Tracking the fate of individual avocado flowers following hand pollination (inset). Photos from Iñaki Hormaza.

Factors Influencing Avocado Fruit Set and Yield

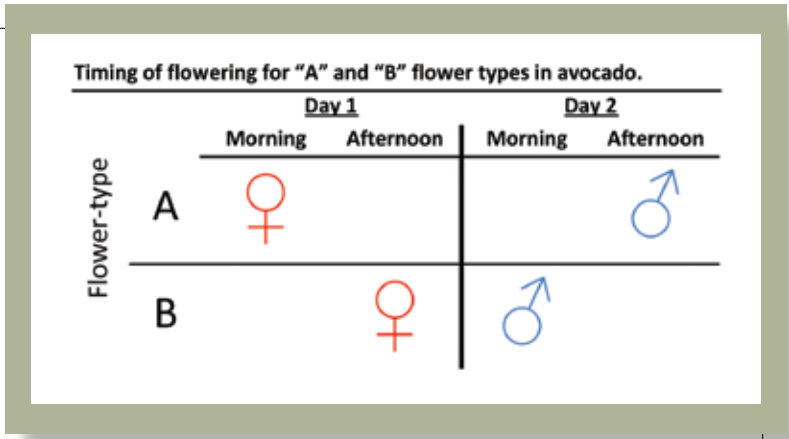
(Editor's Note: This article is a summary of a talk given on January 13, 2014, in Fallbrook by Dr. Iñaki Hormaza, Professor at the Institute for Mediterranean and Subtropical Horticulture in Malaga, Spain.)

As for every tree crop, the factors that lead to successful fruit set and yield of avocados are many and complex. In avocado, the setup for yield begins almost two years before harvest with the growth of a summer flush shoot. The buds on that shoot then undergo floral induction in late summer to early fall. During winter, floral initiation occurs, and the flowers open during bloom the following spring. Once the flowers open, there must be pollen transfer from anthers to stigmas, pollen germination and pollen tube growth, and finally fertilization of the ovule. If conditions are right and resources – water, light, temperature, nutrients – are available in the correct amounts, a year later an avocado can be harvested.

Avocados are characterized as having low fruit set, meaning that most of the flowers never set fruit. In many species, this can result from inadequate pollination, and this holds true for avocado where studies have found that under natural conditions fruit set is just 0.15 percent. That means that for about every 700 flowers produced only one fruit is set.

To test if low fruit set is the result of inadequate natural pollination, hand pollination studies were conducted. Hand pollination increased fruit set to 2.8 percent (or about 3 fruit for every 100 flowers), an improvement but still low.

Interestingly, there is no difference in the percent fruit set between on and off years; differences in yield are due to the differences in the total number of flowers produced. Collectively, these findings suggest that inadequate pollination does play a role in avocado's low fruit set, but other factors must also be involved.



Flower Types

One factor that influences inadequate pollination in avocado is the tree's unusual flowering habit. Avocado flowers open twice, once in the female stage and once in the male stage. When they open during each stage determines whether they are classified as "A" or "B" flowering type. Cultivars with "A" flowering behavior (e.g. Hass) open in the female stage the morning of day one and in the male stage the afternoon of day two. Cultivars with "B" flowering behavior (e.g. Fuerte) open in the female stage the afternoon of day one and in the male stage the morning of day two. Evolutionarily, this flowering pattern favors cross pollination since a female "A" flower overlaps with a male "B" flower and vice versa.

Pollen Viability

Assuming adequate overlap exists among flower types in an orchard, the pollen that gets transferred from one flower to another must be viable. Some species have inherently low pollen viability. Under conditions in southern Spain, germination tests indicate that avocado pollen has a viability of about 50 percent to 60 percent. Anecdotal evidence suggests that viability may be higher under California conditions. However, it is not surprising that a species like avocado — which is native to cool, moist climates — has reduced pollen viability in warm, dry climates like California and southern Spain. When stored at 39°F, pollen viability is measurably reduced after as little as one day. However, when flowers were pollinated with fresh or stored (one-day-old) pollen there was no measurable reduction in final fruit set. This suggests that pollen viability may not be a major factor in avocado's low fruit set.

Flower Quality

An interesting question is whether all flowers in an inflorescence are created equal. Physical examination of individual flowers from within an inflorescence revealed no external differences among flowers. However, when flowers were analyzed for starch content, up to ten-fold variation was found among flowers within the same inflorescence. And starch content was strongly correlated with fruit set, with flowers that set fruit having three times higher starch content, on average, compared with flowers that dropped. Differences in flower starch content were not associated with position of the flower in the inflorescence, whether the inflorescence was determinate or indeterminate, or whether it was an on or off year. How to increase flower starch content and whether this can improve fruit set is a focus of ongoing research.

Pollination

Pollination, the act of moving pollen from the anther (male part) of a flower to the stigma (female part), in avocados requires pollinators (something, usually an animal or insect, that physically moves the pollen). As mentioned earlier, poor pollination is among the factors that contribute to poor fruit set in avocado. One reason for this is that honeybees, which are native to Europe, did not evolve with avocados and are not well-adapted to pollinating this species. In its native range, avocados are pollinated by several different stingless bee species and at least one species of wasp. Bumble bees or other insects may be more efficient pollinators under commercial production conditions and the prevailing weather conditions during bloom, but they are not as easily established in orchards as honeybees.

Pollination and flowering type also have a strong interaction that affects fruit set. When flowers were tracked from pollination through fruit set, it was found that the flowers whose stigmas had the fewest pollen grains were more likely to drop and those with the most pollen grains (> 40) were the most likely to set fruit. In order for the most pollen possible to be transferred among flowers there needs to be sufficient overlap of male and female stages on a given day and overlap across the bloom period.

The source of pollen may also be important to successful fruit set. In a hand pollination study, Hass flowers were pollinated with pollen from Nobel, Marvel or Fuerte. Flowers that were pollinated with Nobel and Marvel pollen had 8.4 percent and 7.4 percent fruit set, respectively, whereas those pollinated with Fuerte had only 2.8 percent fruit set.

However, the necessity of pollinizers is not that clear cut. In an experiment where a solid Hass block was adjacent to a solid Fuerte block, cross pollination between the two cultivars was examined by DNA analysis on the seeds of Hass fruit. In the first row of trees adjacent to the Fuerte block, 40 percent to 50 percent of the fruit resulted from cross pollination; in the second row of trees about 30 percent to 40 percent of the fruit resulted from cross pollination; and

Female (top) and male (bottom) avocado flowers. Photos from Iñaki Hormaza.

in the third row only 20 percent to 30 percent of the fruit resulted from cross pollination. And over a 13-year-period there was no significant effect of distance to pollen source on yield, except in two off years when the closest row of Hass trees to the Fuerte block had higher yield.

Environmental Factors

Temperature and relative humidity are important factors that strongly influence flowering and fruit set. In general, cooler temperatures result in a more protracted bloom and vice versa. But temperature is also important to the daily cycle of flower opening and closing and pollen viability. Maximum pollen adhesion to the stigma occurs from 68 to 77°F, and pollen germination also peaks in this temperature range. Once the pollen grains germinate, temperature affects how fast the pollen tube grows to the ovary allowing for fertilization. From 68 to 86°F, pollen tubes reached the ovary in approximately 8 to 12 hours; however, at 50°F it can take up to 48 hours.

In order for pollen grains to adhere to the stigma, the stigma must be moist. Maximum pollen adhesion and germination was found to occur at 75 percent relative humidity, which suggests that the dry climate of California and southern Spain adversely affects pollen adhesion and germination. It is unknown whether irrigation or canopy water sprays could increase relative humidity enough to positively affect stigmatic receptivity and pollen germination.

Fruit set and yield in avocado is a result of the interaction of numerous complex factors. In a commercial production system we would ideally manipulate these factors to maximize yield, but many of them are out of our control (e.g., temperature, humidity) or we simply don't have enough knowledge to control them (e.g., flower starch content). Therefore, we need to make the best choices possible by carefully selecting pollinizers based on overlap of sexual stages and bloom period; encourage pollinator activity in the orchard; and manage fertilization, irrigation and pruning to develop good summer flush to maximize flowering potential.