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A Study in Cross-Pollination of Avocados in Southern California

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It is certain that the proper interplanting of the present day varieties of the avocado will greatly increase the chances that fruit will set and will thereby lead to the production of more abundant and more uniform crops.

That cross-pollination is very necessary for the best setting of fruit in avocados will be very evident to anyone who makes some observations of the behavior of the flowers. First of all, each flower of all varieties thus far studied has normally two separate periods of opening. During the first period (illustrations II, III, V, VII, IX and XI) the pistil is ready to be pollinated, but it is only during the second period of opening (illustrations I, IV, VI, VIII and X) that pollen is shed. The majority of flowers open and close without any opportunity for a proper self-pollination.

Furthermore, the majority of flowers of any variety open and close for each of the two periods in unison and at different times. Thus, during certain hours of the day, one can find on a tree of any variety only flowers open for the first time. Later, these flowers are closed and another set will be open for the second time. This habit of the alternating opening of flowers of one condition in unison or in rhythmic cycles decidedly limits the opportunity for pollen to be carried from one flower to another on the same tree. A single tree or a group of trees of one variety may bloom day after day and be visited continuously by many bees and other insects and yet very few or even no flowers may be pollinated properly. This makes cross-pollination between varieties highly necessary for the setting of much fruit.

Cross-pollination is possible between certain varieties, but not between others. At 10 a.m. on a series of warm, sunny days, the flowers of a Fuerte tree will usually be shedding pollen abundantly (see I,) while on a neighboring Dickinson tree only flowers open for the first time are to be found (see II.) An examination of the flowers on these same trees at 3:30 p.m. of the same day will show many flowers open for the first time on Fuerte (VII,) while on Dickinson the only flowers open are those that are shedding pollen (VIII.) In the forenoon there is opportunity for pollen to be carried from Fuerte to Dickinson, while in the afternoon there is chance for pollen to be carried from Dickinson to Fuerte. Thus the different times of the opening and closing of flowers for the two periods in these two varieties decidedly favors reciprocal cross-pollination.

But an examination of trees of Dickinson (II,) Sharpless (III) and Taft (V) at 11 a.m. of this same day will show that all the flowers which are open are those open for the first time. A visit to those same trees at 3:30 p.m. will reveal that then all the flowers that are open are those of the second period, which are shedding pollen. Thus these three varieties are behaving in quite the same manner throughout the entire day and the

same kind of flowers are open at the same time. Obviously, this does not facilitate cross-pollination even though insects go freely from one variety to the others

The cases just cited indicate very clearly the first principle which determines whether an interplanting of two or more varieties will favor cross-pollination. It is not sufficient that two varieties interplanted be in flower on the same calendar dates. They must supplement each other in the two alternate periods of the opening of flowers. One must be shedding pollen when the flowers of the other are open for the first time, as is the case with Fuerte and Dickinson, and this should be continued day after day.

During the past season of bloom the writer has attempted to determine the relative blooming habits of many varieties in order to obtain evidence regarding the particular interplantings which will most fully favor cross-pollination. Trees of numerous varieties blooming at the same date were observed at frequent intervals throughout the hours of daylight and also, in some cases, during the night. Flowers were also frequently tagged and observation made of their behavior on following days.

A record typical for one day of such observation may be summarized graphically in chart No. 1. It should be stated that this record was taken at Thomas Sheddon's place, near Monrovia. The date was May 5, 1923. The day was hot, dry and sunny, and there had been no fog during the night before, there having been several such days and nights preceding. As shown in the chart, on that day all the varieties observed fell into two distinct groups. One group here designated as "A" had first-period flowers open during the forenoon and second-period flowers open in the afternoon. For the other group (group B) the time of the two periods of opening was exactly the reverse. The change from one kind of flower to the other in both groups occurred rather sharply and quite uniformly between 1 and 2 o'clock. There was some overlapping of the two types of flowers and the change was somewhat later for the varieties Spinks and Taft. Most of the pollen of varieties in class B was shed between 10:30 and 12:30 o'clock a.m., covering the time when pistils of flowers of class A were most ready to be pollinated. Also pollen of class A was shed abundantly from 2:30 to 4:30 o'clock p.m., during which time the pistils of class B were most receptive to pollination.

In respect to the time relations of flowers opening, it is obvious that on this day there was the possibility for cross-pollination between any one variety of class A and any one variety of class B and that there was very little opportunity for cross-pollination between any two varieties of either class A or of class B. Possibly a few of the late firsts on Spinks and Taft could have been cross-pollinated about 2 o'clock with pollen from several other varieties of this same class.

The general survey made indicates that many, if not all, varieties of avocados may be grouped as normally forenoon or afternoon shedders of pollen. From the data now at hand, it appears that, in addition to those listed in the chart, the following varieties are to be included in class A: Benik, Cantel, El Grande, El Presidente, Kashlan, Perfecto, Solano and Ultimate. The following may, it seems, be included in class B: Cabnal, Champion, Dorothea, Hanson, Ishim, Ishkal, Lamat, Meserve, Nabal, Stephen's Choice, Tertoh and Tumin. The writer has not been able to observe the flowers of numerous varieties and in the case of others, further observation seems necessary before they can be properly placed. This is especially true of varieties that bloom early in the

season. Further and more extended study may change the grouping of some of the varieties mentioned above.

The grouping here given is based on the relative behavior during a series of warm sunny days. Cool, cloudy weather makes the opening of flowers irregular and retarded. Fog at night and rainy weather affect the regularity, the continuity and the sequence of bloom. If such conditions are long continued, they may have a decided effect in limiting the setting of fruit, even when there is a proper interplanting.

The effect of somewhat inclement weather is well shown in chart 2. The date of this record was May 17, and the trees observed were the same as those for which chart 1 was compiled, with the exception only of those varieties out of bloom on the later date. The day was cool and cloudy following a night of rather heavy fog and a preceding day that was cool and cloudy. On this day the time for the two periods of opening for all varieties of class A was exactly reversed. Pollen was shed during the forenoon and the first-period flowers were open only during the afternoon. The records of tagged flowers on this day and on numerous similar days reveal that this apparent reversal was due to a retarded opening of flowers. Those shedding pollen in the forenoon were flowers that should have opened on the previous afternoon and those open for the first time in the afternoon were those that would on a warm, sunny day, have opened during the forenoon. Although there were some minor variations, the varieties in class A were, so far as observed, quite similar in the changed behavior. They all made the shift in rather marked agreement and, observed on such days only, they might be mistaken as belonging in class B.

Only four of the varieties of class B observed on May 5 were in bloom on the 17th. No first-period flowers were open at any time during the day on trees of Rey and Linda. On Queen and Panchoy a few first-period flowers were partially open until afternoon. The weather continued cool, cloudy and somewhat foggy at night and on the 18th the behavior of the flowers was quite as on the l7th.

The morning of the 19th was cool and cloudy, but by 11 a.m. the sun was shining, and at 1 o'clock the temperature was high enough to make the afternoon decidedly warm. The behavior of the flowers for this day is shown in chart 3, the observation being for the same trees whose behavior on earlier dates is shown in charts 1 and 2. First, taking the varieties of class A, it is to be noted that there were three sets of flowers that opened during the day. During the forenoon a set was open for the second time and was shedding pollen. These were flowers delayed from opening on the previous afternoon, a delay of about eighteen hours. About noon a set of flowers opened for the first time. The opening of these was delayed about four hours. Then about 3 or 4 o'clock, another set of flowers opened and began to shed pollen. These were flowers that in warm, sunny weather normally open about noon. The nine varieties observed all behaved in quite the same manner. The behavior of the varieties of class B on this day was somewhat more irregular. For Linda and Panchoy no first flowers opened. This was also the case for Murrieta Two Pound and for Meserve. Rey shed pollen nearly all day and had a few first flowers open in the late afternoon. Queen had two sets of firsts and one set of second flowers open at times quite the reverse of the opening of similar flowers by varieties of class A.

The reversal in the type of flowers open by clock hours is shown in the photos of flowers of Challenge (IX), Queen (X) and Taft (XI.) This picture was taken at 2:30 p.m. on the 19th, and as one will see by referring to the picture and to chart 3, at this time Challenge and Taft had only first flowers open, which were ready to be pollinated, while Queen had only seconds, which were shedding pollen. For these varieties at this hour the types of flower open are exactly the reverse compared with the same hour on the 5th of the month.

Individual cases of delayed opening are indeed quite confusing in any preliminary or hasty study of flower behavior. But when the observations are extended to the relative behavior of a series of varieties over a considerable period of time the delayed action becomes quite apparent. The important point is that the same relations for cross-pollination that exist on other days, are still decidedly in operation. It will be observed that during this cloudy, cool weather for several varieties of class B no first flowers opened at any time during the day.

Irregular opening of flowers is very marked during the winter months on all of the early-blooming varieties such as Harmon, Northrup, Fowler and Puebla. During decidedly inclement weather some of these varieties may go for several days with only flowers of the second period opening. Frequently there is on a single tree an overlapping of flowers in the two stages of opening and the stigmatic ends of pistils may remain white until flowers open for the second time.

There is some question as to what extent flowers that open out of stride or with delay can function in fertilization and fruit setting. Many self- and close-pollinations, when these were possible, were made by hand on such varieties as Fuerte, Northrup and Harmon with complete failure in all cases, but some of such pollinations made on Carton did set fruit.

Observations made day after day during the winter on such varieties as Northrup, Puebla, Harmon, Fowler, San Sebastian and others show that in each of these the opening of flowers in unison is well marked and that the need for cross-pollination is very decided.

Experience seems to indicate that possibly some varieties may set fruit when there is no opportunity for cross-pollination. A most adequate field test of this would be the growing of trees of a variety in complete isolation from any other variety. In some of the varieties that set fruit abundantly and consistently there is frequent overlapping of flower types with apparent chance for close-pollination. But this is also equally well marked in trees of Taft, Fuerte and Harmon that do not produce a single fruit. In respect to the behavior in the opening of flowers there appears to be no distinctive difference which would indicate that a variety will be more self-fruitful than another. The ideal avocado, from the standpoint of self-fruitfulness is one that normally and rather continually overlaps for the two periods of opening and is in addition compatible in the close-pollinations that are thereby possible. Overlapping does occur more or less on every variety—frequently for different sides of the same tree according to exposure to sun and wind. Occasional or sporadic setting of fruit to close-pollination may be expected for any variety and it is possible that a peculiar set of local conditions may be favorable to close-pollination. But until it is definitely determined that there are varieties which will consistently and very

generally set and mature fruit when alone one can scarcely advise the planting in solid blocks of any one variety.

When fruit is set in abundance by an avocado tree there is invariably considerable dropping of immature fruit. In general, perhaps, it may be said that fruit setting in the avocado is a matter chiefly of proper pollination and that the holding and maturing of fruit is a matter of proper cultural treatment. Yet this may not be entirely the; case. In many of the young fruits which are about to fall prematurely, the embryos are very frequently dead or dying, which may be in part due to a poor or weak grade of fertilization as well as to influences of temperature or of water and food relations. It is possible that when fruits set in abundance many set without the most proper pollination or with no pollination whatever and that the majority of the fruits which remain to maturity are those whose embryos are the products of a cross-fertilization.

It has been suggested that these matters of flower behavior and of the relations of pollination in fruit setting are too intricate for the average grower of avocados to consider and that what is needed is a simple "rule of thumb" for the most successful interplantings. It seems very obvious that cross-pollination will be best promoted by interplanting a variety of group A with a variety of group B, provided, of course, they blossom during a considerable part of the same calendar period. Thus Fuerte and Dickinson seem able to cross-pollinate reciprocally. But Dickinson is somewhat mere tender and its period of flowering is somewhat later than that of Fuerte. Furthermore, in certain localities, local conditions may keep one or the other or perhaps both out of the normal sequence of bloom more or less continually. At the lower and cooler edge of a certain large grove of avocados, the flowers on the Fuerte trees are repeatedly two or more hours later in opening for the first time than are the flowers on the trees of Fuerte growing at the upper end of the same grove. Thus local conditions, such as pockets of cool air during the day or of fog at night, may decidedly affect the efficiency of a particular interplanting. It looks as though the growers must give attention to these matters to be most completely successful in securing crops of fruit.

Several thousand cross-pollinations have been made by hand during the past season in the effort to determine whether certain cross-relations between varieties of class A and B are more compatible than others. The percentages of flowers that set fruits were on the whole too low and irregular to admit of satisfactory comparisons. These pollinations were carefully made at the time when pistils and pollen seemed most suitable for the proper reactions, but only relatively few fruits set, and many of these were shed prematurely. The results do indicate that the time for the most favorable and successful pollinations is decidedly limited, that the pistils are most receptive for only a short time and that many cross-pollinations effected while flowers are open for the first time are doomed to be failures. The most successful interplanting is that which favors frequent and continued cross-pollinations during the particular and limited period of time when pollen and pistils are "most right." This is without a doubt best provided for when a variety normally shedding pollen in the forenoon is interplanted with a variety whose flowers open for the first time during the forenoon. The further selection of particular sets of varieties for interplanting must, of course, be determined by cultural requirements of varieties, their habits of growth, the quality of fruit and the season of maturity with reference to the demands of the trade.

The matter of how an interplanting should be done depends very decidedly on the habits and activities of insects, and most especially of honey bees, in their relation to the peculiar and rather unique behavior of flowers. The pollen is lifted out of the anthers by valves, and for a time remains in somewhat sticky masses on the upturned valves, but exposed to the air. When bees in their quest for nectar visit flowers thus shedding pollen, they become much covered with the pollen grains; but to distribute these to receptive pistils where they can function they must soon visit a flower that is open for the first time, and this involves, as a rule, a visit to a tree of another variety whose flowers open in reverse order. Bees do visit the open flowers of avocado trees in abundance. They fly from flower to flower on a tree collecting nectar. Frequently they force open flowers that are closed between the first and second periods of opening. It would seem that this habit would facilitate close-pollination, provided the pistils of such flowers are still receptive, but in many cases the ends of the pistils are black and many controlled pollinations of such flowers whose pistils were still white were all failures.

But the activities of honey bees on avocado flowers do not necessarily lead to cross-pollination. Bees do not frequently and continually pass back and forth from a tree of one variety that is shedding pollen to another variety which has flowers ready for proper pollination. To facilitate this, the interplanting should be mixed and close, much more so than is deemed necessary for the interplanting of cherries, almonds or prunes. Possibly the alternate interplanting of two or more varieties which bloom at the same time and which supplement each other in respect to alternative opening may in many localities be sufficient to yield good crops. Perhaps the trees of two such varieties can be, planted in pairs only a few feet apart, as has been suggested by one avocado grower. The writer is inclined to advise the growing of two or perhaps three varieties on the trunk of one tree and the arranging of these so that no two parts adjacent in any direction are of the same combination. To establish and maintain these relations most satisfactorily, will of course, call forth the skill of the orchardist in selecting and grafting varieties which grow well together and in pruning these to maintain a well-balanced tree.

But in all cases there should be provided bees in abundance and it will be of advantage if there is nothing close by to attract them from the avocados during the time the latter are in bloom.

The studies made by the writer in California during the present season of bloom of avocados fully confirm the main observations and conclusions made by Nirody in Florida (see Annual Report of California Avocado Association for year 1921-1922) that the pistil of an avocado flower matures before the pollen is shed by that flower, that this alternative development of the essential parts of the flowers is decidedly synchronous for a tree as a whole, that cross-pollination is hence necessary for the proper setting of much fruit, and that the time relations favor chances for crosses between certain varieties more than between others.

There are however several points of difference in the observations:

(a) The proterogyny is more decided than Nirody reports, for the flowers normally have two distinct periods of opening instead of one.

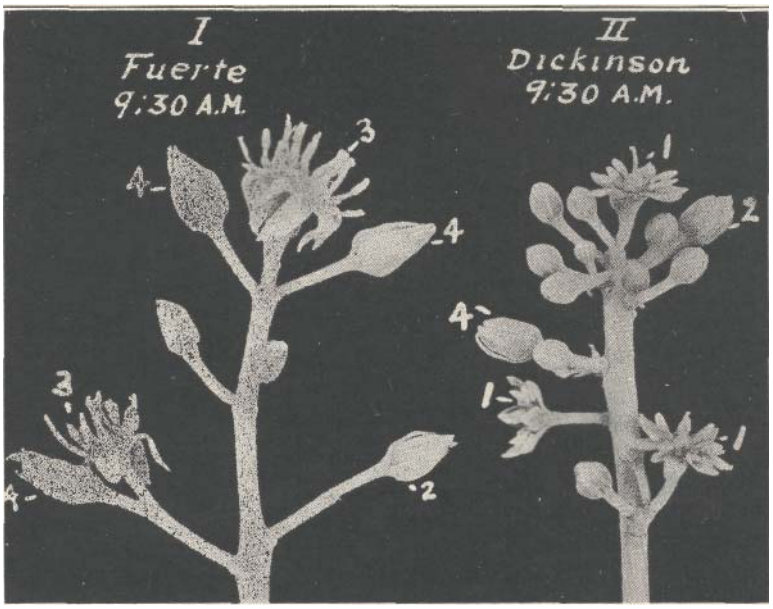
(b) The off-stride and irregular blooming under various weather conditions gives wide variations in the hours by clock when pollen is shed. This, however, may be much more

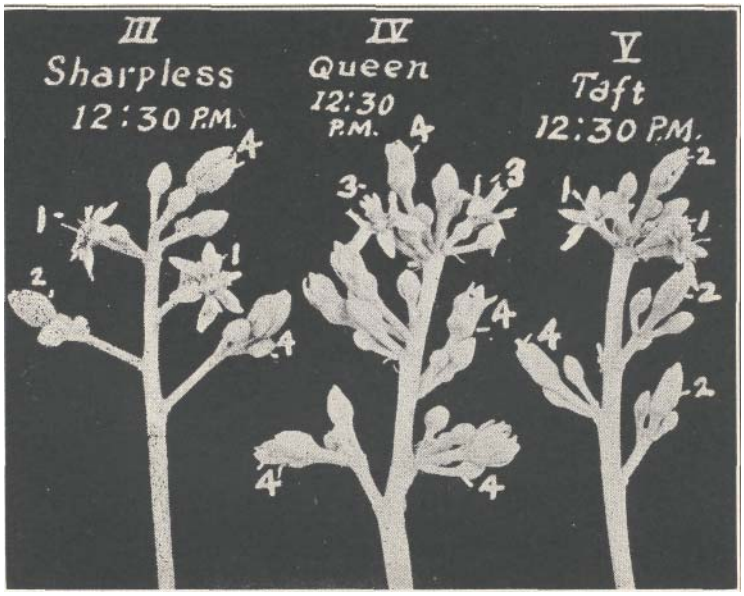
complex under California conditions than is reported for Florida.

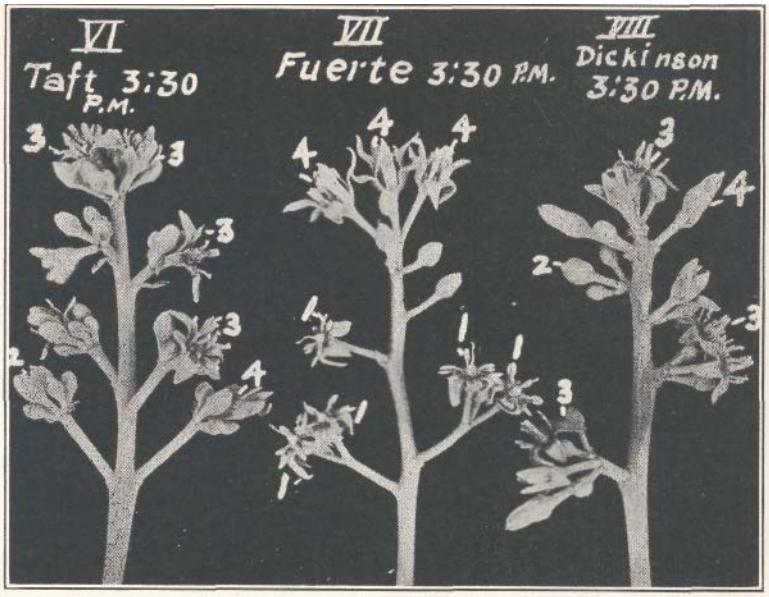
(c) The grouping of varieties in two rather definite classes with respect to the normal behavior of flowers makes the inter-relations between varieties somewhat simpler than the hour and hour relations reported by Nirody.

[During the academic year of 1922-1923 Dr. Stout was a visiting member of the faculty at Pomona College on leave of absence from the New York Botanical Garden. For a number of years his main research has been on sterility and fertility in plants with special reference to crop production. The flowering conditions in the avocado appealed to his interest and training and at the request of certain officers of the California Avocado Association and with the consent of the authorities of Pomona College, the studies were undertaken. About half the time over a period of six months was devoted to the investigation. Mr. Howard Lorbeer, a graduate student in Pomona College, very ably assisted, especially in studies of the activity of insects in pollination. During the month following the meeting on May 11-12 of the California Avocado Association considerable additional data were obtained. This made possible the more complete discussion of off-stride blooming, of the grouping of varieties, of fruit setting without cross-pollination, and of the best method of interplanting here printed as published in the Farm and Tractor section of the Los Angeles Times in the issue of July 8, 1923 under the title "Clocking the Avocado."—EDITOR.]

The photographs show clearly the normal habits of flowering which make cross-pollination in avocados necessary for the most abundant setting of fruit. No. 1 in each cluster designates flowers open for the first time; No. 2, flowers closed after the first opening, but taken before the second opening; No. 3, flowers in the second period of opening when pollen is shed; No. 4, flowers that have shed pollen and are either closing or fully closed for the last time. This particular set of photos illustrates the behavior of flowers on a series of warm, sunny days, such as are indicated in chart 1, below, and which may perhaps be considered as normal. Fuerte (I) and Queen (IV) normally shed pollen in the forenoon from flowers open for the second time, but in the afternoon a set of flowers (see Fuerte VII) is open for the first time and ready for pollination. Dickinson (II,) Sharpless (III) and Taft (V) are good examples of varieties which normally have first-period flowers open for pollination in the forenoon, but these flowers close during mid-day and a set of second-period flowers open to shed pollen, as shown by Taft (VI) and Dickinson (VIII.) The maturing of pistils and stamens of the same flower at different times makes self-pollination rarely possible. The alternative opening and closing of flowers in unison for the two stages of development decidedly limits the chances for close-pollination. Cross-pollination, furthermore, is also much restricted except when a variety sheds pollen at a time when the flowers of another variety are open for the first time. Thus Fuerte and Dickinson work well together (see I and II for forenoon relations and VII and VIII for afternoon relations,) while Dickinson, Sharpless and Taft do not.


I
Fuerte
9:30 A.M.
II
Dickinson
9:30 A.M.


III
Sharpless
12:30 P.M.
IV
Queen
12:30
P.M.
V
Taft
12:30 P.M.



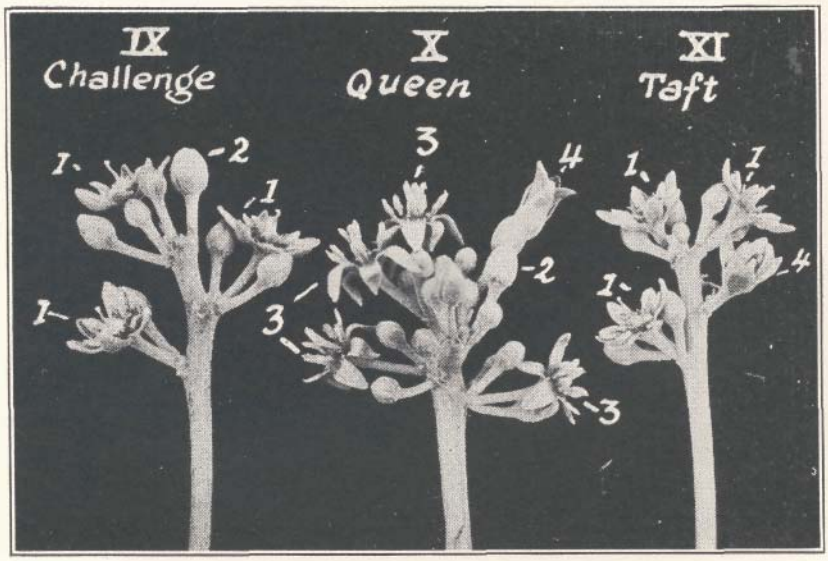


Photo taken at 2:30 p. m. on May 19, after inclement weather conditions had thrown blooming sequence out of stride. Queen is now shedding pollen in the afternoon, and on Taft and Challenge the only flowers open are firsts. At this particluar time, cross-pollination only is possible. Later in the day, as shown in chart 3, another set of flowers opened on each of these varieties.

FLOWERS OF QUEEN AVOCADO

The photograph, taken at 11 a. m. on May 17, shows an overlapping of flowers open for the first time, (1) with flowers open for the second time, (3) all on the same flower cluster, and apparently affording opportunity for close-pollination.

Chart 1

Hours of the day

May 5, 1923 — 9 10 11 12 1 2 3 4 5 6 7

A

- Blakeman
- Challenge
- Clower
- Colorado
- Dickinson
- Dicky
- El Oro
- Murieta Green
- Mayapan
- Sharpless
- Spinks
- Taft

B

- Furte
- Ganter
- Linda
- Lyon
- Montezuma
- Panchoy
- Queen
- Rey
- Walker

Chart 2.

Hours of the day

May 17, 1923 8 9 10 11 12 1 2 3 4 5 6

A
Blakeman
Challenge
Colorado
Dickinson
Dicky
Murrieta Green
Mayapan
Sharpless
Spinks
Taft

B
Linda
Panchoy
Queen
Rey

El Presidente
Meserve
Murrieta 2 lb

Chart 3.

Hours of the day

A May 19, 1923. 8 9 10 11 12 1 2 3 4 5 6