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Pollination of Avocado - Some New Insights with Special Reference to the 'Hass' Variety

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The avocado flower has a fascinating bloom habit, and much is known about how this occurs in different varieties. The benefits of cross-pollination and the introduction of bees have been well documented for several varieties that were formerly of great importance, especially 'Fuerte'. More research needs to be done, however, in determining more precisely the roles of bees and cross-pollination for the 'Hass' variety. I will begin with what is known about the flowering process, then present the traditional view of avocado pollination, and finally present some recent evidence that supports cross-pollination and the introduction of bees for 'Hass'.

Figures 1 and 2 show the structure of the avocado flower and the positions of its parts in the female stage (I) and the male stage (II). The non-sexual parts consist of three petals and three sepals. The sexual parts of the flower consist of a single pistil (female) in the center and two whorls of stamens (male) just outside the pistil (3 inside, 6 outside). Two nectaries at the base of each stamen and three staminodes (vestigial stamens) alternating with the inner stamens complete the picture. A single avocado tree has as many as one million flowers, but only one in 5000 needs to be pollinated to get a commercial yield of 100 Ibs./tree (10,000 Ibs./acre). This is only 0.02% of the total number of flowers!

Each avocado flower opens twice, on two successive days. At the first (female, or stage I) opening, the stigma of the pistil is prominent and receptive to pollination. The stamens are bent outward and do not release pollen at this stage (Fig. 1). At the second (male, or stage II) opening, the pistil is shriveled and no longer receptive. The stamens project upward, and their anthers release pollen at this stage (Fig. 2). To further complicate the picture, there are two "types" of avocado varieties - A and B. "A" type varieties have flowers which are female in the morning of the first day and male in the afternoon of the next. "B" type varieties have flowers which are female in the afternoon of the first day and male in the morning of the next. This pattern is diagrammed in the following table:

	DAY ONE			DAY TWO	
	AM	PM		AM	PM
A:	female	closed		closed	male
B:		female	(closed)	male	

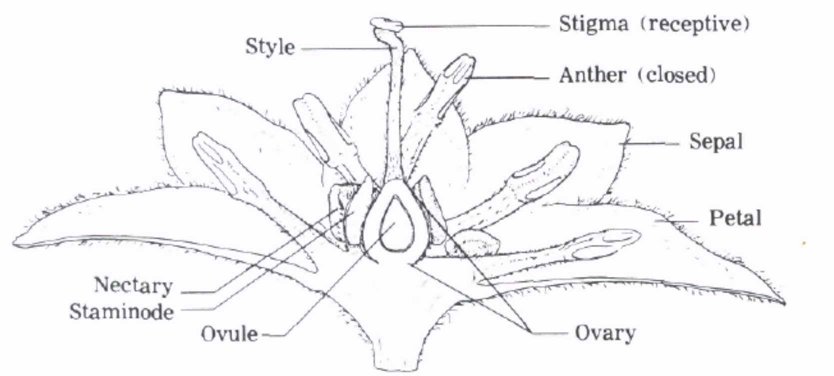

Fig. 1. Stage I (female stage)

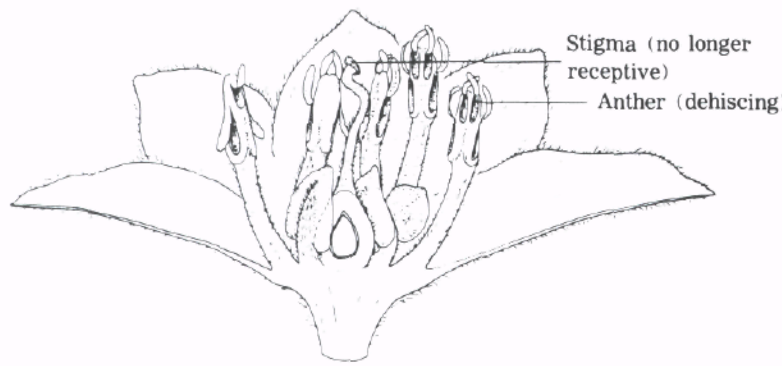

Fig. 2. Stage II (male stage)

However, there are many flowers opening every day, so there is overlap between flowers in Day One of the cycle and flowers in Day Two of the cycle. Thus the pattern becomes:

	DAY ONE			DAY TWO	
	AM	PM		AM	PM
A:	female	male	(closed)	female	male
B:	male	female	(closed)	male	female

In other words, type "A" varieties have flowers which are female in the morning and male in the afternoon, and type "B" varieties have flowers which are male in the morning and female in the afternoon. Some common "A" type varieties in our area are Hass, Pinkerton, MacArthur, and Gwen; "B" types include Bacon, Zutano, Fuerte, and Whitsell.

Because the male and female stages do not overlap, we have traditionally planted varieties of more than one type and introduced bees to move pollen between them. Field studies with several different combinations of "A" and "B" type varieties have shown that fruit set of the main variety increased up to 50% by the addition of pollinizer trees and the introduction of bees (Bergh, 1967, 1968). None of these studies has tested 'Hass' as the main variety, although circumstantial evidence has supported the use of pollinizer trees for this variety. In a recent study with the electrophoresis technique, Vrecenar-Gadus and Ellstrand (1985) found that 89.6% of the 'Hass' fruit in a mixed Hass and Bacon planting (alternate rows) had been pollinated by 'Bacon' pollen, In an adjacent grove that was solid 'Hass', 42.2% of the 'Hass' fruit had been pollinated by 'Bacon', and the nearest 'Bacon' tree was 250 feet away. The 'Hass' trees in the mixed orchard also bore 49.7% more fruit than those in the solid 'Hass' orchard. Finally, the rate of outcrossing was positively correlated with the yield in both orchards. These results suggest that much of the fruit set in 'Hass' does result from cross-pollination, and that bees may carry pollen for a considerable distance from pollinizer trees.

Many different arrangements of pollinizer trees are possible. Some arrangements which have been used are alternate rows, or every third tree in every third row. Lee (1973) presented a pattern of every fifth tree in every third row, which leads to an arrangement of four main variety trees surrounding each pollinizer tree after two thinning operations have occurred. It has also been a common practice to plant a windbreak of the pollinizer variety to provide pollen for the main variety. Research suggests that the primary movement of pollen from a windbreak is by bees, rather than by wind, as the pollen of avocado flowers is heavy and sticky and not readily released into the air (Free, 1970). Another method which works but is not as practical is to graft limbs of the pollinizer variety onto the main variety trees (Bergh, 1968), The problems here are that fruit must be removed from the pollinizer limbs to assure a strong bloom every year, and that the pollinizer limbs may be overgrown by the main variety (or vice-versa),

The major considerations in choosing a pollinizer variety have been the value of the fruit and the overlap of bloom time. The latter has not been a major problem in California, as the bloom periods of most varieties extend over several months and sufficient overlap occurs between most varieties. The primary problem has been that it is increasingly difficult to locate a high-value pollinizer. Since 'Hass' has overtaken other varieties in importance, the price obtained for the fruits of pollinizer varieties like 'Bacon' has not even paid picking costs in the past several years. Growers have also begun to question the value of pollinizer trees, as there are many examples of groves of solid 'Hass' which are yielding well.

Thus there is conflicting evidence for the need for cross-pollination of 'Hass'. The need for bees, however, has not been disputed. One reason for providing bees, as mentioned earlier, is to transfer pollen from type "A" trees to type "B" and vice-versa. Even if only one variety is present in an orchard, however, there is still good evidence that the introduction of bees will be beneficial. In cage studies, Peterson (1955) found that 'Hass' trees set an average of 284 fruits when bees were present and only 5 fruits when no bees were in the cage. This can be explained by the fact that there is some overlap between bloom stages among the flowers of a given tree, and among different trees of the same variety (Lesley and Bringhurst, 1951). There is also the possibility that pollen collected from stage II flowers by bees remains on their bodies in viable form long enough to pollinate stage I flowers in the afternoon (type "B" varieties) or even until the following morning (type "A" varieties). This possibility has been mentioned by several workers (Kalman, 1978; Free, 1970; Bergh, 1967). All of these reasons support the introduction of bees, regardless of whether a pollinizer variety is present in the orchard.

Many factors may influence the effectiveness of the pollination process, even if both pollinizer trees and bees are present. These complicate the picture just presented, and make it difficult in some cases to determine whether there was in fact a benefit to planting the pollinizer variety and/or to introducing bees. I will discuss seven of these below, with particular emphasis on the 'Hass' variety.

1. Temperature. Sedgley and Annells (1981) did a comprehensive study of the behavior of 'Hass' flowers at various combinations of day and night temperatures. The most ideal range for floral behavior, pollen-tube growth, and embryo development was a daytime temperature of 25°C (77°F) and a nighttime temperature of 20°C (68°F). At temperatures as high as 33/28 degrees C (91.4/82.4 degrees F), floral behavior was normal, but at a lower temperature regime of 17/12 degrees C (62.6/53.6 degrees F), the cycle was reversed to be more like a type "B" variety. The flowers opened in the afternoon in the female stage, and did not open again in the male stage until the afternoon two days later. This suggests that lower temperatures may result in considerable overlap of flower stages in the 'Hass' variety. Other workers have come to the same conclusion. Lesley and Bringhurst (1951) also found that low temperatures delayed flower opening, resulting in overlap of flowering stages. This advantageous effect could be canceled, however, if temperatures were too low, due to the reduction in pollen tube growth rate and bee flight.

Other climatic factors may also affect fruit set. Hot, dry weather will desiccate the flowers and result in less set. Cold, strong winds during bloom will also reduce fruit set, probably because of their effects on pollen tube growth and bee flight.

2. Distance from the coast. There is circumstantial evidence that growers whose 'Hass' groves are closer to the coast have less need for cross-pollination with another variety. This may be related to cooler temperatures, which result in increased overlap between the male and female stages of flower opening within a grove (see above). Lesley and Bringhurst (1951) noted this effect, and found considerable difference in flowering behavior between Riverside (inland) and Los Angeles (more coastal). They found that both maximum and minimum air temperatures, and possibly humidity, were involved.

3. Other pollinators. Other farm advisors and I have observed large numbers of gnats on flowers in several of the orchards in canyons in Santa Barbara County. Many of these orchards have very high yields, and consist only of the Hass variety. Although it has not been proven, it seems likely that the gnats are contributing to pollination. Other insect pollinators may also exist.

4. Tree-to-tree variability, "off-types", microclimates. Many of us have seen variation within avocado trees of the same variety. Not only may leaf and fruit characteristics vary somewhat, but bloom time may not be exactly the same. As mentioned earlier, cage studies and field observations have shown this to be true with 'Hass' and other varieties. Variations in temperature within an orchard may also result in staggered bloom times. Even a small fraction of trees that bloom later or earlier in the day may provide pollen for the rest. I have observed Hass flowers in the female stage on some trees, when at the same time other trees in the same orchard had flowers in the male stage.

5. Wind. Avocado pollen is too sticky and heavy to be carried by the wind, according to the literature (Free, 1970; Bergh, 1967). Yet studies have shown a considerable benefit from windbreaks of a pollinizer variety. This may be due only to movement of pollen by bees, but it may also be related to wind distribution of pollen or a sheltering effect of the wind break. The microclimate in the rows immediately adjacent to the wind break is likely to be more conducive both to bee flight and to pollen tube growth.

6. Year-to-year variability. The fact that 'Hass' avocados pay produce very heavily one year and very lightly the next is often credited to a natural "alternate bearing" tendency. However, it is also possible that the benefits of cross-pollination are shown more strongly in some years than others. In years when a given orchard has considerable overlap between stage I and stage II flowers, there may be little necessity for cross-pollination. But in years when temperatures support a strong separation of stages, it may be important to have both types in the orchard. This argument would support the planting of pollinizer trees as "insurance" for those years when bloom overlap does not occur.

7. Pollen donor. Sedgley (1979) found that the effectiveness of pollination was not related to the variety of the pollen donor. However, Gazit and Gafni (1986) found that selfed fruits may be aborted more readily than cross-pollinated fruits. This might help to explain the high rate of drop of young fruitlets in some orchards.

CONCLUSIONS

I believe that these arguments support the continued interplanting of pollinizer trees, but at considerably wider spacings than has been recommended in the past. The study by Vrecenar-Gadus and Ellstrand (1985) suggests that some out-crossing may occur even if pollinizer trees are as much as 200 feet from the main-variety trees. The decision as to whether to interplant with pollinizers, and how many, will have to be a compromise between the decreased fruit value of pollinizer trees and the potential increased yield of the main-variety trees with the pollinizers present.

Regardless of the decision on interplanting pollinizer trees, there is overwhelming evidence to support the introduction of bees. It is important to emphasize that bees or another insect will still be needed to move pollen between stage II and stage I flowers even if only one variety is present. When one considers that there is no chance to increase the number of fruit on the tree once the bloom period is over, the introduction of bees may be considered one of the most important orchard management practices.

WORKING WITH YOUR BEEKEEPER

The introduction of bees to an orchard is a cooperative venture between the grower and the beekeeper. Although there is evidence that avocado orchards might benefit from more than one hive per acre, bees do not gather very much nectar from avocados; and beekeepers are often reluctant to provide hives at a greater density. Too many hives per acre may actually result in a loss of strength of the colonies and a corresponding loss to the beekeeper. Colonies are generally transported in pallets of 12, so any request for specific placement or numbers of colonies should keep this in mind. Placing the colonies in small groups (multiples of 12) is generally more desirable from a pollination standpoint than placing larger numbers of them in one place in the orchard. It is also recommended that the bees be placed within the orchard if possible, rather than at the periphery, especially if there is a more attractive crop such as citrus nearby.

It is important to place the bees in the orchard *after* bloom begins so that the bees do not become trained to an alternate food source before the avocados begin to flower.

The best time to introduce bees is at 10% bloom. It is also not necessary to keep the bees in the orchard until the last flower has bloomed. Late-season flowers will produce "off-season" fruit which is unlikely to be picked anyway, and beekeepers are eager to move their hives on to alfalfa and other crops where they can strengthen their colonies and gain more honey. (The honey produced from avocados, if any, is low-grade, dark, strong-tasting, and does not bring a very good price on the market). Beekeepers may ask a fee for the pollination service, especially if there is no good nectar source nearby such as sage or citrus that is blooming at the same time. This is not unreasonable, as this is a common practice in other crops and helps the beekeeper pay for loss of honey, movement of colonies, and regular maintenance of the hives while they are in the avocado orchard.

REFERENCES CITED

Bergh, B.O.1967. Reasons for low yields of avocados. Calif. Avocado Soc. Yrbk. 51: 161-172.

Bergh, B.O. 1968. Cross-pollination increases avocado set. Calif. Citrograph 53(3): 97-100.

Free, J.B. 1970. Insect pollination of crops. Academic, New York. 544 p.

Gazit, S. and E. Gafni. 1986. Effect of hand pollination with different pollen donors on initial fruit-set in avocado. Israel Agresearch 1: 3-17.

Kalman, C. 1978. Avocado pollination. Proc. IVth. Int. Symp. on Pollination-1978: 207-209.

Lee, B.W. 1973. A planting plan for avocados. Calif. Avocado Soc. Yrbk. 1973: 76-81.

Lesley, J.W. and R.S. Bringhurst. 1951. Environmental conditions affecting pollination of avocados. Calif. Avocado Soc. Yrbk. 1951: 161-173.

Peterson, P.A. 1955. Avocado flower pollination and fruit set. Calif. Avocado Soc. Yrbk. 39: 163-169.

Sedgley, M., 1979. Structural changes in the pollinated and unrollinated avocado stigma and style. J. Cell Sci. 38: 49-60.

Sedgley, M. and C.M. Annells. 1981. Flowering and fruit-set response to temperature in the avocado cultivar 'Hass'. Scientia Horticulturae 14: 27-33.

Vrecenar-Gadus, M. and N.C. Ellstrand. 1985. The effect of planting design on out-crossing rate and yield in the 'Hass' avocado. Scientia Horticulturae 27: 215-221