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Studies on the Bearing Behavior of the Fuerte Avocado Variety
A PROGRESS REPORT

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INTRODUCTORY

The Fuerte avocado tree in California is characterized by erratic and unsatisfactory bearing behavior, which seems to comprise the only weakness of this important and otherwise excellent variety. This defect, although early recognized, has caused much perplexity and anxiety to California avocado growers and the conclusion is now general that unless practicable means can be devised for regulating its production this variety will have to be discarded.

HISTORY AND SCOPE OF THE INVESTIGATION TO DATE

In recognition of the importance of this problem there was prepared in 1927 an Experiment Station project which outlined a general study of flower development and behavior in the avocado and of the factors affecting fruit-setting.

Inasmuch as the Division of Subtropical Horticulture was then located in Berkeley it was necessary to confine the work to field observations on flower behavior, pollination and fruit-setting, and laboratory studies of a cytological nature. These preliminary studies resulted in two conclusions—(1) that flower behavior and pollination are not factors of primary importance in the bearing behavior of the avocado in California and (2) that the embryo-sac is fully developed at the time of the first opening of the flower—and indicated the need for field trials in which to study the factors influencing bearing behavior.

The removal of the Division to Los Angeles, in the fall of 1932, provided more favorable conditions for the continuation of this investigation and permitted the undertaking of field experiments, which were started in the fall of 1933. The work undertaken since that time has consisted of two major lines of inquiry—(1) an analysis, based on yield records, of the bearing behavior of Fuerte avocado trees, and study of modifying environmental factors, and (2) experiments to determine possible means by which this behavior may be influenced or controlled, including (a) girdling, (b) crop removal, (c) fertilization and (d) fruit-thinning. The results presented in this paper are to be considered as preliminary and are offered merely as a progress report. (See also Hodgson, R. W., and S. H. Cameron. On the Bearing Behavior of the Puerte Avocado Variety in Southern California. Proc. Amer. Soc. Hort. Sci. 32: 200-203. 1934.)

THE NATURE OF THE BEARING BEHAVIOR OF THE FUERTE VARIETY — MODIFYING INFLUENCES

The average annual production per tree, in number of fruits, for the past seven years, 1928-29 to 1934-35 inclusive, of a group of 128 trees now 14 years old, is shown in the lower graph of figure 1. The sequence of crops, beginning with that of 1928-29, has been medium, small, large, medium, small, small, and very large. It will be observed that this period included three small crops, two medium crops, one large crop, and one very large crop. It will also be noted that while small crops have succeeded each other the two large crops were four years apart and in each case were preceded by small crops. Assuming that this group of trees is representative, this crop sequence suggests a pronounced tendency to the alternate bearing habit, in which large crops never occur in succession and are always preceded by small crops. It is clear, however, that the alternation is not perfect and that there must be some modifying influence which accounts for the medium crops and the production of small crops in succession.

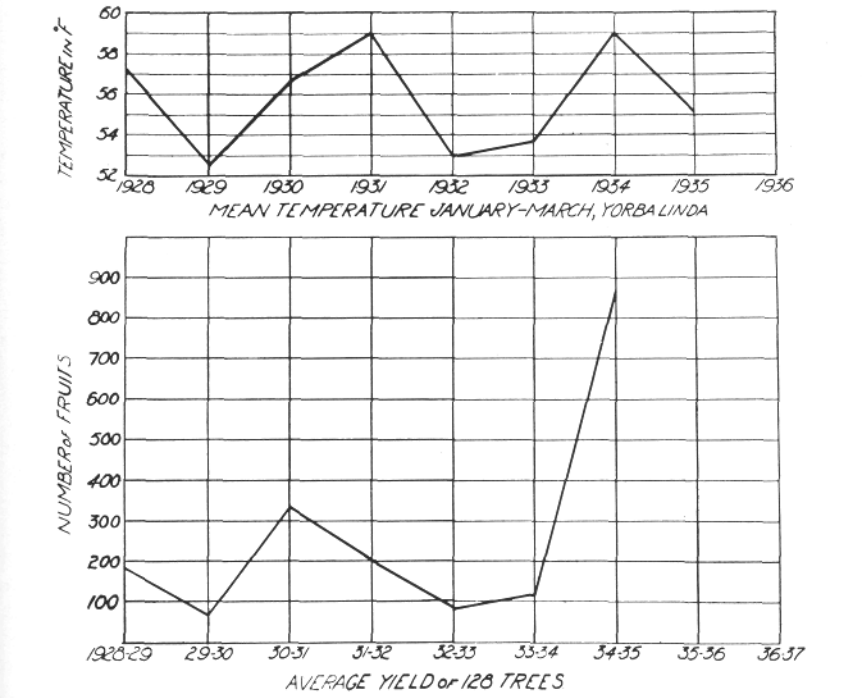

Figure 1. Average yields per tree of 128 trees for the period 1928-29 to 1934-35 inclusive, and average mean temperature for the months January to March inclusive.

It is believed that the general nature of this factor is revealed by examination of the relation which exists between the yield graph and mean temperatures during the period of bloom, which are shown in the upper graph of figure 1. Attention is first directed to the fact that the two large crops both followed bloom periods of high mean temperature. In the absence of data for the preceding season, the factors responsible for the medium crop of 1928-29 are not evident. It will be observed, however, that the medium crop of 1931-32 followed the second of two successive mild winters and was preceded by a

large crop. This strongly suggests that high mean temperature during the period of bloom favors the production of a large crop. It will also be noted that the three small crops, two of which occurred in succession, followed bloom periods during which mean temperatures were much below average. This suggests that low mean temperatures during the period of bloom are definitely unfavorable to fruit production irrespective of the amount of crop produced the previous season, and leads to the conclusion that mean temperature during the bloom period, together with the alternate bearing tendency above mentioned, determines the bearing behavior of this variety. The probability that temperature during the bloom period may be an important factor in the bearing behavior of the avocado has been suggested by others.
(Coit, J. E. The Setting of Avocados as Affected by Weather Conditions. Ann. Report Calif. Avocado Assn., 1927. PP. 123-125.
Knight, E. E. Success and Failure with Avocados. Calif. Cult. vol. 80, No. 20, Dec. 9, 1933. P. 547.)

The availability of the individual tree yield records for this group of trees has made possible a much more detailed study of this subject, which it is believed affords ample evidence to support the validity of these general conclusions. The yields for each tree have been plotted. A study of all the graphs has shown that with seven minor exceptions, there are four groups of trees of similar behavior. Since it is not practicable to reproduce all the graphs here, the average yields in each of the four groups have been determined and plotted. They are shown separately in figure 2 and together in figure 3. The average mean temperatures for the months of January to March inclusive at the nearest Weather Bureau station, some ten miles distant, are shown in the upper graph of each figure.

Group 1 (22 trees). It will be observed that the trees in this group have alternated regularly in crop production throughout the period and that their two large crops followed bloom periods of high mean temperatures. As to the reasons for the medium crop of 1928-28 we have no evidence but it will be noted that the rather above medium crop of 1932-33 corresponded with a bloom period of unfavorable temperatures. One reason for this behavior appears to be the small crop of 1931-32, which provided the possibility for a succeeding large crop. The other, and much more important reason in our opinion, is the fact that the trees in this group are nearly all situated in the upper portion of the orchard where temperatures are more favorable. The three small crops all succeeded large or medium crops and two of them followed bloom periods of unfavorable temperatures. On the contrary one small crop, that of 1931-32, followed a bloom period of very favorable temperatures. The reason for this appears to be the fact that the preceding crop was the largest produced up to that time, in fact the largest of all four groups (figure 3).

Group 2 (12 trees). For six of the seven years the trees in this group likewise alternated regularly but exactly opposite to the trees in group 1. In the seventh year, following a bloom period of unprecedented mild weather, their alternation was upset and their yield increased materially in spite of the medium crop of the preceding season. Indeed only 2

of the trees in this group, both high in yield in 1933-34, continued to alternate in 1934-35. In this group, therefore, both large crops followed bloom periods of much-above-average temperature. The large crop of 1931-32 seems definitely to be related to the small crop of 1930-31, the smallest of all four groups (figure 3). In both cases the medium crops of this group succeeded small crops and followed bloom periods of low temperatures which evidently depressed production. Concerning the reason for the small crop of 1928-29 we have no evidence, but of the other small crops, 1930-31 and 1932-33, the first, which occurred in a season of favorable temperatures during the bloom period, seems to be related to the medium crop of 1929-30; the second, the smallest produced by any group, followed the large crop of 1931-32, the largest for the four groups (see figure 3), and was associated with an unfavorable bloom period.

Group 3 (25 trees). The two large crops produced by the trees in this group corresponded with the large crops of group 2, and apparently for the same general reasons. The causes for the two medium crops, 1928-29 and 1930-31, are not clear but it will be observed that each of the three small crops followed bloom periods of low mean temperatures, two of which occurred in succession. The smallest crop, that of 1932-33, followed the largest produced up to that time. Attention is called to the fact that the trees in this group were in stride with those in group 1 for the first two years but reversed stride in 1930-31, apparently because of the production of only a medium crop. In 1933-34, however, they came back into stride again, apparently because of the production of a small crop. In both instances the crop at which point the stride was changed followed a small or medium crop which was associated with an unfavorable bloom period.

Group 4 (69 trees). This is the largest group of the four and that which provides the general trend to the graph of average production on figure 1. It will be observed that this group alternated perfectly for the first four years in stride with group 1, when a change in stride occurred, which followed a medium crop and was associated with an unfavorable bloom period. It remained in opposite stride for two years, and the two came back together in 1933-34, following two successive unfavorable bloom periods. Attention should also be called to the fact that with the exception of the two years 1930-31 and 1931-32, during which they were reversed, groups 3 and 4 were in stride together. In 1930-31 this group produced a large crop while group 3 produced a medium crop; in 1931-32 the situation was exactly reversed. Both crops corresponded with favorable bloom periods and in each case change of stride was associated with production of a medium crop.

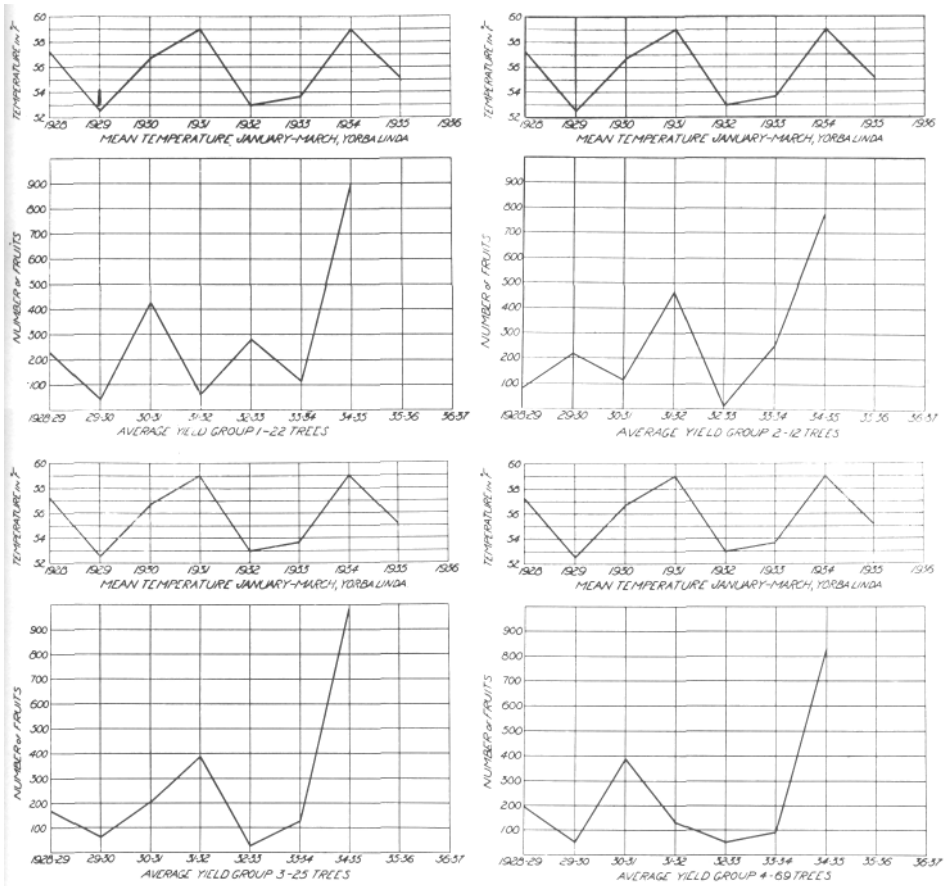

Figure 2. Average yields of the 4 groups of similar behavior, and average mean temperature during the bloom period. Upper left: group 1—Perfect alternation throughout the 7-year period. Upper right: group 2—Reciprocal alternation to group 1 until 1933-34, when the stride was changed. Lower left and right: groups 3 and 4—Alternation stride twice changed during the period.

Examination of figure 3, which gives the graphs of all four groups together, makes possible their direct comparison and shows the periods of correspondence and reversal of stride to which reference has been made. It reveals highly interesting and apparently significant reciprocal relationships between amount of crop and successive years, and strongly indicates the repressive effect on yield of bloom periods of low average temperatures. It will be observed that almost without exception the smaller the crop one season, the larger it was the following season. It will also be noted that changes in stride were nearly always associated with two successive seasons of above or below average temperature during the bloom period and invariably followed medium or small crops. It will further be seen that large crops occurred only in seasons of high mean temperatures during the bloom period and that they never occurred in succession. It is also evident that large crops followed small or medium crops and were likewise followed by medium or small crops even though temperature conditions during the period of bloom were favorable.

It is believed that these studies support the following conclusions:

1. That in Southern California the Fuerte avocado variety exhibits a pronounced tendency to the alternate bearing habit, the causal factor for which is the amount of crop

produced the previous season.

2. That temperature conditions during the bloom period comprise an important factor in the bearing behavior of this variety.

3. That the alternation may be reversed by two successive bloom periods of above or below average temperature.

4. That the crop produced in any given area and season is determined by the percentages of trees in the on-crop phase and temperature conditions during the period of bloom; large crops occur only as the combined result of a preceding small or medium crop and high mean temperatures during the bloom.

Based on the last-mentioned conclusion, the forecast was offered in March 1934 that the crop of 1934-35 would be the largest ever produced, a prediction which the harvest verified. The application of this conclusion to the data at hand indicates that the crop of 1935-36, still in the blossom stage at this date (May 1935), cannot reasonably be expected to exceed a medium crop and is more likely to be small.

(Editor's note. At the date of going to press (October, 1935) this prediction seems already to be confirmed.)

POSSIBLE MEANS FOR INFLUENCING OR CONTROLLING THE BEARING BEHAVIOR

Girdling. Avocado growers have experimented with girdling, to a considerable extent, in efforts to cause non-productive trees to bear and to control the bearing behavior of the Fuerte and other varieties. The results seem to have been contradictory; in some instances production was increased but in others there was apparently no effect. Our work has been both too limited in amount and of too short duration to afford a satisfactory basis for recommendations concerning the use of this practice. It has given results which are suggestive, however, and we plan to study this practice much more extensively during the coming crop season.

Preliminary experiments on the effect of girdling as a means of bringing nonproductive trees into bearing, started in the fall of 1933, have been successful to some degree and have provided data concerning the best time for girdling for this purpose. In this connection it should be stated that the trees in question were non-productive because of failure to set fruit; they bloom very heavily every season but thus far have failed to produce a crop. Limb-girdling trials were conducted in duplicate on these trees. Limbs girdled in early November and December bore a fair crop whereas limbs girdled in the latter part of January and March behaved exactly like the ungirdled branches. In both cases the December treatment produced the largest crop and in all cases the crops on the girdled limbs were several times greater than those on the rest of the tree, which served as the control treatment. Had all the limbs been treated and produced as much as the girdled limbs, the resulting crop would have been considered reasonably satisfactory.

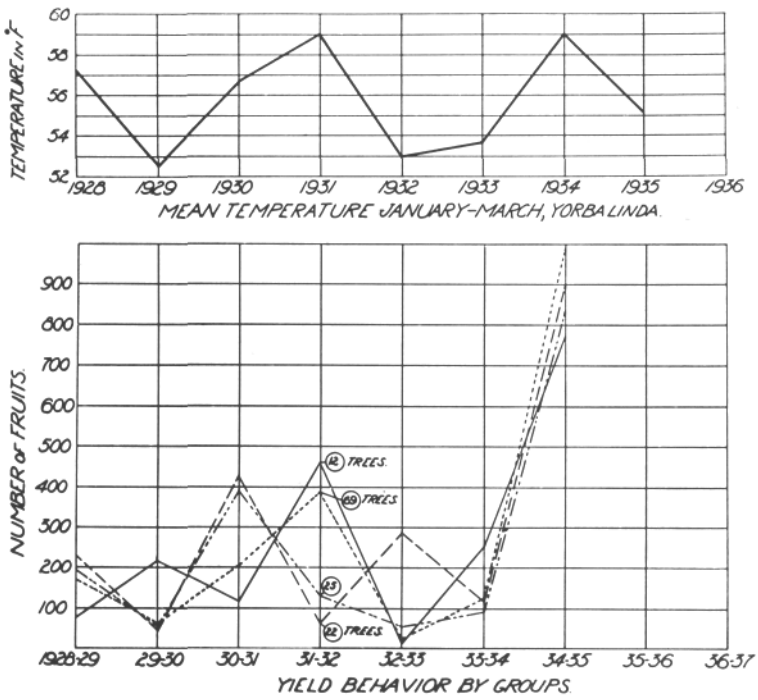

Figure 3. Average yields of each of the 4 groups, and average mean temperature during the bloom period; a composite of figure 2.

These data, admittedly small in amount, are consistent in the suggestion that where girdling is employed for the purpose of causing non-productive trees to bear it should be done during the early part of the bloom period. In this experiment the best results were obtained from treatment about a month after bloom started. As to whether still earlier treatment will give equally satisfactory results we have no evidence, though the results summarized by Coit would suggest that possibility.

(Coit, J. E. Effect of Girdling Trees on the Fruiting of Avocados. Ann. Report Calif. Avocado Assn. 1920-1921. Pp. 69-70.)

Girdling for the purpose of regulating or controlling the bearing behavior has given results in our experiments which, thus far at least, are either inconclusive or negative. Limbs in trees bearing heavy crops (on-crop phase) have been girdled in November and March, in the hope that this treatment might cause them to bear two heavy crops in succession, and limbs in similar trees bearing light crops (off-crop phase) have received like treatment. In the first instance girdling alone has consistently failed to cause the setting of a crop; the girdled limbs have behaved like the ungirdled controls. In the second case some of the November-girdled limbs seem to have borne heavier crops than the ungirdled controls but the differences have been small and the results must as yet be considered inconclusive.

Crop Removal (Early Harvesting). In view of the well known fact that avocado fruits are commonly, if not generally allowed to remain on the trees for several months after they are horticulturally mature, during which period they continue to grow and increase

in oil content, it seemed logical to conduct experiments on the possible effects of early harvesting on bearing behavior the following season.

For this purpose pairs of trees were selected of which one member was in the on-crop phase, carrying a heavy crop, and the other in the off-crop phase, carrying a light crop. In each tree two adjacent limbs as nearly alike as it was possible to find, were selected and girdled in early November, 1933. The crop was harvested from one member of each pair of limbs at the time of girdling, at which time tests showed the fruit to be horticulturally mature. The crop was left on the other limb until the middle of the following March, long after the beginning of the bloom period. Records were kept of the period and amount of bloom, time and amount of new growth, set of fruit and yield.

The subsequent behavior of the two limbs in tree 6(1), which at the beginning of the experiment was in the on-crop phase, has been significantly different. The behavior of the pair of limbs in the off-crop-phase tree, 3(5), has been similar in all respects and has not differed significantly from untreated limbs in the same tree.

A comparison of the behavior of the pair of limbs in tree 6(1) provides information which it is believed may have considerable significance and value. The limb from which the crop, 33 fruits, was harvested in early November, 1933, bloomed early and heavily in comparison with the companion limb on which the crop, 82 fruits, was left until the middle of March. It came into bloom approximately a month earlier and produced a very heavy bloom which was associated with a heavy leaf drop. The companion limb not only bloomed later and very lightly but started terminal growth earlier and made much more growth. The early-harvest limb set approximately 200 fruits, which continued to drop until well toward the end of September, 1934, and matured 51 fruits, which were harvested in early March, 1935. The late-harvest limb set 2 fruits, of which one dropped, and one matured, which was also harvested in March, 1935. From the data just reviewed it will be noted that one limb, that from which the crop was harvested early (November, 1933) has produced a total of 84 fruits during the past 2 seasons—33 in 1933-34 and 51 in 1934-35. The other has produced a total of 83 fruits—82 in 1933-34 and 1 in 1934-35. Since they have been treated alike in all respects except date of harvesting of the 1933-34 crop, we are forced to conclude that their subsequent difference in behavior, bearing and otherwise, is the result of time of harvesting.

It will be noted, however, that the 1934-35 crop was harvested from the treated limbs at the same time. This was done in order that further evidence might be obtained as to the effect of amount of crop on blooming and bearing behavior. Suffice it to say that these two limbs are now exactly reversed in condition from that which existed a year ago. The limb which produced one fruit this season, and which last year bloomed late and very lightly, came into bloom early and is now carrying an extremely heavy bloom (figure 4). The companion limb, which produced 51 fruits this season, and which bloomed early and heavily last year, has thus far produced only one flower cluster (figure 4).

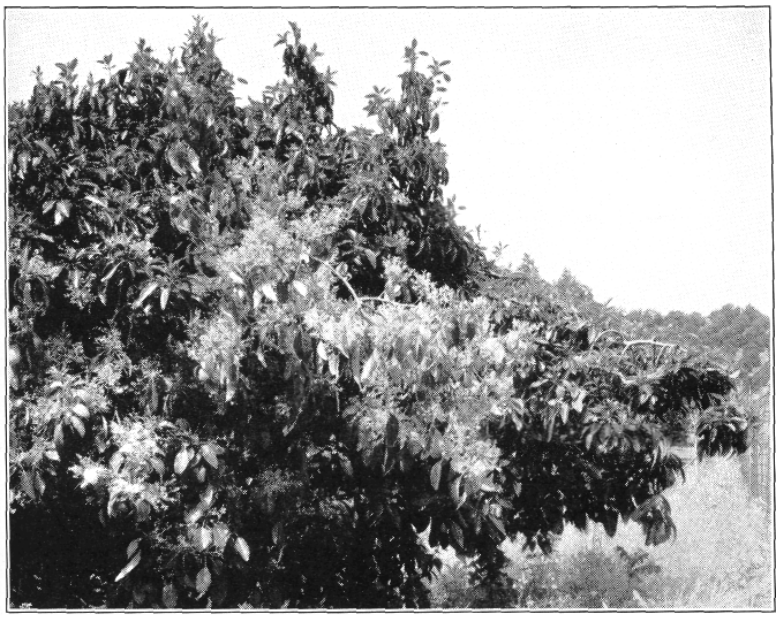

Figure 4. Contrasting pair of limbs in tree 6 (1) April 25, 1935. Lower center: Limb which bore 82 fruits in 1933-34 and 1 in 1934-35. Note the heavy and early bloom and pale color of the leaves. Lower right: Limb which bore 33 fruits in 1933-34 and 51 in 1934-35. Note the absence of bloom and dark foliage color.

In November, 1934, a much more extensive set of experiments on the effect of harvesting at various intervals was undertaken, the results of which will not be available until the close of the next crop season. It is already evident, however, that the blooming behavior of trees in the on-crop phase has been affected by early harvesting in 1934 as it was in 1933 (figure 5).

In our experiments we now have, therefore, individual limbs which have bloomed early and heavily this season apparently as the result of one or the other of two different causes—(1) early harvesting and (2) lack of crop during the present crop season. The similarity in behavior of these limbs in contrast with the behavior of limbs from which the crop was harvested late strongly suggests that the presence of fruit is depressive to fruit-bud differentiation and that there is a definite relation between amount of crop and period and quantity of bloom.

In all instances where our treatments have caused excessive bloom it has been accompanied by pale color of the adjoining foliage, and excessive leaf drop. This correlation, which has also been observed for many years under field conditions, suggests that excessive bloom may deplete the leaves of a portion of their nitrogen content. Preliminary data showed a pronounced and significant difference in total nitrogen content between the normal dark green leaves of our control limbs, on which there is little bloom, and the pale green leaves of our treated limbs, where bloom is excessive (figures 4 and 5).

These experiments, admittedly too few in number and of too short duration to serve as a basis for recommendations, led to the following tentative conclusions:

1. The production of an excessive crop delays the time of bloom, reduces its quantity,

and markedly decreases the yield the following season.

2. Early harvesting may provide a practicable means of regulating the blossoming and bearing behavior.

3. An excessive bloom appears to reduce the nitrogen content of adjacent leaves.

Fertilization. In view of the claims of benefits from the use of nitrogenous fertilizers applied for the purpose of stimulating fruit-setting, it seemed desirable to conduct simple trials to determine whether fertilization might influence the bearing behavior. In November, 1933, experiments were started in three widely separated localities—Carpintaria, Oxnard and La Habra Heights. Two of the trials, namely Carpintaria and La Habra Heights, were based on the use of paired trees of similar age and size, one member of which was in the on-crop phase and the other in the off-crop-phase. In the Oxnard experiment this was not possible since none of the trees have produced crops to date though now in their thirteenth year. Adjacent untreated trees were used as checks in each case.

The treatments consisted of ten pounds of nitrogen per tree from each of the following carriers—ammonium sulfate, calcium nitrate and ammonium phosphate—and approximately 200 pounds per tree (2 bales) of cereal straw. The purpose of the straw treatment was to reduce the nitrate nitrogen supply, which has apparently been accomplished since tests made in one of the experiments have either failed to indicate its presence or have revealed traces only. There are, therefore, three soil conditions represented in these trials—(1) high nitrogen (10 pounds per tree), (2) high nitrogen and phosphorus (10 pounds nitrogen and 12½ pounds phosphate) and (3) low nitrogen.

The second application was made six months ago to two of these experiments, one having been abandoned, so the trees have now been subject to the conditions provided by the treatments for a period of 18 months. Thus far there has not been the slightest indication of any effect on the bearing behavior of the trees. They have continued to behave like the untreated controls. It should be pointed out, however, that both these orchards have been well supplied with nitrogen and these tests should therefore not be interpreted as a demonstration of lack of need for fertilization. They merely indicate that, thus far at least, the availability of nitrogen or lack of it have not affected the bearing behavior.

Fruit-Thinning. This practice has been reported as providing a means for the control of the alternate bearing habit in some fruits, in addition to increasing the size of the individual fruits. It seemed desirable, therefore, to include fruit-thinning in our experiments. A series of trials was initiated in the summer of 1934 using both girdled limbs and whole trees ungirdled. The rates of thinning employed were half, three-quarters and seven-eighths of the crop respectively and the periods of thinning June, July, and September.

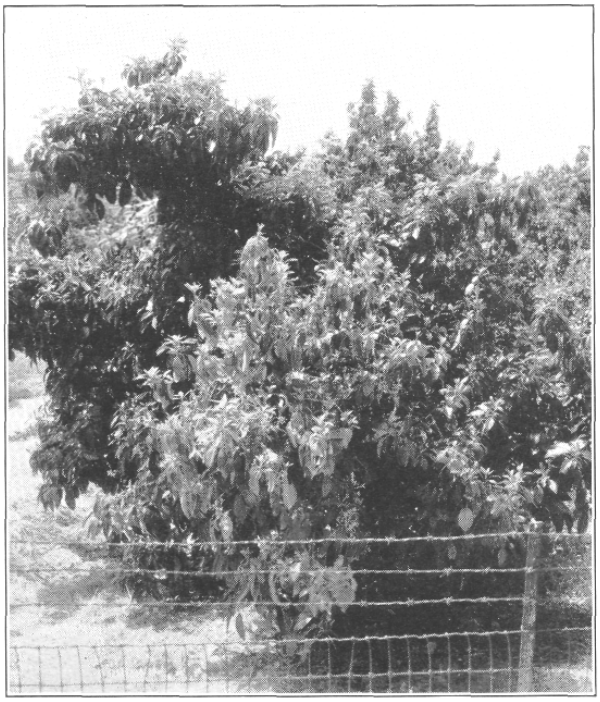

Figure 5. Limb from which crop was harvested in November, 1934. Note the early and heavy bloom and pale color of the leaves as contrasted with the rest of the tree. Tree 1 (1), photographed April 25, 1935.

In October the thinning trials were gone over carefully and compared with the unthinned controls. As nearly as could be determined the natural thinning on the control limbs and trees, which had extended well into September, had reduced the crop to approximately the same amount as the June and July thinnings, where seven-eighths of the crop had been removed. The harvest records from these trials show that in some cases fruit size was increased presumably by the thinning, while in others there was no difference.

Obviously the effects on the bearing behavior will not be known until the 1935-36 crop has been harvested.

PRESENT STATUS OF THE EXPERIMENTAL RESULTS

We desire to emphasize the fact, already referred to in several connections, that these investigations do not yet provide a safe basis for recommendations as to practice. The results must be considered as merely preliminary and suggestive and require testing on a larger scale and under more varied environmental conditions.

ACKNOWLEDGMENTS

In conclusion we wish to acknowledge the invaluable assistance of the individuals whose splendid cooperation has made these studies possible. Among these, special mention should be made of P. J. Weisel and his Superintendent R. H. Marsh of La Habra Heights, A. J. Borchard of Oxnard, and George Bliss of Carpinteria.