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Report of Long-term Research on the Avocado

Studies on alternate bearing, varieties, rootstock, propagation and storage by Division of Subtropical Horticulture

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Erratic bearing behavior and consequent low-average yield of the principal commercial variety of avocado—Fuerte—was noted by growers when the industry was young. It 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 in southern California.

At the time the research program of the Division of Subtropical Horticulture was started, this behavior was generally attributed to uncertain or inadequate pollination. The former was thought to result from irregularity in the two opening and closing periods which characterize avocado flowers; and, the latter from lack of cross pollination from a reciprocal variety. Early field observations on flower behavior, pollination and fruit-setting did not support this belief. Actually, 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. This conclusion later was strengthened by field experimentation, though further study is desirable and is planned by the Division.



Two adjoining Fuerte avocado trees in opposite bearing phase. *Left*, on-phase effect of early and late harvesting on girdled limbs. Extreme right, late harvesting and in bloom; *right*, off-phase, heavy crop but very little and late bloom; heavy crop and light bloom; center, early harvesting and heavy bloom.

Studies were undertaken to investigate the bearing behavior of the Fuerte variety in the major commercial districts and to determine 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 five to 15 years, of nearly a thousand trees in widely distributed plantings and the correlation of the findings with weather data for the blossoming and fruit-setting period. The latter involved field experiments on the effect of girdling, fruit-thinning, crop removal, early harvesting, pruning, soil fertilization, topworking, double-working and rootstocks, conducted over a period of years.

It 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 factors, in that it can cause accentuation or depression of the alternation or actually bring about change in the stride of alternation. 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%—for the 20-year period 1926-46 reveals almost perfect alternation throughout. Only three changes in stride occurred—one in 1931-32 following two mild winters, and two following the succession of cold winters in 1934-35 and again in 1941-42.

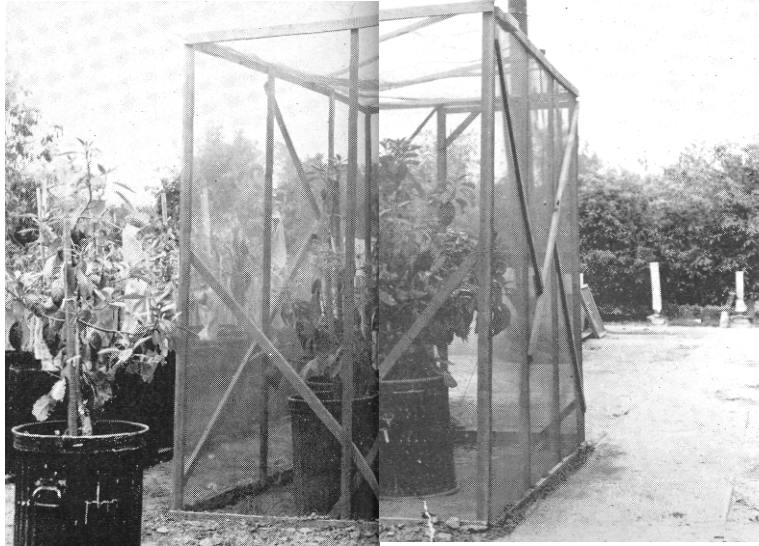
While the bearing behavior of other varieties has not been studied as exhaustively as that of Fuerte, it is evident that most varieties exhibit a definite and fairly regular alternate-bearing tendency, some more so than others, but that there are a few comparatively little affected.

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 can not 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.



Tubbed trees with bees in screened enclosure is one of the procedures in the breeding program. The result is hybrids of known parentage or seedlings resulting from selfing.

Better Varieties

Since the alternate-bearing tendency is an inherent varietal characteristic and to date no practicable means has 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.

Studies revealed 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 the 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 become evident from observations on chance seedlings, many of which were 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 co-operated 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.

One of the young avocado rootstock trials under study by the Division of Subtropical Horticulture

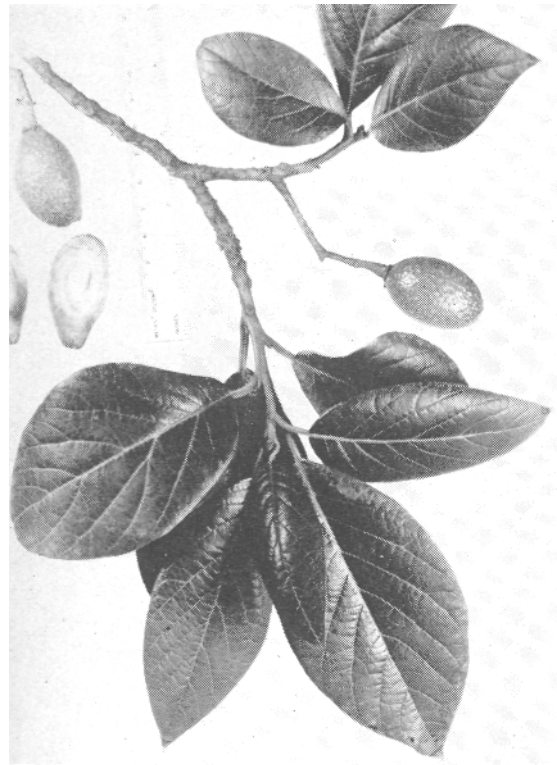


Rootstocks

Because of the insistence of nurserymen, in 1937, that field evidence existed of superior Mexican race rootstock varieties and seedlings, 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.



One of the wild avocados, *Persea rubigena*,
under trial as rootstock.

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 co-operation 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.

Propagation

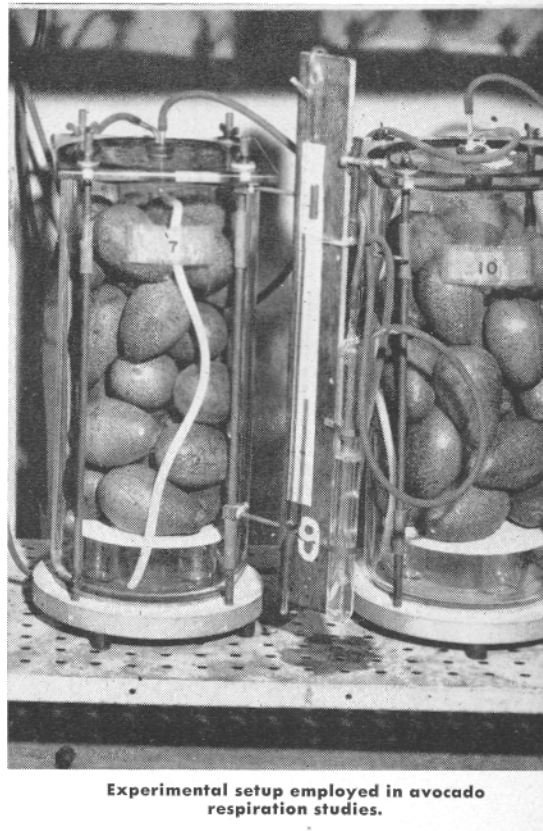
Incidental to or in connection with the rootstock studies, the investigations of the division have contributed materially to the knowledge concerning propagation problems and methods and to the practices employed by nurserymen.

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.



Mexicola avocado seedlings of the same age: 4 and 6, seedcoats left on; 5, seedcoats peeled.



Experimental setup employed in avocado respiration studies.

Storage Problems

With financial co-operation from the industry, 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 research 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.

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