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AVOCADO FLOWER POLLINATION AND FRUIT SET

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Introduction

From the beginning of studies on the behavior of the avocado flower by Nirody (7) and Stout (10), considerable attention has been focused on the role of bees in avocado pollination and fertilization. Nirody's and Stout's studies clearly showed that the avocado flower undergoes a dual opening cycle —stage I, the first opening or female stage when the stigma is receptive, and stage II, the second opening or male stage when pollen is shed. They also found that in some varieties (type A) stage I occurs in the A.M. and stage II occurs in the P.M. of the following day. In another group (type B) the flowers function as females in the P.M. and as males the following A.M. In view of his studies on the avocado flower, (11) recommended the use of bees to facilitate cross pollination and thus increase the fruit set of avocados.

Later studies involving pollination by bees were aimed at solving two general problems: (1) is there a difference in the number of fruit set following cross versus close (the transfer of pollen from one flower to the stigma of another flower of the same tree) pollination?; and (2) does a flower ever pollinate itself and subsequently set fruit? Robinson and Savage (8) found that the total fruit set, where there was no chance for cross (versus close) pollination, was greatly diminished despite long-continued and intensive working by bees. In another study of close pollination, Clark and Clark (4) reported similar findings—i.e., cross pollination was more beneficial to fruit setting in most varieties. (Fuerte responded similarly to both cross and close pollination.) Clark (1926 and earlier), in connection with these experiments, found that there was no effect from a large supply of bees since 36 fruit were obtained where there were many bees inside a netted tree and 35 fruit when only 4 to 6 bees were present at one time.

In 1923, Clark reported an incomplete experiment on a Dickinson tree, half of which was exposed to open pollination while the other half was enclosed in a net without bees. This tree yielded 6 fruit outside the net while 3 fruit, which dropped after a short time, set on the branches inside the net. This represents the earliest attempt at a controlled experiment designed to determine the role of bees in pollination.

In 1942, Lammerts (5) concluded that large dipterous and hymenopterous insects are necessary for pollination, at least for the type A varieties, since fruit set on a caged tree where hand pollinations were made, but no fruit set in the areas where the flowers were emasculated or in other areas where the flowers were not handled. Similarly, Lesley and Bringhurst (6) observed that a tree caged two consecutive years with bees set fruit while a tree of another variety caged with no bees bore no fruit.

In another interesting experiment, Schroeder (9) showed that pollen was transferred from the anther to the stigma of the same flower without the visitation of large insects. Furthermore, this pollen subsequently germinated. Although the supply of pollen on the stigma was less than that found in the case of flowers exposed to insect visitation, there was theoretically an adequate amount of pollen to provide a good crop of fruit.

In view of these varied findings on the role of bees in the pollination and fertilization of the avocado flower, the following controlled experiment was conducted in an attempt to clarify the problem.

Methods and Results

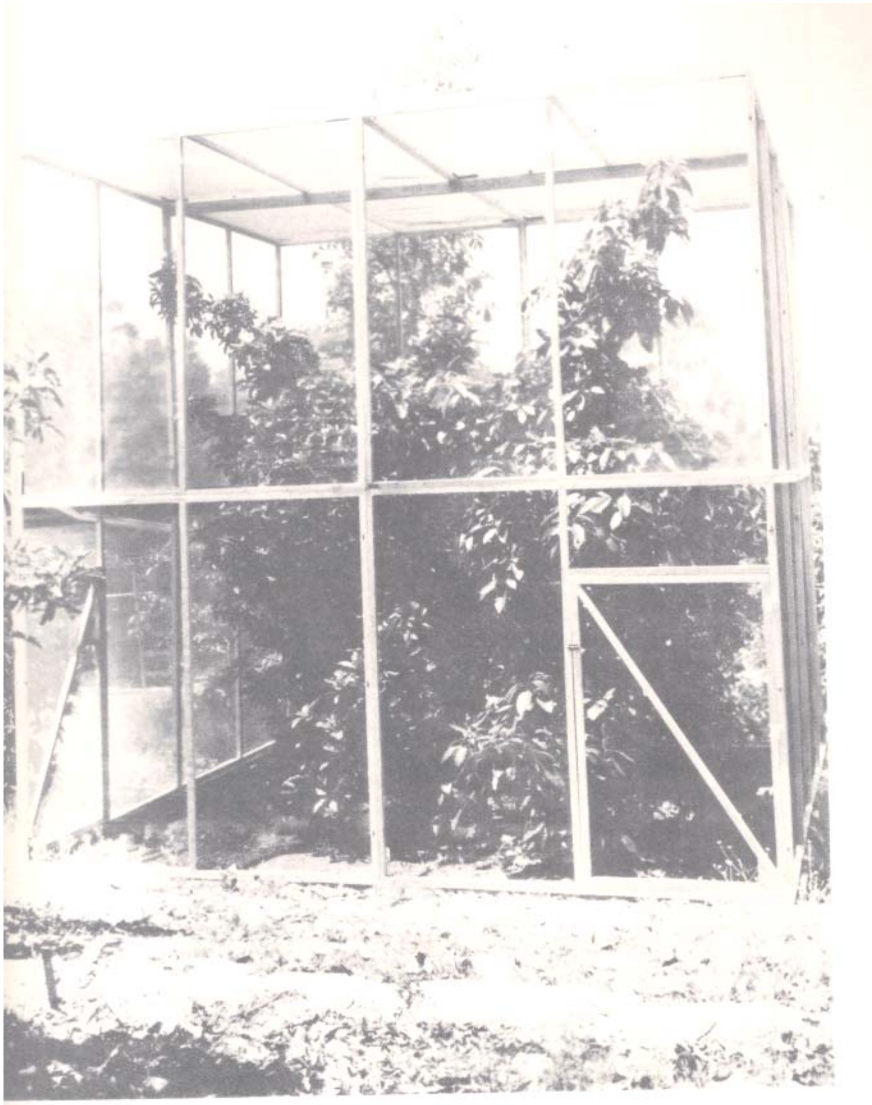
In the Spring of 1954 two different plots were established—one at Riverside with the Zutano variety, representing type B, and the other at the Harlan Griswold Ranch in San Luis Rey Heights with the Hass variety, representing type A. Each plot contained two trees of approximately the same age and vigor. Each tree was caged individually, and, if any advantage existed among the trees, this tree was chosen as the one to be caged without bees. All cages were 12' x 12' x 16' except tree No. 2 in the Hass plot which was only 12' high. The cages were constructed of regular window screening with a "Lumite" cloth top, except for tree No. 1 of the Hass plot which had a cheesecloth covering on top.

In the Hass plot, the trees were flowering abundantly and had begun to set fruit—the fruit ranging from ½ to 2 cm. in length. Prior to completing the enclosure of the trees, all fruit and open flowers were removed and only enclosed buds remained. These trees were caged on March 1, and a hive (*The single story hives contained 10 frames. In the Hass plot 8 frames were full; in the Zutano plot, 2 were full.*) was placed in the cage under tree No. 2 on March 3- On June 14, at the end of the blooming season, the bees were removed and the cage was dismantled.

The flowering cycle of the Hass trees on the various days of observation appeared to be somewhat delayed, i.e., the flowers were in stage I just prior to Noon until 4 P.M., and in stage II in the late P.M. of the following day with perhaps some pollen still being shed the following A.M. Bringhurst observed similar behavior in the University of California at Los Angeles orchards.

In the Zutano plot, the trees were not equal in amount of bloom and the beeless cage was assigned to the tree with the greater number of flowers. Tree No. 2 (with bees) was oversized for the cage and in pruning the tree, much of the bloom was eliminated. Also, tree No. 2 had set a good crop of fruit in 1953 while tree No. 1, the beeless tree, had borne only about 10 fruit, because it was also caged during 1953 for hand pollination purposes. These cages were erected on February 23 and 24, 1954. The trees started to bloom during the first week in March, and a hive was placed in the cage under tree No. 2 on March 15. On May 20 the bees were removed, and the cages were dismantled on June 2 and 3.

The bees were fed periodically with a honey-water mixture. The hives were placed in the southeast corner of the cage. During a warm day, the bees actively worked the flowers. During cold and cloudy weather the bees were quite inactive, often not working the flowers at all.



A typical cage enclosing an avocado tree. This cage is 16' high and 16' on all sides. The screen inhibits the entrance of larger flying insects.

After removal of the cages, the following results were tabulated:

Number of fruit counted on each caged tree

	Beeless	Bees
Zutano	4	120
Hass	5	284

The superior yield of the trees caged with the bees is significant. The fruit count on the trees not exposed to bee activity is almost certainly accurate, whereas the count on the trees exposed to bees represents a minimal count. The fruit size in early June varied from ½ to 2¼, cm. on the Hass trees. On the Zutano tree, the fruit on tree No. 2 (bees) varied from 0.4 to 2.5 cm. On tree No. 1, the fruit ranged from 7 to 8 cm. in length. One possible explanation for the setting of fruit on trees in the beeless cages might be the occasional transfer of pollen by thrips or chance wind pollination. Also, this fruit may have been set prior to erecting the cage despite efforts to remove all open flowers.

In addition to this experiment, others were performed that bear on this problem of the role of bees in pollination. One of these involved a comparison of branches, protected against bee entrance by cheesecloth sleeves, some of which were hand pollinated while others were not pollinated (controls). Five different varieties were thus tested. The following results were obtained:

		No. of Sleeves	Total No. of Flowers	No. of Initial Fruit Set
Ryan	Pollinated	9	78	5
	Control	3	93	0
Bacon	Pollinated	12	76	14
	Control	6	98	0
Clifton	Pollinated	7	36	8
	Control	10	*167*	*4*
Hass	Pollinated	26	289	33
	Control	13	321	0
Regina	Pollinated	14	140	69
	Control	10	110	0

Fruit set only on the enclosed branches in which the flowers were hand pollinated, except in the case of the Clifton where 4 fruit set in the control sleeve. Bringhurst (2), testing various varieties in a similar manner, found that fruit, which could not be accounted for by hand pollination, set only on enclosed branches of the Mexicola.

In another experiment conducted in the greenhouse (from which all large flying insects were excluded) 46 fruit developed from the 95 flowers that were hand pollinated on a Zutano tree. In the control, where no stage I pollinations were made, 84 flowers set no fruit. Thus, without some agent of pollen transfer fertilization did not occur.

In 1953, three caged trees (Zutano; Wilhorne; and Hass, MacArthur and Duke on one stump) located in the avocado orchard in Riverside yielded no fruit except on those branches that were hand pollinated.

Discussion

Two very distinct stages exist in the avocado flower cycle. It was early shown (Stout 10) that stage I of the individual flower cycle is the female or pollen-receptive stage while stage II is the male or pollen-bearing stage.

The avocado flower stigma comes in contact with its own anthers, containing valves loaded with pollen, only during stage II. Schroeder (9) showed that in an individual flower in this stage pollen was transferred to its own stigma and subsequently germinated. However, in other experiments (Peterson, unpublished), hand pollinations on the most receptive fresh-appearing, stage II stigmas have never resulted in the setting of fruit. Under greenhouse conditions of high humidity and moderate temperature, pollen grains germinated on stage II stigmas in the Zutano and Fuerte, although they did not effect fertilization in such a stage II pollination. Thus, an individual flower apparently cannot pollinate itself and subsequently produce a fruit. It is important that the pollen not only reach the stigma but that it arrive there at the proper time in the flower cycle.

Therefore, since an individual flower does not set a fruit after self-pollination, some agent of pollen transfer *must* be necessary. However, a "tree can self" itself (close pollination) through the medium of bees when the two stages overlap, so that for brief periods of the day pollen and receptive stigmas are present on a tree at the same time. In addition, "residual" pollen might be carried on the bees and remain viable for effective pollination even if no overlap of stages occurs.

However, as previously stated, most experiments designed to test the effectiveness of close versus cross pollination have clearly shown that the latter is more effective. This is best illustrated in the following observation of Robinson and Savage (8). They reported a case of a 10 acre planting in Lake Eloise, Florida, containing Fuerte avocado trees, 10 to 12 years of age, which failed season after season to produce any fruit. When a young adjoining grove containing other varieties first produced flowers, the row of Fuerte trees next to this new planting set a full crop of fruit; in the second row there was a fair set of fruit and in the third row only one tree out of 12 set any fruit, while no fruit could be found in any of the succeeding rows. This indicates the response of Fuerte trees to varieties having the complementary flower cycle (type A), and suggests the limitation in range of bees in pollinating activity, at least in this area of Florida. In Hawaii (Storey, personal communication), a similar need exists for interplanting varieties possessing reciprocal types of flower behavior. In this case, there is rarely any overlap of stages due to normal high night temperatures.

Conclusion

1. Some agent of pollen transfer is necessary in the pollination and subsequent setting of avocado fruit.
2. Honey bees are known to be good pollinators.
3. There is only a short period during the cycle of the avocado flower in which pollination can be effective.

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