiarid areas of the Southwest.

Plant tissue culture research, a pioneering effort at the CES, has been very productive. Plants free of known pathogens such as viruses, viroids, and mycoplasmas have been obtained for citrus, carnations, chrysanthemums, lily, and rhubarb. Restoration of yield and quality already have occurred in plants such as potato and carnation and can be expected for others. Pathogen-free stock should hasten the day when it will be permissible to move many more plants internationally.

In clonal propagation of plants, tissue culture results in multiplication of uniform plants a million times faster than traditional asexual methods. CRC-AES studies have led to the commercial propagation of cymbidium and catleya orchids, gerber daisy, ferns, and many tropical foliage plants. Because of well-established principles, procedures can be worked out quickly for tissue culture propagation of most of the herbaceous genera and for some species of trees.

Tissue culture also offers great promise for hybridization and new variety development. Rare hybrids have been obtained in orchids through embryo and ovule cultures. Methods under current development should make possible genetic combinations which cannot be obtained through conventional plant breeding techniques.

Post-harvest physiology research on citrus and avocados has elucidated the principles for the most effective handling of these fruits at harvest, during storage, through shipment, and until their sale in retail outlets. These comprehensive studies have minimized biological, chemical, and physical losses.

Almost from its beginning in southern California, the citrus industry has used oil-fired heaters for frost protection. Later, wind machines or combinations of wind machines and heaters were installed. During the past decade, research has emphasized the use of scientific data to construct models for calculating the parameters of frost protection needs under a wide range of conditions. Findings from this research have simplified frost protection requirements from heaters, wind machines, and water as affected by inversion layers, wind, humidity, fog, and smog.

The Citrus Variety Improvement Program (CVIP) was established in 1958 to control virus diseases, which cause major losses by reducing vigor, yield, and quality of citrus trees. The main objective of the CVIP is to establish and maintain primary sources of virus-free, true-to-name citrus selections. Budwood from these selections is available to nurserymen and growers for the production of superior nursery trees in a nursery increase block or for producing nursery trees certified by the California Department of Food and Agriculture. In close cooperation with this agency, the complex program is progressing well. About 140 citrus selections are now available as sources of budwood, and additional selections will be released as soon as their critical evaluation requirements have been met.

Plant growth regulator research with many compounds resulted in the profitable use of 2,4-D and gibberellic acid in citrus production. The growth regulator 2,4-D controls preharvest fruit drop, minimizes leaf and fruit drop resulting from petroleum oil sprays used for insect and mite control on oranges, lemons, and grapefruit, increases the size of navel and Valencia oranges, and controls fungal decay under the buttons of lemons in storage. Gibberellic acid desirably retards maturity of lemon fruits, and to some extent regulates the time of flowering. Its use enables lemon growers to adjust harvest to the time when demand for lemons is greatest. Gibberellic acid also increases the proportion of high quality lemons. Furthermore, it reduces rind staining and water spot of navel oranges, both serious problems.

Herbicide research with hundreds of chemicals for weed control in citrus orchards has resulted in development of a group of herbicides that provide control on a year-round basis. This practice has reduced cultivation costs by about 50% and permits nontillage of orchards (which has several beneficial effects). Herbicide usage is standard practice for more than 70% of California's citrus acreage (about 235,000 of some 318,000 acres). Also, there is an increasing percentage of avocado acreage being treated with herbicides for weed control.

Research on soils and irrigation has been continuous since the station's beginning. The greatest accomplishment in the soils work resulted from the early classic studies on base exchange, which, together with other relevant soil chemistry research, made possible reclamation of both black alkali and white alkali soils. Other findings have led to effective management of soil salinity in citrus orchards and other crop fields and also to the widespread use of tensiometers to determine the most effective irrigation regimes for citrus, avocados, and certain vegetable crops.

Soils that repel, rather than adsorb, water have been found to exist naturally in large areas of southern California's brushlands. These water-repellent soils impede water intake and thereby contribute to runoff and erosion. Wildfires destroy protective vegetation and greatly increase water repellency of soils, causing a drastic reduction in water intake rates and maximizing runoff and erosion. As a result, large amounts of erosion debris produce sediments in surface waters and create serious problems with roads, storage reservoirs, and groundwater recharge facilities. Treating water-repellent soils with surface-active organic chemicals has effectively reduced water repellency and erosion.

The long persistence of certain pesticides in soils is a major problem in many areas. Research has shown that the diffusion and volatilization of chlorinated hydrocarbon pesticides from soils is one of the mechanisms whereby these chemicals get into the atmosphere and become distributed throughout the environment.

Studies have demonstrated that the amounts of nitrate-nitrogen leaching to groundwaters or into tile drains are sufficiently large to adversely affect water quality in certain situations. The studies also indicate the need for substantially more research on the efficiency with which crop plants use nitrogen fertilizer.

Cadmium contaminates soils, water, and plants in localized areas near emission sources. When this heavy metal is ingested in large amounts by humans, it causes serious illness and sometimes death. Studies have shown that when cadmium-amended municipal sewage sludge is applied to soils, it can be toxic to some plants and that it accumulates in the edible portions of some plants, particularly vegetables. Therefore, if large amounts of sludges that contain cadmium are used on croplands, a serious problem may develop. Cadmium should be removed from waste waters before they are discharged into city sewage systems.

The citrus nematode infests the roots of citrus trees in some 300,000 acres of orchards. Its damage is reflected by decline in tree vigor and reduction in fruit yield. Research on this nematode's biology, life cycle, and pathogenicity has led to effective and economical control procedures through use of chemicals and resistant rootstocks. The preplant and postplant soil treatment for control with nematicides has established fundamental principals useful in the general field of nematode control for perennial plants. Chemical control procedures also have been developed for several species of nematodes on various vegetable and field crops. Basic research on the mode of action of nematicides and on the movement of these compounds in various soil types has provided valuable information to guide development of control procedures. The station's research on biological control and on the ecology of nematodes, particularly the effects of soil factors on nematode populations, has received worldwide recognition. Development of one of the largest research, reference, and teaching collections of plant parasitic nematodes has greatly expedited the overall research program.

An early and great accomplishment in plant pathology at Riverside was the finding that copper spray provides good control of brown rot gummosis fungus, which decays lemon fruit and destroys the bark of lemon, orange, and grapefruit trees. This is a major problem in all of the world's citrus-growing areas.

In 1933 the causal agent of psorosis disease of citrus was identified as a virus. Since insects did not appear to be involved in transmission of the virus, a propagation program was soon developed using virus-free registered budwood and rootstocks to produce healthy citrus nursery trees. Psorosis was the first of many virus diseases to be discovered in citrus trees.

In the early 1940s many thousands of California orange trees were declining rapidly or dying quickly from an unknown cause. The disease was tentatively named "quick decline." Later, however, it was shown to be the same as the earlier-identified "tristeza," a disease of oranges in Brazil, so that name was adopted here. A crash research program was developed that involved staff members from six departments at Riverside. Investigations soon showed that the disease was caused by a virus and transmitted by the melon aphid. The disease was most severe on sweet orange trees growing on sour orange rootstock. About 70% of the orange trees in this state were growing on susceptible rootstocks at that time, and the disease was spreading fairly rapidly. From several hundred rootstocks tested, a few were found that would tolerate the virus, and Troyer citrange proved to be the most important one, providing a solution for this serious problem.

Some 15 virus diseases of citrus have been identified in California. Until quite recently, it was thought that stubborn disease, the state's current most important disease of oranges, grapefruit, and tangelo, also was caused by a virus. But CRC-AES research has now shown that stubborn disease is caused by *Spiroplasma citri*, a mycoplasma-like organism. Several species of leafhoppers are known to be natural carriers of the organism and are suspected of being its vectors in California citrus. Stubborn disease can seriously deform and greatly reduce the amount of fruit produced by infected trees. Most fruit from trees in advanced stages of the disease are not marketable. Although the trees decline and become deformed, they usually are not killed by the disease. No satisfactory control method for stubborn disease has been found, but the search continues. Growing nursery trees in screenhouses to avoid natural infection before planting them in the field is desirable. Since the disease is caused by a bacteria-like organism, not a virus, it is possible that a systemic biocide can be found to control infection within a tree; research along this line is in progress.

Exocortis disease of citrus, also formerly believed to be caused by a virus, has been shown by station researchers to be caused by a small naked RNA molecule that is one-tenth the size of other typical viral nucleic acids. Many properties of this pathogenic RNA ("viroid") are similar to those reported for potato spindle tuber and chrysanthemum stunt viroids. These three unique disease-causing agents may establish a new class of pathogens. Extensive investigations of the citrus exocortis system warrant the conclusion that pathogenic exocortis RNA is a novel molecule. Culture, purification, and bioassay techniques have been developed to provide sufficient research quantities of biologically active RNA separated from host RNA species.

Decay of fruit in storage and in shipping, including export, is an important problem of the citrus industry. The primary pathogens are the green and blue mold fungi, *Penicillium* species. Control measures are applied in the packinghouse operation. Hundreds of compounds have been studied for their control potential. Some were synthesized in laboratories on the Riverside campus. The use of 2-aminobutane and thiabendazole to control these fungi developed largely from CRC-AES research. Current work on the use of benomyl for their control looks promising. Resistance development on the part of the green and blue mold fungi to these types of compounds is a critical matter, and manipulation of their use to avoid or delay the resistance phenomenon is necessary.

Avocado root rot, caused by a *Phytophthora* fungus in the soil, is the most serious disease affecting the state's avocado industry. About 5,000 acres have gone out of production due to the disease, which either kills the trees outright or causes such severe decline that they are almost nonproductive. Extensive research during the past two decades has dealt in detail with practically every aspect of the disease and its control.

The only known way to avoid avocado root rot is to propagate disease-free nursery trees, plant them in disease-free soil, and then take precautionary measures to prevent introduction of the fungus into the orchard through contaminated soil or irrigation water. Disease-resistant rootstocks are the ideal solution to the problem, and promising results are being obtained in comprehensive, long-range studies at Riverside. While many fungicides have been studied, not one has proved practical to use.

Sunblotch is the only known virus disease of the avocado. CRC-AES investigations have resulted in the development of a certification program that provides virus-free nursery trees. Since there are no known vectors of the virus, the certification program is expected to eliminate losses due to the disease.

Basic studies in plant pathology, designed to explain how fungi enter cells, have resulted in the remarkable and probably the first synthesis of a visible cell wall in the absence of a living cell or its membranes. This breakthrough opens new possibilities for understanding of the formation of cellulose and chitin, two of the most important natural substances in the world.

The cell walls of fungi are composed of chitin; the cell walls of higher plants are cellulose. Present research involves isolation of a soluble fungus enzyme, which then is activated to form chitin microfibrils (tiny fibers), the skeletal components and main ingredient in cell walls of fungi. The findings thus far relate only to chitin, but they may apply to cellulose since these two substances are similar.

Control of insect and mite pests by chemicals (insecticides) and by biological means (parasites, predators, and diseases) has been a major research effort at this station since its early days. At present, the CRC-AES is recognized as having one of the three best departments of entomology in this country. Programs employing the newer insecticides have been developed for more than 200 species of insects and mites and for about 50 different crops.

Before the virtual explosion of organic insecticides during and following World War II, research with hundreds of compounds resulted in the development and successful use of a dinitrophenol compound for control of red spiders on citrus and walnuts, and of an antimony compound (tartar emetic) for control of citrus thrips on citrus.

When the organochlorine, organophosphorus, and carbamate compounds become available following World War II, very effective uses of DDT, parathion, carbaryl, and others were developed for control of many species of insects and mites on citrus, avocados, walnuts, and on several vegetable and field crops. Laboratory and field studies with a large number of new compounds provided by chemical industries are continuous, with the result that needed and effective uses are being developed for these materials on various crops. Basic research in insect physiology, toxicology, and biochemistry, involving organochlorine, organophosphorus, and carbamate compounds, resulted in the planned synthesis of many new and promising insecticides.

Purpose of this basic research is to develop selective and biodegradable compounds that are effective insecticides with low toxicity to warm-blooded animals and with no, or at least tolerable, adverse effects on environmental quality. One example of the good progress in this work involves the exploitation of available information on differences in rates of metabolism of specific chemical moieties in insects and warm-blooded animals to design selectively toxic molecules. Using this approach, staff members have synthesized many novel N-arylsulfenyl derivatives of toxic carbamate esters. These derivatives are proving to be promising insecticides with a high degree of safety to mammals.

Because resistance of insects and mites to insecticides is so critical in the development of new chemicals, genetic and other relevant biological and chemical research has been conducted to provide a better understanding of the phenomenon. As a result, the principles involved have been elucidated for several compounds.

Pesticide residue research is also important in the development of new compounds. Accurate determination of the residues of promising new compounds is essential, because of the vital need to protect the consumer of produce treated with pesticides and to protect man and other animals from pesticides used for public health purposes. Chemists have devised extremely sensitive and accurate methods for determining residues for many of these new chemicals. For certain compounds, it is possible to reliably determine the presence of residues in amounts approaching 0.001 part per million. Data from these analytical methods have been widely used in obtaining state and federal approval for the commercial use of many new compounds. The pioneering work on residue detection methodology at Riverside has resulted in the recognition of CRC-AES as one of the leading centers in the world for this field.

Petroleum oil sprays of varying composition have been used for more than 50 years to control scale insects and mite pests on citrus, even though the sprays often resulted in mild to serious injury to trees and fruits. Research during the 1930s led to development of specifications for the various grades of spray oils which became a requirement for their sale. Although these regulations brought about more satisfactory use of oil sprays, leaf and fruit drop and impairment of fruit quality under certain conditions still remained limiting factors in their use. During the past few years, continuing research has shown that current specifications for petroleum oils, together with maintenance of specified irrigation practices, can be used effectively without adversely affecting trees and fruit.

In the mid-1950s, the spotted alfalfa aphid was discovered in southern California. New to the state, this serious pest of alfalfa spread rapidly and caused millions of dollars in losses to growers. Within four years after the U.C. research program on this insect began, the aphid was reduced to a minor pest by the combined action of parasites introduced from the Middle East, a fungus disease, better chemical controls, and the use of an alfalfa variety that was fairly resistant to attack by the aphid. This is an example of integrated control, now popularly referred to as "pest management."

Insect pests of stored grain and dried food products cause losses estimated at more than 10% of world production. Research over many years has resulted in recognition of the CRC-AES laboratory as one of the world's outstanding centers in combatting these losses. Major accomplishments include: the first demonstration that malathion is an effective and safe grain protectant (now universally used); the first evaluation of the fumigant hydrogen phosphide, for use in the U.S., resulting in its general acceptance here and in Canada for insect control in many stored products; development of the first use of gas chromatography to measure and monitor fumigant concentrations throughout the exposure period for stored grain and dried food products.

In 1953 the khapra beetle, a very important pest of stored grain and other stored products, was found for the first time in limited areas of California, Arizona, and New Mexico. Research showed that fumigation of stored products with methyl bromide and treatment with malathion of a barrier area of soil around the fumigated products were two highly effective weapons against the beetle. Using these chemicals, state and federal efforts eradicated the beetle from California within ten years.

Before fresh fruits can be moved from areas infested with a fruit fly pest to non-infested areas, they must be treated to ensure that they carry no living insects. CRC-AES staff members in cooperation with the U.S. Department of Agriculture (USDA) in Hawaii developed the successful use of ethylene dibromide as a quarantine treatment for this purpose. The treatment has been used universally for many years.

Research on the pink bollworm, an injurious pest of cotton, resulted in development of a chemical control program. Although this program is widely used, it is expensive, and sometimes adverse side effects result from the chemicals. As an alternative, intensive research has been done on pheromones, volatile compounds emitted by the female pink bollworm moth to attract the male moth for mating. As a result, the two compounds involved have been identified and synthesized. Use of the female pheromones in a 1974 field experiment on about 4,000 acres of desert cotton produced encouraging results with respect to controlling the pest by disrupting its mating. An adequate concentration of pheromones in the air confuses male pink bollworm moths to the extent that they cannot locate females for mating and no viable eggs are produced.

Mosquitoes in California have developed resistance to most of the insecticides that formerly were effective controls. Among the many control strategies under study is the use of self-imposed regulatory mechanisms inherent in mosquito larvae. It was found that when there is overcrowding, the larvae produce compounds which regulate the population. Several of these compounds have been identified, synthesized, and evaluated for possible use in mosquito control. This is the first time a chemical basis for overcrowding stress has been established in animals. Work is continuing to exploit these chemicals for mosquito larvae control.

Research on nuisance and disease-carrying flies (for example, the Hippelates eye gnat, a serious pest in portions of the state) has shown that the most promising control strategy entails the use of attractant chemical baits. Formulations of a synthetic attractant (U.C. Fly Attractant) and also enzymatically and microbially produced baits have been developed and used for effective areawide control of eye gnats in the Coachella Valley. This is the first example of successful use of attractive baits to control the eye gnat pest, and promising results are being obtained with bait formulations for the integrated management of other nuisance and disease-carrying flies.

Research on the diapause phenomenon in larvae of oriental fruit moths and codling moths resulted in a valuable breakthrough. It was found that diapause is induced by exposure of the fruit in which larvae are feeding to day lengths (light and darkness) characteristic of the period in late summer and autumn during which they normally enter hibernation. Use of other day lengths and complete darkness prevents diapause and allows continuous rearing of the insect. It is now practical to mass-produce these two species, and many others on which to rear large numbers of parasites, predators, or disease pathogens for biological control work, and for insecticide evaluation research—all work that requires a continuous supply of insect eggs, larvae, pupae, or adults.

Since 1924 the station at Riverside has been America's leading university center for biological control research. One of the classic examples of biological control is the citrophilus mealybug on citrus, an introduced species first found in this state in 1913. It spread rapidly, and by the late 1920s infested over 100,000 acres of citrus. Moderate to heavy infestations caused serious crop losses, with no satisfactory chemical control method available. But in 1927 a station staff member discovered in Australia several species of mealybug parasites, which were successfully imported into California. These parasites were mass-produced in insectaries and released in many infested citrus orchards in each locality. Two species multiplied rapidly and dispersed to other infested orchards. Within one year the citrophilus mealybug was no longer of economic importance. Two species of parasites have kept the mealybug population at sub-economic levels since 1930.

While less spectacular than the biological control of citrophilus mealybug, highly significant control resulted from parasites introduced from various parts of the world to suppress the black and red scale insects and the woolly whitefly and citrus whitefly on citrus, the walnut aphid on walnuts, the pea aphid on peas, the green peach aphid on peaches and several other crops, and the olive parlatoria scale on olives and various ornamental plants. CES staff members conducted foreign explorations for natural enemies of parlatoria scale insect and discovered the two species of parasites, one in West Pakistan and the other in Iran, that proved to be very effective in controlling this pest. Staff members at U.C. Berkeley received these parasite shipments from abroad, developed methods of mass-producing them for field liberation, and evaluated the results, which appears to be a classic example of biological control.

The discovery in various foreign countries and the introduction of several species of predaceous mites to control spider mites on citrus, avocados, and other crops also is yielding promising results.

Biological control research in insect pathology led to the commercial use of the bacterium *Bacillus thuringiensis* to control larvae (caterpillars) of several species of moths that are pests of various crops.

Puncture vine, a serious weed pest, has been brought under fairly satisfactory control in southern California by two introduced species of weevils. It no longer is necessary to apply herbicides on this roadside weed to prevent spread of its sharply spined seeds. Formerly, this was a necessary regulatory practice.

Historically, date production in the Coachella Valley has required the arduous and hazardous work of climbing date palms up to 50 ft high to hand-pollinate their flowers and to harvest their fruits. Due to labor shortages for this work, cooperative research by CRC-AES and USDA agricultural engineers began in the early 1960s to develop mechanical methods for pollinating and harvesting the fruits. Shake-harvest methods were developed and have been widely accepted for harvest of the principal variety, Deglet Noor. Mechanical harvesting reduced labor by 80% and eliminated most of the hazards. Somewhat later, a successful high-velocity, high-nozzle pollen duster was developed. Recent research has resulted in a pollen threshing and recovery machine which supplies enough pollen for the pollen dusting operation.

Mechanical harvesting of citrus also has been studied extensively in cooperation with the USDA, and the parameters of the problem have been established. Prototype machines for moving pickers into fruit-bearing zones of trees and for shake-and-catch mechanical harvest were developed. After many tests on the nine most promising machines, it has become clear that the relatively small increase in harvest rate provided by these machines will not justify their cost nor offset the many problems of managing a large fleet of them. However, with shake-and-catch harvest machines, it is technically feasible to harvest grapefruit in the Coachella Valley and also to harvest the Bacon variety of avocado.

During the 1920s and 1930s when most of the English walnut industry was in southern California, research by CES staff members provided a solution for several major problems of this crop. Late-season irrigation proved to be a simple solution to the serious problem of moldy and discolored kernels. Irrigation caused the walnut husks to split, permitting the walnuts to drop clean, and harvest was speeded up. Artificial dehydration of walnuts was developed, which maintained high quality and also enabled growers to market their crop early to take advantage of the Christmas trade. Dieback of large limbs in many orchards was a serious problem, until station researchers found that irrigation in the dormant (winter) season would solve it. Irrigation and fertilizer regimes and also pest control programs were developed.

Air pollution research to determine the effects of smog on plants was initiated in 1951 by staff members at the Riverside station. Perhaps the first diagnosis of plant injury by air pollution in the South Coast Air Basin was made by a staff member in the early 1940s. In the early stages of air pollution research, ozonated olefins were believed to be the agents principally responsible for plant injury in the basin. However, later research results showed that ozone and peroxyacyl nitrate (PANs) were the phytotoxic substances and that the PANs were important eye irritants. The peroxyacyl nitrate compounds were first detected, identified, and used experimentally at Riverside. Extensive studies have revealed highly significant reductions in crops of navel oranges, lemons, grapes, and cotton growing in polluted areas. Continuing experiments indicate that crop reduction due to oxidant pollutants may extend to sweet corn, alfalfa, tomato, strawberry, chili pepper, and probably to other crops. Air pollution damage also occurs on several ornamental plants and on pine trees growing in nearby mountains.

Pioneering work showed that repeated exposure to hydrogen fluoride concentrations in the range of 1 to 2 parts per billion could suppress citrus tree growth, reduce fruit production, and, in some instances, produce visible leaf symptoms. One result of this research was development of fluoride emission controls by specific industries.

Investigations of the contribution of agricultural waste burning, range burning, and disposal of forest waste to the overall air pollution problem have shown that while the soiling properties of the smoke and the obscuring of visibility from these operations are objectionable, the smoke's contribution of precursors of smog and generation of toxic substances is minimal.

Research on vitamin D during the past decade at the CRC-AES has resulted in phenomenal developments in understanding this vitamin's biochemical mode of action. Fat-soluble vitamin D is essential to higher animals to ensure their adequate absorption of dietary calcium, which is necessary for normal development of the skeleton; otherwise, the rickets disease ensues.

Basic studies in biochemistry revealed that the molecular form of vitamin D (active in the intestine) which stimulates calcium absorption is produced only after two successive structural modifications of the parent vitamin D. Both involve hydroxylation: the first occurs in the liver to give 25-hydroxy-vitamin D and the second in the kidney to yield the hormonally active form, 1,25-$(OH)_2$-D_3. This latter compound, after its production by the kidney, migrates to the intestine. There it localizes in the nucleus of the cell to mobilize genetic information required for elicitation of the typical vitamin D-related biological responses, including stimulation of intestinal calcium transport.

This new information has profound medical implications. It is now known that people develop uremia or chronic kidney failure because of diseased kidneys, which cannot produce the vitamin D metabolite (1,25-$(OH)_2$-D_3) necessary to prevent these lesions. This compound now has been synthesized on a large scale, and it has been clinically evaluated on uremia and other diseases related to vitamin D deficiency.

Two staff members were elected to the prestigious National Academy of Sciences as the result of basic research they performed while at the station: the late Dr. Walter P. Kelley, Soil Chemistry, 1942, and Dr. Robert L. Metcalf, Insect Toxicology and Physiology, 1967.

A tangible measure of an institution's scientific accomplishments is the quantity and quality of publications reporting its research results. About 35 major books or monographs have been published by station staff members. No tally has been made of the station's technical publications in recognized scientific journals. However, it is estimated that the station's total contributions since its founding in 1907 greatly exceed 5,000 in the scientific journals, various University of California publications series (*Hilgardia*, bulletins, and circulars), *California Agriculture*, semi-technical agricultural and other trade journals.

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HYBRID GRAIN

TO EVALUATE the relative merits of grain sorghum hybrid cultivars and their interaction with environment, seven hybrids were grown in comparison with two established varieties (Meloland and D.D. 38) and one experimental variety in trials conducted at the Imperial Valley Field Station. The trials were planted April 15, June 1, and July 15 in each of five years, 1962 to 1967, on 40-inch beds with five replications. Cultural practices were typical for the Imperial Valley area, except plants were hand-harvested.

Emergence time was the same for varieties and hybrids, with the June and July plantings emerging one to two days sooner than the April plantings. Days from planting to flowering varied among cultivars and planting dates. They range from 69 days for RS 610 to 77 days for Meloland, 55 days for DeKalb C44b to 69 days for Paymaster Apache, and 54 days for DeKalb C44b to 64 days for IV 581400 for April, June, and July plantings, respectively. The average of all cultivars was 73, 63, and 60 days for April, June, and July plantings, respectively, decreasing as planting was delayed except for RS 610 and NK 210 which flowered earlier at the June planting than the July planting. The greatest difference was between the April planting date and the June and July plantings. Cultivars, date of planting, and cultivar by planting date interaction were significant at the 5% level.

Cultivars accounted for the major differences in plant height. Planting date