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Results of Pollination and Other Experiments on Avocados at the Orchards of the Point Loma Homestead

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The orchards at the Point Loma Homestead were established and are directed by Katherine Tingley as part of the educational work of the Theosophical University. The Homestead has no commercial interest in promoting any of the fruits mentioned in this report.

The writers alone are responsible for the conclusions stated in this report, which is written by request of the California Avocado Association and others and consists of data not heretofore published.

Fresh Fruits All the Year. An object of these orchards, in addition to their educational purpose, is to grow for the several hundred children, students, teachers and other residents here an all-the-year-around daily supply of fruits fresh from the trees in reasonable and regular quantities. The problem of growing such a daily fresh fruit supply for so large a body of people was a hitherto untried proposition for which fruit growing previous to this undertaking was not a sufficient guide. Data had to be developed by the orchardists through years of observation and experience here and the testing of about four hundred varieties and sub-varieties of fruits, of which about 100 varieties are now being grown in quantity. Those chiefly grown have been selected for succession of ripening as well as for quality and productiveness.

For economic, health and other reasons this fruit supply has come to be much appreciated by the people here and has received wide publicity in California, elsewhere in the United States, and in many other countries as an example of what can be done in the coast district of Southern California. So far as known, no such comprehensive supply of fruits picked fresh from the trees practically every day of the year—as shown by the accompanying table—is being produced anywhere else. World-wide climatic and horticultural data collected here show that for climatic reasons no such supply *of* temperate zone and subtropical fresh fruits could be grown in any one locality outside of Southern California. All other subtropical parts of the world have either cool winters that prevent the growing of some of the best fruits or they have warm summers that rush the ripening of most fruits. Here we have warm winters and cool summers both in one locality. Only in such a climate is it practical to combine the growing of temperate zone and subtropical fruits as has been done here and thus secure the ripening of several different kinds of fruits at all times during the whole year.

Avocados

The Homestead's avocado orchard was started in 1916 by the planting of about 100

budded trees. During the two following years about as many more were added, and in succeeding years other additions were made. The early plantings included all of the varieties then chiefly recommended. The soil is underlaid at a depth of 1½ to 3 feet by heavy hardpan- not entirely impervious to soil moisture.

The trees have made good growth, but are not above medium size for their age. They are unusually well and uniformly shaped for avocados and are suitable for comparative studies and to furnish experimental data of value. A very few varieties have never borne well and are being grafted. The orchard's crops have been good on the average, but not as heavy as they promise to be in the future as the result of the discoveries to be explained.

Climatic Factors. This orchard has been practically free from frost and entirely free from desert wind. The location chosen does not receive the full force of storm winds or of the daily breeze.

Many trees here, as in other orchards, have shown a tendency to a variable, sometimes alternating or biennial, succession of light and heavy crops. These variations in amount of crop have not usually been chiefly due to climatic causes. This is shown by the fact that every year but one—when blooming was preceded by continuous heavy rains—there have been many trees in the orchard with very heavy crops. Each year it is observed here that avocado flowers set the most young fruits during periods of clear and warm, but not hot weather, whereas periods of cool weather cause the flowers and young fruits to drop. However, each year there is enough of the best weather so that at least a few trees which are in the most favorable condition can and do set very heavy crops, which are at the rate of 15,000 pounds to 35,000 pounds per acre. Tabulations have been made of the records kept at the weather station on these grounds of all essential factors of climate—temperature, humidity, sunshine, wind and rain. A thorough comparison of these records of weather conditions with records of the crops which might have been affected by them, shows that here variations in weather are not ordinarily the chief determining factor in avocado productiveness. The moderate variations in weather here not having been the main factor have made it possible to prove the effect of some other important factors.

Irrigation. As to the irrigation of avocados in California or elsewhere, very little, if any, experimental data with comparative results have been published. Data from the records of this orchard are therefore given.

A home-invented, convenient irrigation system for furrow irrigation was installed by which it is easy to accurately control and record the number of gallons of water given to each row at each irrigation. Our engineers have found that measurements by this system are practically the same as by the city water meter. During the last seven years complete records have been kept and tabulated of the dates and amounts of irrigation of each row. These irrigation records, together with complete crop production records of each tree and various other records and tests, have made possible the study of the irrigation requirements of avocados of the size and age of these trees under these conditions.

The records of experiments and experience here give much evidence that as to productiveness avocados are more sensitive to the bad effects of either extreme of soil

moisture than any other of the many varieties of fruits grown here. Avocados appear to be even more easily injured by too much or too little irrigation than oranges. Even though the extremes of dryness or wetness are only temporary, and to the casual glance may not appear to have had much effect on the appearance of the trees, the maturing crop and the crop from the following blooming season also are liable to be only half as large as on adjoining comparable trees of the same variety properly irrigated and otherwise receiving the 'same treatment. At times, some avocado trees were given more irrigation than the average and some less than the average. These experiments proved that too much or too little or poorly distributed soil moisture lessened the crops by causing excessive dropping of flowers and young fruits and much dropping of mature fruits. Some examples of these effects follow.

During the months of December and January, 1921-22, there was at Point Loma 15 inches of rain, keeping the soil very wet for a long period. This did not conspicuously affect the appearance of avocado trees, but it did *so* weaken every tree that none set or matured a large number of fruits from the following blooming season. The same effect was produced on all oranges, feijoas and loquats in the same orchard. The total crops of all of these were far below normal, showing a danger for evergreen fruits from continued excessive soil moisture. The avocados produced only 10% of an average crop, loquats 15%, feijoas 30% and oranges 25%. A year later, however, the trees set a very heavy crop.

The same rains caused no injury to deciduous fruit trees on similar soils nearby, the deciduous trees having been dormant at the time of the rains. During a subsequent year, at two successive monthly irrigations, several avocado trees were given extra water by the spreading of water outside their furrows. As a result these trees began to rapidly drop a large proportion of their heavy crop of maturing fruits. Adjoining trees of the same variety with equally heavy crops, but not receiving the extra irrigation, did not drop their fruit. At another time a tree in the best of bearing condition and carrying a very heavy crop of one-third-grown fruits was accidentally given 3000 gallons (equivalent to 7 inches of rain) more irrigation than the adjoining trees of the same size and variety. As a result, its fruits dropped badly and it produced only half as large a crop as the adjoining trees. Careful observations showed no other reason than the excessive irrigation for the dropping and diminished crop.

It has sometimes been found here in the early Spring that a large proportion of small avocado roots were dead and decaying, due, apparently, to cool weather keeping the soil too cool for avocados. These have been found after a very dry winter during which light irrigations had been necessary. In such cases it was certainly not due to any excess of soil moisture, which, if it had existed, must certainly have made the trouble much worse. To avoid winter injury through having the soil too wet, only very light irrigations have been given to avocados as well as to other evergreen fruits during the months when rains may increase the soil moisture at any time. Such irrigations, when necessary, have been given in only one furrow per row, run for a shorter time than during warm weather, and repeated about once a week until rains—each irrigation being in a furrow at a different distance from the trees or on the opposite side of the row. Thus, winter soil moisture is, if possible, kept to the lowest desirable minimum. If heavy irrigations were given, and this should be followed by heavy rain, the weakening

of the trees during the blooming season to follow would be serious. The frequent use of the soil augur or the shovel to determine soil moisture conditions has been found indispensable.

The amounts of irrigation now being given to the ten-year-old trees are about three acre-inches per month during the dry season, which is, we believe, little if any more than would be recommended by experts for orange trees of the same size in similar locations. This amount of irrigation is giving satisfactory results which about two acre-inches per month did not do.

Fertilization of the Soil. There has seemed to be no definite knowledge in regard to fertilizing the soil for bearing avocados. Prof. Ryerson (1) says: "Very little is known concerning the fertilization requirements of the avocado." This fact and the inquiries received indicate the need for a report of tests made and recorded and of results secured in the Homestead's orchard. Evidently, conclusions from these results will not apply equally to all varieties and all soils. Fortunately, however, they help to clarify this complicated and hitherto speculative subject.

This orchard was planted on ground which had previously been used for many years for the growing of oats. Because of the high price of irrigation water no intercrops or cover crops have been grown. The mechanical condition of the soil has remained good. Except a very few weaklings, none of the trees were given fertilizer until experiments were begun on a limited number when they had reached bearing age. Most of the trees received no fertilizer of any kind until 7 years old. During the first 5 years after planting the young trees grew with reasonable vigor which was sufficient to prevent them from bearing well.

The growing of the young trees and their first heavy crop produced from a soil not naturally rich and which had never been fertilized exhausted the soil. This brought the older trees (except those which had been experimentally fertilized) to a condition of undernourishment which was was not quickly overcome. The undernourishment was shown by a marked decrease in the rate of growth and a decrease in the amount of crops and a less rich green color in the leaves. This rather unusual and unprofitable treatment was part of the experimental plan and made it possible to secure more definite results from fertilizer experiments and much more quickly than could have been secured under any other conditions. When the experiments were begun, very conspicuous contrasts were produced and gave the strongest possible proofs that what the trees needed was fertilizer. A few scattered trees of different varieties became sick from no other discoverable cause and appeared to be dying, but when given nitrogen they very quickly showed partial or complete recovery.

When the trees were 6 years old, cross rows, including several varieties, were given ½ Ib. each of actual nitrogen and 4 months later the same amount was repeated. Most of them quickly took on a much better appearance than the adjoining unfertilized trees. An additional number of trees were then given nitrogen. Their improvement was much slower, because they had by that time reached a more serious condition of undernourishment. Records show that 3 Challenge trees which were the first to be given nitrogen when 6 years old, and received it regularly thereafter, averaged for the 3 succeeding years practically 100% more fruit per tree than the 17 nearest adjoining

closely comparable Challenge trees which received no nitrogen until one year later, when they showed conspicuous need for it. Those not large trees which first received nitrogen averaged 151 Ibs. fruit per tree per year for the 3 years, as compared with 77 Ibs. per tree per year for those not so treated. Similar results were produced on some other varieties, but not on all. All trees and all varieties have not responded equally to nitrogen. Trees which had not exhausted their soil because they were still young or were poor producers showed less benefit from fertilizers as compared with older trees which had borne heavily, and some showed no apparent benefit.

Nitrate of soda at the rate of 10 Ibs. per tree on 9 trees was broadcasted and soaked in by over-head irrigation. This showed no more benefit or even less benefit, than 5 Ibs. applied at the same time in the same manner to other adjoining trees of the same *size,* age and variety. Trees receiving only one, or two, applications of nitrogen, but with the applications not repeated, have shown very little if any permanent benefit.

In 1924 and 1925 sulphate of ammonia 4 Ibs. per tree per year was given to 11 Challenge trees. In the same rows 9 Challenge trees of the size and age and otherwise receiving the same treatment, were given no nitrogen. The two succeeding crops matured by these trees, in 1925 and 1926, were as follows: The trees which received nitrogen, averaged 81 Ibs. of fruit per tree per year, those which were not given nitrogen averaged 22 Ibs. of fruit per tree per year, an increase of 268% in favor of nitrogen. None of the 10 year old trees in this experiment were suffering from a complete lack of nitrogen. All of them received 5 Ibs. of nitrate of soda in July, 1923, and 3-5 cubic yard per tree of dairy fertilizer in October, 1924. All of them must also have received at least a little benefit from nitrogen given to the trees adjoining them. We have now proof that all these Challenge trees would have borne heavier crops had they been given, during the years of this experiment, more water and had there been a better moisture distribution throughout the soil.

Repeated experimental attempts have been made to increase the set of fruits—as is generally practiced with oranges, apples, and other fruits—by applying nitrate of soda or sulphate of ammonia to some trees at or shortly before blooming time. These attempts have all failed to accomplish that purpose on avocados here. The best crops have only been obtained by maintaining the trees in the best condition all the year but without causing excessive new growth. On similar soils nearby, many other varieties of fruit trees, including oranges, were given similar treatment and experiments as to the withholding and giving of fertilizer. Nearly all showed a benefit from nitrogen, but none except persimmons showed so conspicuous a response to nitrogen as did avocados.

Finally, regular applications of nitrogen were begun on most of the orchard, with generally favorable results. To continue the avocado experiment, a few trees were still left without fertilizer; they continued to decline in health and productiveness until for their preservation nitrogen had to be given to most of them.

As was expected, a dairy fertilizer was found to be slower but more lasting in its effects than concentrated forms of nitrogen. Some of the weak young trees which were first given dairy fertilizer are now the most productive. Last year a fertilizer program of commercial nitrogen and dairy fertilizer was inaugurated for the whole orchard and very promising results have already become apparent.

Many other factors limit or increase productiveness, but these experiments leave no possible doubt that heavy bearing cannot be maintained without regular applications of nitrogen in some form. The value of this knowledge will be readily appreciated by all concerned. Few fruit trees make so luxuriant growth as the avocado. No other tree produces so many pounds of concentrated food as a heavy bearing avocado tree. As avocado orchards get older these heavy demands will exhaust the soil, and soil fertilization will prove one of the most important operations.

Leaf and Growth Conditions. Systematic observations have been made here of the appearance of the foliage of fruit trees as an indication of their condition. None have been found whose foliage appearance seemed more sensitive to the effects of irrigation and fertilization than avocados. It has been found that usually to a remarkable degree the foliage appearance of avocados of bearing age either controls or forecasts the amount of the future crop of the tree. Certain favorable conditions precede and accompany (perhaps cause) the setting and maturing of heavy crops, while either unfavorable foliage conditions or excessive growth prevent heavy crops. This, in part, clears away the seeming mystery that has surrounded the variable productiveness of avocado trees, and has caused endless speculation as to its reason. Once these foliage conditions and their results are recognized their causes and control may be discovered.

It has been found here that (variety permitting) those avocado trees which *during all seasons of the year* have the greatest number of well matured, well nourished healthy old leaves are the trees which bear the heavy crops. Excessive or spasmodic new growth are both very unfavorable to heavy bearing. Trees which have the greatest number of healthy old leaves, of a color which for the variety is a rich dark green, are in the best bearing condition. Trees are not in good condition which have an insufficient number of leaves, as only new leaves, or leaves that are drying (tip-burn), or are pale and sallow in color. Such trees do not mature good crops. Sufficient investigation usually reveals causes and remedies for such leaf conditions.

Several times a year for several years a tabulated record has been made of the leaf condition of each bearing avocado tree in the orchard. Trees, if any, having the greatest possible number of mature leaves entirely rich green in color have been credited with 100% of green or chlorophyll. Trees with fewer leaves and with less of the best color have been recorded at a proportionately lower percentage. Immature leaves have been recorded separately, and various special leaf conditions have been noted. It has been found that different persons working separately but following this rule and sometimes estimating many of the same trees agreed closely in their estimates. It has been found that comparison of these leaf-condition percentage records with crop production records reveals much that is striking. With slight variations and few exceptions, trees thus credited with the highest percentage of healthy mature green leaves during the whole year, set and matured the heaviest crops for their variety. Those credited with lower percentages of green produced crops, proportionately smaller. Quick improvements in growth condition have not given a heavier set of fruits from the following blooming; not until those improvements have been maintained for a year. To the extent to which leaf conditions can be understood, they furnish indications, always in sight, of the care needed by the orchard. Trees are forever giving innumerable and subtle, as well as plain, signals of their needs. Avocado trees are particularly sensitive in this respect. This

new method of studying avocados may be adapted to the study of some other orchard problems as well. The leaders in the horticultural sciences are men of the highest scientific and widest practical training. As we have known them, they are devoted and not irreverent observers of this natural language of the plant world, and are seeking further progress along this line.

Pollination. Reports of experiments in this orchard on the pollination of avocados have twice been made to the Avocado Association. (2) The results given in this last previous report upset the then prevailing views on the subject, but left much yet to be determined. Since that report was written some further results have been secured. The method of making the experiments was described in the former reports, and many of the details need not be repeated here. This is the only successful method found for experimentally testing the pollination of avocados. Partly because of the very complicated nature of the subject, and the labor, time and expense involved, no similar tests have been carried out elsewhere, though the present state of knowledge leaves much to be desired.

In the first report: "Avocado Pollination and Bees," the observation was noted that abundant work of bees is likely to be followed by a heavy crop. Later, the question was raised whether the visits of numerous bees were not a mere indication rather than a cause of a heavy crop to follow. Evidently, the bees are attracted by a good flow of nectar, indicating in some cases a good productive condition of flowers and trees. It seemed possible that such a good condition might be followed by an abundant crop of mature fruits even though the number of bees and pollinations had been comparatively few. To test this question, half of a Fuerte tree was, during blooming, covered with netting on a frame. No bees were put in the net. This net was not completely closed, so that a very few bees and other pollen-carrying insects found their way inside, but apparently seldom found their way out again. Daily recorded observations showed that an average of 4 bees or other insects could be found inside the net. Very, very rarely could any of these be seen to be visiting flowers. On the half of the tree outside the net, the number of bees and other insects actually at work averaged 60, which was an unusually large number for a tree of this size. Seldom in any other year have we seen so many bees and other insects at work on avocado flowers as there were on the exposed half of this not large 7 year old tree, as well as on many other trees in the orchard. Though the flowers inside the net produced only a few small fruits, a large proportion of those small fruits matured. The flowers inside the net matured 55 fruits, and those outside 36 fruits. In this case, the great difference in number of bees and other insects, inside and outside, made no practical difference in the number of matured fruits. We do not know if this will always prove to be the rule. This test was on the chief commercial variety, the Fuerte, which it had been found is not (in this orchard) benefited by cross-pollination. Theoretically at least, it would seem that varieties which are believed to require cross-pollination should have an abundance *of* bees to insure a sufficient number of cross-pollinations. It was shown in a former report that the entire exclusion of insects prevented the setting and production of any fruit.

As noted in a previous report, it has been found here that the very slight shade of a netting during the long blooming period of the Fuerte, which lasts several months, has some effect on the foliage and probably on the setting of young fruits. To equalize this

effect of shading, the outside half of this tree was shaded with netting, but not enclosed, and the free access of insects was not prevented.

Part of a 6 year old Fuerte tree and part of a 7 year old Spinks were enclosed together in one net with two hives of bees in the net, to test the cross-pollination of these two varieties. The Fuerte bore no fruit and the Spinks bore only 5 fruits. The cause for this failure to set fruits was not apparent; probably, it was due in part to the slight shade of the netting. Whatever the cause, the greatly increased amount of cross-pollination between these two varieties was not potent to overcome that cause and produce a crop. It seems likely that the effect of slight shading on productiveness might be reversed if the growth condition of the tree were different, or if the trees were of some other variety, or if sunshine were more intense as in locations further from the Coast.

During 3 successive years, tests of self-pollination compared with cross-pollination were made on a Dickinson tree. One side of the tree was enclosed in a net with a hive of bees and thus could receive only self-pollination. The other side of the tree was open to cross-pollination. The second year the opposite side of the tree was enclosed. The second year the side of the tree not enclosed was shaded with netting so that both sides should be equally shaded. The third year one side of the tree was enclosed in a large long net with trees of Lyon, Queen and Linda, all in the same net to cross-pollinate the Dickinson. The other side of the Dickinson was enclosed by itself for comparison. This test with both sides en-closed may be considered to give the best comparison. It did not, however, give any pollination test on the other three varieties. The Dickinson tree experimented on is now 10 feet tall with a spread of 14 ft. It was not possible to divide the tree into equal halves. Each year measurements similar to those used for fumigating citrus, were made to determine the proportion of the tree on each side. These measurements, and estimates made with the eye, agreed closely. The figures to follow show each test as occupying 2 years because the fruits pollinated one year matured the following year. The number of mature fruits produced each year were as follows:

1923-4 self-pollinated 24 frs.; cross-pollinated 71 frs.
1924-5 self-pollinated 64 frs.; cross-pollinated 89 frs.
1925-6 self-pollinated 24 frs; cross-pollinated 51 frs.

Calculating cross-pollination as giving in each case 100'% of a crop, and taking into consideration the amount of foliage in each side of the tree, each year gives the following percentages:

In 1923-4 cross pollination gave 100% and self-pollination 42% of a crop.
In 1924-5 cross pollination gave 100% and self-pollination 62½% of a crop.
In 1925-6 cross pollination gave 100% and self-pollination 33% of a crop.

No difference in size of mature fruits and no other differences have been seen between those fruits produced by cross-pollination and those by self-pollination either on the Dickinson or on other varieties.

According to Dr. Stout's tables, confirmed for this locality by records here, the daily blooming periods of Lyon, Queen, and Linda are right for pollinating the Dickinson. The records here also show that they all bloom during the same months. The Linda,

however, is often a very light bloomer and could not therefore be recommended as a pollinizer.

These figures show plainly a need of the Dickinson in this locality for cross-pollination. Experiments previously reported show that the Fuerte is self-fertile here. Pollination requirements may not be the same further from the Coast. No sufficient evidence has been obtained here to show which, if any, other varieties are benefited by cross-pollination.

References

1. "Avocado Culture in California." University of California Bulletin 365, June, 1923.
2. California Avocado Association Annual Report, 1922-23. Same 1923-24.

Pounds of Fruit Picked from the Point Loma Homestead Orchards and Delivered to Their Refectory Each Month During 1925

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Apples	.....	.....	.....	.....	.....	.....	.....	.....	622	272	80	.....	974
Avocados	103	92	253	863	642	640	621	509	416	174	92	41	4,446
Cherimoyas	21	3	.....	1	.....	.....	.....	.....	.....	.....	19	104	148
Feijos	.....	.....	.....	.....	.....	.....	.....	.....	338	3,171	409	.....	3,918
Figs	.....	.....	.....	.....	.....	3	30	5,713	3,264	7,066	3,117	12	19,205
Grapes	.....	.....	.....	.....	.....	.....	.....	120	1,443	.....	.....	.....	1,563
Lemons	498	330	330	631	528	400	400	400	630	700	530	700	6,077
Loquats	.....	.....	24	.....	1,432	288	.....	.....	.....	.....	.....	.....	1,744
Olives	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	50	120	170
Oranges	935	3,002	3,382	3,192	3,534	3,572	2,926	950	200	61	775	2,584	25,113
Peaches	.....	.....	.....	.....	.....	789	1,648	2,311	611	12	.....	.....	5,371
Pears	.....	.....	.....	.....	.....	.....	.....	347	341	1,230	442	.....	2,360
Persimmons	3,840	1,439	59	.....	.....	.....	.....	.....	.....	161	1,631	4,498	11,628
Plums	.....	.....	.....	.....	.....	1,294	4,404	2,381	198	.....	.....	.....	8,277
Quinces	.....	.....	.....	.....	.....	.....	.....	30	462	111	.....	.....	603
Sapotas	.....	.....	.....	.....	.....	.....	.....	.....	62	38	.....	.....	100
Monthly Totals	5,397	4,866	4,048	4,687	6,136	6,986	10,029	12,761	8,587	12,996	7,145	8,059	91,697