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A REVIEW OF AVOCADO RESEARCH AT THE UNIVERSITY OF CALIFORNIA, RIVERSIDE

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It is the purpose of this paper to review the over-all avocado research program now in progress at Riverside. Because of the limitation of space, only a very brief outline of the most important projects will be presented.

It, seems appropriate to preface this review with some remarks concerning the California Avocado Society. I am sure that I speak for all of my colleagues at the Citrus Experiment Station when I say that we are very grateful to the members of your organization for the friendly and intelligent cooperation you have rendered to us in our research efforts conducted in your orchards. You have been most generous in supplying land, trees, fruit, facilities and labor in support of our field research projects. But, most of all, we are grateful for the stimulus that you have provided to the individual research worker. We find among avocado growers an unusually high proportion of men who have boundless enthusiasm for fruit growing, coupled with real vision and insight into cultural problems. Through these qualities, your leaders have been able to instill in us a very strong desire to help to solve your problems.

The unusual qualities of many avocado growers are also reflected in the activities of the California Avocado Society. It has had a very significant influence in shaping and supporting the present program of avocado research at Riverside. For example, the California Avocado Society played a prominent role in persuading the Regents of the University to establish the South Coast Field Station at Tustin. These efforts began more than 10 years ago, and recently the station celebrated its 5th anniversary. To date, more than 30 acres of experimental avocado plantings have been established at this field station. Grants from the California Avocado Society to the University have had a strong influence in accelerating research programs aimed at finding orchard control measures for the cinnamon fungus problem, and in partly financing foreign explorations for fungus resistant rootstocks. You have contributed additional grants for the support of basic work on avocado nutrition and the biological control of avocado insects.

Thus it is with a great deal of pleasure and satisfaction that we take this opportunity to express to you our sincere gratitude for your very substantial efforts in our behalf. In a very real sense, the program reviewed below is your research program. The California Avocado Society played an important role in shaping its direction and developing its momentum.

Avocado Variety Evaluation (W. B. Storey): The objectives of this project are: a) To

appraise the performance of avocado varieties, with particular reference to the intermediate valley climatic zone designated Area 8 by the Avocado Variety Committee of the California Avocado Society; b) To evaluate newly introduced or newly registered varieties, and varieties produced in the avocado breeding program; c) To maintain a source of varietal material for use in avocado breeding.

Seventy varieties and strains are represented in an orchard on the Riverside campus. Nineteen varieties are represented in an orchard planted at Greenspot, San Bernardino County, in cooperation with the East Highlands Orange Company. Observations are continuing on flowering, tendency to alternate bearing, cold tolerance, productivity, and fruit quality. Supplementary observations on these and other varieties in other climatic areas are made in conjunction with the activities of the Avocado Variety Committee.

A list of 72 varieties has been drawn up in collaboration with Dr. B. O. Bergh for topworking to well established seedlings in Field 23 at the South Coast Field Station. The varieties selected represent those which either are of commercial importance in California or have some value for breeding, various lines of research, or classroom instruction. Also to be included in the orchard are several varieties from out-of-state sources, and new hybrids which look promising for introduction into the trade as commercial varieties.

Avocado Rootstock Experiments (W. B. Storey, F. F. Halma): The objectives of this project are: a) To determine the effects of rootstock varieties on productivity and economic longevity of commercially important scion varieties; b) To determine root-stock effects on tree size, and, if possible, on fruit size, quality and time of maturity; c) To observe the reaction of rootstock varieties to different soils, environmental factors, and tree disorders.

About 35 out of 50 seedling rootstock plots established with cooperators continue active. These plots consist of seedling rootstocks from 37 varieties of parent trees. Represented are 13 Mexican, 22 Guatemalan, and 2 West Indian varieties. Grafted to these, depending upon the climatic areas in which the plots are located, are 5 commercial varieties: Fuerte, Hass, Anaheim, MacArthur, and Rincón. Observations are continuing on these plots.

Of interest are two plots on the von Normann property at Fallbrook. One plot consists of standard Fuerte trees grafted on Topa Topa seedlings which are interplanted with own-rooted cuttings of Fuerte. The other plot is similar except the variety is Hass. The plots were installed in 1954. Some yield records have become available from the Hass plot. So far it has been observed that variability in yield is as great among the rooted cutting trees as among the grafted trees.

About 400 cuttings representing about 40 clones have been rooted for a clonal root-stock experiment to go into Field 5 at the South Coast Field Station. As the cuttings become ready, the Newman strain of Fuerte is being grafted to them in accordance with the recommendation of this Committee at its meeting on December 15, 1958, that this strain of Fuerte be the scion variety tested on clonal rootstocks.

Avocado Breeding (B. O. Bergh, W. B. Storey): During the past year approximately 2,500 self-pollinated seedlings were placed with eight new private cooperators. An

additional 1,500 trees were planted on University property. These latter also consisted chiefly of self-pollinated seedlings, but there were a few each of the following: open-pollinated seedlings, hybrids, seedling selections to be tested, varieties to be self-pollinated. Parental varieties involved in last year's plantings were the following, in order of decreasing progeny number: Bacon, Fuerte, Indio (Desert), Hass, and seven miscellaneous varieties.

During the spring, 1961, planting season, approximately 3,800 seedlings were set out. Less than 1,400 of these were placed on University property, either at C.E.S. or at S.C.F.S.; this completes all presently available University land space for avocado seedlings. The remaining seedlings were placed with private cooperators in San Diego, Orange, Riverside, Ventura, Santa Barbara and Glenn counties. A few hundred seedlings had to be discarded due to lack of planting space. Hass and Bacon were the parents used most extensively; Fuerte. MacArthur. Taft. Duke. Ganter, and Nowels are also represented amongst the progenies. Perhaps because low avocado prices have resulted in reduced interest in growing the trees, many of the private cooperators failed to provide adequate care for our trees during this past year. As a result, of all trees placed on private property to date, only about one-half remain in good condition.

Selection of the most promising seedlings is continuing. These, of course, require extensive testing, in different locations and in different years, before any of them can seriously be considered for naming as a new variety. Last April, nineteen of these selections were top-worked in from one to three different locations in San Diego County; these and a number of other selections have also been top-worked to trees in different locations in the San Joaquin Valley.

A shortage of suitable land under effective control of the University continues to be the chief factor limiting the rate of progress on this avocado breeding project. An additional 10 to 20 acres could be used very effectively for the purpose of planting and fruiting out hybrid and selfed seedlings.

Avocado Fertilizer Studies (T. W. Embleton, W. W. Jones, C. K. Labanauskas): Previous studies showed that too little or too much nitrogen applied to Fuerte avocado resulted in a reduction in yield. The most productive range of nitrogen in Fuerte leaves sampled in the August-September period was found to be from 1.6 to 2.0% N.

Studies with the MacArthur variety indicate that the leaf standards are similar to those of the Fuerte, but considerably larger applications of nitrogen are needed to bring the nitrogen in the leaf in the desirable range than is needed for the Fuerte variety. In a clean cultivated MacArthur orchard, 5 pounds of nitrogen per tree applied in the spring of I960 resulted in only 1.85% N in the leaves in September. The last year's results show the following leaf nitrogen yield relationship for the Mac-Arthur variety:

% N in leaves 9/59	Pounds of fruit harvested per tree, 5/60
1.59	179
1.29	4
1.39	17
1.51	62

Presumably, yields would have been greater if the leaf levels for N had been higher.

Nitrogen rates applied to the soil have been increased in an attempt to push the leaf level above 2.0%.

Three new nitrogen rate-timing factorial experiments were initiated in 1960, two on Hass and one on Zutano. For 1961 one is contemplated for the Fuerte variety.

Avocado Irrigation (S. J. Richards): Differential irrigation treatments were continued on plots at the Citrus Experiment Station. Because of the poor tree condition under the 10-bar treatment in past years, this treatment was modified to 5 bars. Trunk circumference measurements showed mean tree size to be 25, 22, and 17 inches for the *½-,* 1-, and 5-bar irrigation treatments, respectively. The 5-bar treatment had no fruit and the other treatments produced less than 50 Ibs. per tree. Over 50% of the crop was lost as wind fall.

The Bacon avocado planting on Field *4* of the South Coast Field Station was carried through 1960 under uniform management and irrigation. Of the 680 trees, including future guard rows, on Ganter seedling rootstock, 67% were rated adequate or better and only *2%* were dead. Of the 288 trees grafted on rooted cutting, only 41% appeared adequate and 16% were dead or very poor.

A greenhouse study using Ganter seedlings with soil from the South Coast Field Station showed a response to iron chelate. Leaf analyses by F. T. Bingham confirmed the observed symptoms.

Alluvial soil with sand and silt layers was shown to favor root rot development in Santa Barbara County. Fuerte avocado trees growing in 55-gallon drum containers have not as yet shown differential growth response from irrigation treatments after inoculating the soil with root rot fungus,

Avocado roots avoid growing into sand as demonstrated in a greenhouse experiment with layered soil conditions.

Studies of the Biology and Control of Insect and Other Pests of the Avocado (W. H. Ewart, J. C. Ortega): Studies were initiated during 1960 at the South Coast Field Station to systematically evaluate phytotoxicity characteristics of several insecticides that might be useful in controlling one or more avocado pests in orchards where the natural control balance now maintained is disturbed. Preliminary information has been obtained on young Fuerte, Hass, Bacon, and Anaheim trees sprayed with 13 insecticides, each of which was applied at a dosage of one-half pound toxic compound per 100 gallons of water. No apparent damage occurred on trees sprayed with Delnav, Diazinon, Dibrom, Guthion, lindane, malathion, Phosphamidon, Sevin, Tedion, and Thiodan. Dirnethoate caused a slight drop of older leaves on all four varieties while Trithion caused a similar type of damage, but less pronounced and only on the Bacon and Anaheim varieties. Ethion resulted in a slight burning of the margins of young leaves.

In field tests, sprays containing a sabadilla preparation (Thriptox) plus sugar showed promise in suppressing greenhouse thrips populations.

Greenhouse studies are under way to screen new insecticides from the standpoint of phytotoxicity and effectiveness against various avocado pests. Materials showing promise in these studies will be tested further under Field conditions as suitable

populations of pests become available.

Biological Control of Insects and Mites (C. A. Fleschner, J. A. McMurtry): The mass production and field release of imported mite predators have been receiving emphasis in the program for biological control of avocado pests. Two species of Stethorus beetles have been released in large numbers in several avocado orchards in southern California. Through the cooperation of the Commonwealth Institute of Biological Control, new species of predatory mites will be imported from India. These predators likewise will be released in avocado orchards with the hope that they will become established and play an important part in controlling avocado mites.

Research is also being directed toward the biological control of the greenhouse thrips on avocados. A survey of native natural enemies of this insect has been initiated. An egg parasite, Megaphragma mymaripenne, has been recovered in large numbers in a thrips-infested orchard in San Diego County. The possibility of releasing this parasite in orchards where it is not present will be investigated. Arrangements are being made for the importation of new parasites of the greenhouse thrips from the West Indies and South America. The effects of certain insecticides used for thrips control on natural enemies of insects and mites will be evaluated in the coming year.

This research is being supported in part by contributions from the Nick Thille Memorial fund.

The Biology and Control of Nematodes Attacking Avocado (S. A. Sher): In tests in Ventura County, pre-plant soil fumigation of root-lesion nematode infested land with dichloropropane-dichloropropene (D-D or Vidden D) continues to show marked increase in growth of avocado trees (twice the size of untreated trees) after the fourth growing season. Post-plant treatment of young avocado trees infested with root-lesion nematodes with 1, 2-dibromo-3-chloropropane (Nemagon or Fumazone) has not shown any noticeable response after the first year. Nematode control in treated areas has been good.

Pratylenchus vulnus, the cause of root-lesion nematode disease of avocado, has been found in avocado roots in San Diego County. This is the first finding of this pest in San Diego County.

Avocado Sun-Blotch Disease (J. M. Wallace, P. R. Desjardins, G. A. Zentmyer): When time and facilities have permitted, virus purification, electron microscopy, and mechanical transmission studies have continued in an effort to develop a quick test for sun-blotch virus infection. Nothing of practical use has come from past studies. Future efforts will include serologica! techniques to learn if sun-blotch virus antiserum can be prepared for use in detecting infected trees. Further efforts to transmit the virus by Juice inoculation to hosts which will develop early diagnostic leaf symptoms will be made using the technique recently found by Florida workers to be successful in mechanical transmission of citrus viruses.

The origin of symptom less carrier trees that transmit the virus through seeds to most or all of their seedlings has been quite well worked out.

Other work in progress involves studies on heat elimination of the virus from avocado clones.

When requested by growers, nurserymen and research workers, indexing of trees used as sources of budwood or for rootstocks has been carried out.

Diseases of Avocado and Minor Subtropical Fruits (G. A. Zentmyer, B. O. Bergh, F. T. Bingham, L. J. Klotz, P. H. Tsao): Large numbers of seedlings from California, Florida, Texas, and 9 Latin American countries have been tested for Phytophthora root rot resistance using the nutrient solution method (capacity recently increased 6 times). Several more sources of slight resistance were found, but no high resistance. Trips to Mexico and the Caribbean resulted in 93 additional collections with over 2000 seeds; **P. cinnamomi** was found in several new areas in Mexico and Puerto Rico.

The substance exuding from avocado roots that attracts zoospores of P. cinnamomi is being investigated (cooperative with R. C. Bean); some relation to resistance is evident.

Soil fungicides, Dexon and SD 4741, prevent and control root rot on seedlings in the greenhouse when applied as periodic drenches, and show some benefit in the field. Trials of chemical and mechanical barriers in the field show promise.

A new systemic organic chemical has given good results in chemotherapy tests (upward and downward translocation) against Phytophthora canker of **Persea indica** and of avocado seedlings, and has reduced root rot when applied to foliage (cooperative with W. Moje).

Studies are continuing on biological control of root rot by means of various organic amendments.

In a soil survey conducted by R. M. Burns, close correlation was found between several soil types and root rot occurrence, confirming earlier reports that the disease appeared to be primarily a problem on poorly drained soils.

P. cinnamomi has been found causing a trunk canker of macadamia trees in San Diego County; pathogenicity of the fungus was established by inoculation tests. Of several hundred macadamia trees planted in infested soils, only 3 have developed cankers.

The soil fungus **Rhizoctonia solani** was found to be pathogenic to avocado seeds and to roots of young seedlings in the greenhouse. Soil steaming or fumigation eliminates the fungus under nursery conditions.

Laboratory Studies with Phytophthora Zoospores (G. A. Zentmyer): Young, vigorously growing roots of avocado seedlings were found to have a strong attraction for the free-swimming zoospores of the cinnamon fungus, **Phytophthora cinnamomi,** attacking avocado roots. Such "chemotaxy" of the zoospores for roots occurred within a few minutes, and the concentration of spores was greatest in the rapidly-growing portion of the root just below the root tip. The cinnamon fungus zoospores were not attracted by growing root tips of citrus and several other species of plants tested, or by dead avocado roots. A water soluble substance, when extracted from avocado roots and taken up on filter paper discs, was attractive to the zoospores. These findings may have important implications for a better understanding of resistance and susceptibility of plants to fungus attack, and ultimately in devising effective control measures.

Weed Control (B. E. Day): Field and laboratory studies with monuron for control of

annual weeds in avocado orchards were completed in 1957 and registration for its use was obtained with a residue tolerance of 1 ppm. This herbicide has proven successful in field practice and it has become the standard means of annual weed control in avocados. Most of the avocado acreage ¡s now under treatment with monuron and no unexpected problems or limitations in its use have developed. This method has substantially lowered the cost of weed control in avocado orchards.

Current experiments indicate that simazine may also be safely and effectively used in avocado orchards for the same purpose and with essentially the same limitations as monuron. No leaching is required to incorporate simazine into the soil but once in the soil it remains effective longer than monuron. Field trials have shown that one annual treatment with simazine can provide the equivalent in weed control to the present practice of two treatments per year with monuron. Simazine is not yet registered for use in avocado orchards.

Thirteen herbicides have been screened for possible use in avocados over the past two years. Of these, atrazine shows some promise for possible use in avocados.

Bermuda grass ¡s considered to be the most serious weed problem in avocado culture. Extensive field and laboratory work is in progress aimed at development of an effective and economical chemical control of this weed in citrus and avocado orchards. Of all of the herbicides now commercially available, dalapon provides the most efficient control of bermuda grass. Unfortunately, following treatment, the spray residues remaining on the grass foliage become leached into the soil, causing injury to avocado trees through contact with tree roots. In recent work at Riverside, special formulations of dalapon have appeared to overcome this limitation and offer the promise of providing, for the first time, a safe and economical control of bermuda grass in orchards. This work is continuing as a major effort of the weed control workers at the Citrus Experiment Station.

Biochemistry of Maturation in Avocado Fruits (R. C. Bean, G. G. Porter and Barbara Barr): During the last year extensive work has been done on the possible application of electrical characteristics to the measurement of maturity in avocados. Tests done under field conditions with the cooperation of the testing station in Escondido indicated that there was a correlation of fat content with electrical impedance (measured at 70 cps) but the range between fruit of given fat content was too great in relation to the total range to allow use of this simple test under normal conditions. In laboratory tests in which the impedance was measured under controlled conditions very shortly after harvest, the variability range was considerably better and the test might be considered useful where such conditions could be met. Further tests were carried out to determine whether some other measurement could be used with more reliability. Comparisons of impedance at high and low frequencies showed that most of the impedance was due to capacitive reactance and this was the factor which changed during maturation and ripening. It was found that the changes in capacitive reactance during ripening were inversely correlated with the changes in respiration. The discovery has been useful under laboratory conditions in determining the stage of ripening for individual avocados during tracer experiments.

Changes in total composition and cell wall components have also been followed to determine whether texture and ripening qualities could be correlated with any factor in

the cell wall. The total material soluble in alcohol and in ether (sugars, acids, fats, some polysaccharides) remains constant for all sizes of fruits at any period of growth. There is very little change in this total fraction during growth even though the fat content is increasing steadily. This means that the gain in fat is being offset by losses in sugars, acids and alcohol-soluble polysaccharides.

In the early stages of growth, hot-water-soluble polysaccharides consistently decrease with increased fruit size. In the later stages, as maturation is approached, the water-soluble polysaccharides increase with increasing fruit size. It would appear that two polysaccharides are involved; one which is predominant during early growth but decreases as fruit size increases and another which replaces the first as the fruit matures. Although there is a definite relation to fruit size, these polysaccharides (mainly xylands and glucosans) do not necessarily relate directly to maturity, although there is some basis for belief that further study might show correlation with physiological maturity.

Other cell wall fractions are very small, comparatively, and either appear relatively constant during growth or vary unpredictably. Cellulose tends to show a slight increase with size of fruit but remains constant over the season.

Studies on the formation and interconversions of sugar in the leaves and fruit of the avocado show that mannoheptulose (the unique seven carbon sugar of the avocado) is formed as a product of photosynthesis parallel with sucrose in the leaves. Perseitol (the poly-alcohol derived from mannoheptulose) is formed after mannoheptulose and its formation is not light dependent, indicating that it is a secondary product being formed from previously synthesized sugars. Tracer mannoheptulose and perseitol are interconverted in fruit and leaf discs but not in other types of tissue preparations from the avocado.

Lipid Synthesis by Cell-Free Preparations from Avocado Mesocarp (J. B. Mudd and P. K. Stumpf): In a cooperative study, the Department of Biochemistry and Biophysics, University of California, Davis, and the Department of Plant Biochemistry, University of California, Riverside, isolated mitochondria from avocado mesocarp incorporated radioactive acetate into triglycerides and phospholipids via long chain fatty acids. The fatty acids labeled were palmitic, stearic and oleic. Circumstanial evidence indicated that stearic acid was the precursor of oleic acid. It was shown that the biosynthesis of oleic acid was absolutely dependent on oxygen while the biosynthesis of saturated fatty acids was equally rapid in air or under anaerobic conditions. In the formation of glycerides it was found that the biosynthesized oleic acid was preferentially incorporated into phospholipids.