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THE PRINCIPAL WORK OF THE DIVISION OF SUBTROPICAL HORTICULTURE ON THE AVOCADO

Robert W. Hodgson
Assistant Dean, College of Agriculture, University of California.

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HISTORY

The Division of Subtropical Horticulture (Citriculture until 1923) early became interested in the commercial possibilities for avocado culture in California. A field survey of the comparatively few and small plantings was conducted shortly after the division was created in 1912 and led to the publication of Experiment Station Bulletin 254 in 1915. Members of the division also participated in the organization of the California Avocado Association (Society since 1943) in that same year. For various reasons, mainly associated with World War I, it was not practicable to undertake a research program until more than a decade later. Anticipating the early removal of the division to southern California, which did not occur however until it was transferred to the Los Angeles campus in 1932, in 1927 a general experiment station project was outlined which provided for the study of flower development and behavior and of the factors affecting fruit-setting and bearing. Of necessity the work done while the division remained in Berkeley was confined to field observations and limited laboratory studies. The removal of the division to Los Angeles permitted the undertaking of field experiments, which were started in the fall of 1933 and have been conducted ever since.

For clarity and convenience, in this review the work done to date will be summarized under headings which reflect the major industry problems that have received attention.

BEARING BEHAVIOR

The erratic bearing behavior and consequent low average yield of the principal commercial variety, Fuerte, had early been noted by the growers in the young industry and was a matter of general concern, for it was realized that higher yields and more regular production would be necessary to bring this new and strikingly different fruit within the purchasing power of the average consumer and thus permit the development of a commercial orchard industry.

At the time the research program of the division was started this behavior was generally attributed to uncertain or inadequate pollination, the former resulting from irregularity in the two opening and closing periods which characterize avocado flowers and the latter arising from lack of cross pollination from a reciprocal variety. The field observations on

flower behavior, pollination and fruit-setting made while the division was still headquartered in Berkeley did not support this belief; indeed they resulted in the tentative conclusion that flower behavior and pollination are not factors of primary importance in the bearing behavior of the avocado in California, a conclusion later strengthened by field experimentation, although further study is desirable and is planned.

Immediately following its removal to Los Angeles, studies were undertaken on the bearing behavior of the Fuerte variety and of possible ways and means by which it might be influenced or controlled. The former involved the analysis of the yield records, for periods ranging from 5 to 15 years, of nearly a thousand trees in plantings distributed in the major producing areas and the correlation of the findings with weather data for the blossoming and fruit-setting period. The latter involved field experiments on the effects of girdling, fruit-thinning, crop removal, early harvesting, pruning, soil fertilization, top-working, double-working and rootstocks, conducted over a period of years.

It early became evident that the Fuerte variety exhibits all the characteristics of the alternate bearing habit but that one or more modifying factors are also operative and responsible for the erratic nature of the alternate bearing tendency. Subsequently, it was established that mean temperature during the fruit-setting period is the principal modifying factor, in that it can cause accentuation or depression of the alternation or actually bring about change in the stride of alternation. Thus the industry crop produced in any given season is determined by the percentage of trees in the on-crop phase and temperature conditions during the period of fruit set. Analysis of the production chart of the California avocado industry (Fuerte variety accounts for 65 to 85 per cent) for the 20-year period 1926-46 reveals almost perfect alternation throughout. Only three changes in stride occurred therein —one in 1931-32 following two mild winters, and two following a succession of cold winters, namely in 1934-35 and 1941-42.

While the bearing behavior of other varieties has not been studied as exhaustively *as* that of Fuerte, it is evident that most varieties exhibit a definite and fairly regular alternate bearing tendency, some more so than others, but that there are a few comparatively little affected. The principal reason for the particularly erratic bearing behavior of the Fuerte variety apparently lies in the fact that it blossoms much earlier than most other varieties and hence is subject to lower mean temperatures during the flowering and fruit-setting periods.

Both observational and experimental evidence support the conclusion that in alternate-bearing varieties the production of a large crop so exhausts the tree of certain reserve materials that it is unable to set and mature another large crop until at least one growing season has elapsed. The present evidence suggests that the reserve materials exhausted by the production of a large crop are organic rather than mineral in nature and consist mainly of starch.

To date only two means have been discovered by which the alternate-bearing tendency in the Fuerte variety can be significantly influenced and neither is capable of extensive practical application. First, on girdled limbs and trees, harvesting of the fruit as soon as it has attained horticultural maturity—early harvesting—has been demonstrated to affect

materially both time and amount of bloom for the succeeding crop and to permit the production of two good crops in succession. Ungirdled limbs have not shown this response, but early harvesting of ungirdled trees has shown a tendency to reduce the amplitude of alternation. Obviously, however, early harvesting of entire trees cannot be widely employed throughout the industry because of possible effects on price levels and marketing programs. Second, removal of the entire crop from ungirdled limbs or trees at any stage up to horticultural maturity will change the stride of alternation. This is a useful fact in connection with experimental work but obviously has little practical significance.

BETTER VARIETIES

Since the alternate-bearing tendency is an inherent varietal characteristic and to date no practicable means have been found for its control, it seems clear that the best, if not only, solution to this problem lies in the finding or development, by breeding, of Fuerte-like varieties of more regular bearing behavior and less subject to alternate bearing.

In the bearing behavior studies it early became evident that, under apparently identical conditions of environment, there were trees which consistently were more regular in bearing behavior than others and hence more productive. Limited trials of some 20 selections from both high and low yielding trees have contributed evidence which supports the conclusion that there are two, and possibly more, strains of the Fuerte variety, one of which is a more consistent bearer in the coastal districts. The fact that most of the Fuerte trees planted during the past 15 years have been propagated from parent trees of known superior bearing behavior may well be largely responsible for the consistent increase in trend of orchard yields.

A comprehensive breeding program was undertaken in 1940 in which the problem was attacked from three approaches: (1) Crosses involving Fuerte pollen on varieties of known superior bearing behavior; (2) crosses between other varieties of known desirable characteristics, and (3) the growing of large numbers of seedlings from open and self-pollinated varieties. That the last mentioned procedure offers promise had already become evident from observations on chance seedlings, many of which have been planted by amateurs and home owners. Among those brought to notice are several with better bearing behavior than Fuerte. Unfortunately, for reasons associated primarily with World War II, it was necessary to discontinue work on this project for several years. Active work was resumed last year, however, and the program is now going forward as rapidly as practicable.

For many years members of the division have served on the Variety Committee of the California Avocado Society and the division has cooperated in the variety trials of that organization. In connection therewith numerous introductions have been made, principally from Mexico and Central America, of materials of promise either as commercial varieties or for breeding purposes.

BETTER ROOTSTOCKS

Because of the insistence of nurserymen that field evidence existed of superior Mexican

race rootstock varieties and seedlings, shortly after its transfer to Los Angeles a comprehensive rootstock experiment was initiated which now involves 16 seedling selections and 12 named varieties as rootstocks for the Fuerte and Nabal varieties. This was later supplemented with a considerable number of Guatemalan race varieties and one West Indian race variety employed as rootstocks for a half dozen or more of the principal commercial varieties. A large number of field trials now exist, scattered throughout the industry from San Diego to Santa Barbara.

While most of the trials are still too young to have provided reliable results, and the data accumulated have not been given critical analysis, it appears that there are differences, though not striking, within both the Mexican and Guatemalan race varieties. Moreover, observational evidence of incompatibility between certain Guatemalan race varieties and the Mexican race as a rootstock has come to light and this is now under study. It also appears that rootstocks of the Mexican race are the most susceptible to soil salinity.

The most recent development in the rootstock investigations of the division is concerned with the search for and introduction of cultivated and wild avocado rootstock materials for use in connection with the threat to the industry posed by the avocado root-rot (decline) disease, to which all the rootstocks currently used are susceptible. The division has participated in several trips of exploration to Mexico and Central America, in cooperation with the California Avocado Society, one of the results of which has been the introduction of closely related species which there is reason for believing may have resistance to the root-rot organism. While several of these species have succeeded thus far as grafts on the avocado, it remains to demonstrate their suitability as rootstocks. Plans have been made to materially expand this line of work in the immediate future.

BETTER PROPAGATION PRACTICES

Incidental to or in connection with the above-mentioned rootstock studies, the division has contributed materially to the knowledge concerning propagation problems and methods and to the practices employed by the nurserymen. The desirability of seed selection has been emphasized and the value of seed storage under certain conditions shown. Striking benefits in earliness and uniformity of germination, associated with removal or peeling of the seed coats or clipping or other mutilation of the cotyledons, has been demonstrated. A method for rooting cuttings from old clones has recently been developed, though it is considered still in the experimental stage.

STORAGE PROBLEMS AND POSSIBILITIES

With financial cooperation from the industry, in 1940 studies of the physiology of the avocado fruit were initiated with a view to developing the facts necessary to the understanding and solution of the problems of fruit handling and storage. As a result, a very considerable body of knowledge is now available which may lead to better handling and storage practices and results. Important facts concerning the nature of the softening process and its relations to temperature and respiration have been developed. It has

been shown that the avocado fruit gives off ethylene gas during respiration and that the softening process is closely associated with the climacteric in respiration; also that both processes are markedly affected by the temperature of storage. Decided benefits have been found to occur from reduction in the oxygen content of the storage atmosphere. Striking effects of the carbon dioxide content of the storage atmosphere have been demonstrated in slowing down respiration and delaying softening, even at storage temperatures considerably higher than those currently in use. The possibility of prolonging the storage life of the fruit toward the end of the shipping season and thus extending the marketing period with fruit of excellent quality and appearance is clearly indicated from these studies.

HORTICULTURAL BOTANY

Incident to or associated with the work summarized above, a very considerable amount of study has been given to morphological and physiological problems, among which may be listed the following: time of fruit bud differentiation; morphology of the inflorescence; ontogeny, floral anatomy and embryology; chromosome number; flower behavior; pollination; parthenocarpy; fruit anatomy; bearing behavior; fruit respiration and enzymatic systems; chemical composition of the fruit; and nitrogen economy and storage reserves in the tree.