Subtropical Fruit News. SUMMER 1995. 3(3):4-8

GROWER OPINION:

Harnessing the Honeybee to Improve Pollination of the Avocado Flower: A Summary of Dr. Gad Ish-Am's Seminars

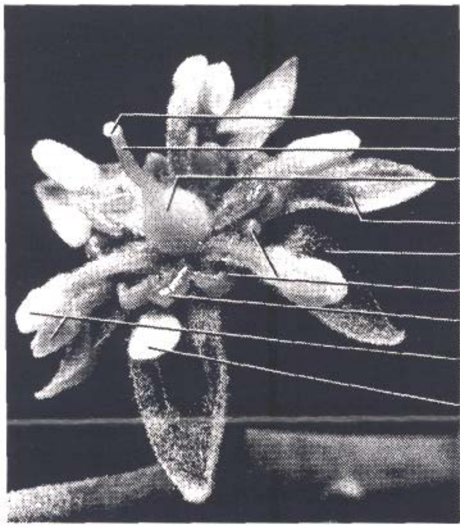
Reuben Hofshi
Del Rey Avocado Co., Fallbrook California

Pollination is a major limiting factor for avocado production in healthy groves in years with normal climatic conditions. The people who had the opportunity to attend Dr. Gad Ish-Am s two lectures on avocado pollination, April 2-3,1995, had a rare treat that will not be easily forgotten. In a very clear and articulate manner he led us through some four hours of background information about pollination parameters and the vectors influencing them, supported by much data, photographs and graphs. He finalized with recommendations regarding pollen donor trees and their placement in the grove as a method of influencing higher productivity while using the European honeybee as the vector. The following is a layman's summary of his discussions and an attempt at reducing his research to the level of the practicing avocado farmer. The tables and the glossary are courtesy of Gad Ish-Am.

The premise upon which Ish-Am built his presentation is that given the avocado flower morphology and the flowering phenology in our semi-arid environment, some type of insect has to act as the pollinating vector. Short of finding and introducing the yet unknown avocado natural pollinator insect from the native habitat, a subject he intends to research in Mexico, the second best thing we have is the European honeybee. Although some pollination is carried on by flies, beetles, and other insects, 90% of pollination in Israel, according to him, is brought about by honeybees.

Production statistics indicate that the production of avocados in both Israel and California does not reach the high potential that could be attained. His data reveal that, in Israel, the Reed variety is significantly more productive than the Hass variety. He attributed this to four potential variables:

1. The onset of the Reed bloom is later than that of the Hass and the Fuerte, which initiate their bloom at a period of relatively low temperatures.
2. As a result of the late onset of bloom, there is less competition from wild flowers and citrus bloom and therefore more frequent visitations by honeybees and thus better pollination, fertilization and fruit set.
3. Reed self fertilization is more efficient than that of most other varieties, and
4. Bees prefer Reed bloom over other avocado varieties because of its nectar's sugar composition *(please refer to next article, Ed.).*



Ish-Am presented to the audience experiments with single variety blocks of Hass and Reed (Hass only and Reed only blocks). Other plots had pollen donor trees of opposite flower type on one or two sides of the block in varying densities. Productivity maps, similar to topographic maps, were generated showing much higher production next to the pollen donor trees with diminishing effect farther away from the pollen donors and towards the center of the plots. His maps showed a phenomenon which also occurred in the single variety plots, where the perimeter rows of the blocks always had higher production than the more centrally located ones. He attributed this to the honeybee preference for an open, well sun-lit tree, rather than a shaded one. His data unequivocally indicate that varieties such as Hass and Nabal require at least another pollen source of an adequate variety. Single variety plots of these two avocado cultivars were not as productive as the multiple variety ones. Reed, he claimed, does not require any outside pollen source and can do extremely well as a single variety. Pinkerton, on the other hand, does very poorly unless it has another variety's pollen available to it for cross-pollination.

Pollination methods were categorized as:

1. Self-pollination, which is pollination within the same flower
2. Close or neighbor pollination which is pollination within the same tree and the same variety, usually during overlapping bloom periods.
3. Cross-pollination, which is pollination with pollen source from another variety either of opposite flowering type or of the same flowering type.

He cited Degani's work using isozyme analysis to show that cross-pollination of Hass and Fuerte produced the majority of the fruit that remained on the trees for harvest in mixed blocks. Degani found that the early set was composed of mostly self-pollinated fruitlets. Following subsequent drops, the remaining fruitlets were Fuerte and Ettinger crosses. At the time of harvest the Ettinger-Hass progenies were predominate. He also indicated, citing Gazit's work, that not all pollen donors are equally effective. In the Israeli experience the Ettinger is the preferred pollen donor as compared with other 'B' flower types such as the Fuerte or other 'A' types such as the Hass.

Gad Ish-Am reviewed some of his research, previously published in the 1991 California Avocado Society Year Book. This article describes research on flower types, defines stages of bloom, sequencing of phases of flower opening and closing, anther dehiscence, receptivity of the stigma, availability and display of nectar in the different stages, etc. He identified periods in both 'A' and 'B' type varieties of overlapping of both female and male flowers within the same tree and within the same cultivar. This bisexual condition, he believes, contributed to the majority of close pollinated fruitlets encountered and could be the main explanation for the productivity of single cultivar orchards. When presented in a graph format plotted against time, temperature and relative humidity; new insights into avocado flowering in relation to pollination are self evident. Ish-Am reported finding a significant negative linear correlation between flowering time and temperature. There was a 15 to 50 minutes delay in flowering for every 1 C drop in temperature. The drop is relative to the daily average temperature which is calculated by dividing by two the sum of the daily maximum and the night minimum temperatures.

He described flower phenology as a multistage (10 stage) progressive process that was true for all studied cultivars. He found that the appearance and disappearance of each stage is synchronized within a cultivar. However, individual flowers changed their stages one by one. While early blooming flowers were moving along to the next stage, new flowers were just opening. Anther dehiscence occurred in two stages where the lower valves opened first and the upper valves opened after one to two hours.

He argued with Davenport's contention that self fertilization occurs frequently, that is the flower pollinates itself. He took issue with the notion that self-pollination can occur in the male stage while the style is still receptive and without a vector. He indicated that experiments have shown that trees with a net placed around them to discourage insect pollination produced almost no fruit. Additionally, he said that pollen grains which were placed on healthy looking stigmas in the male stage failed to either germinate or to produce a pollen tube which was able to reach the ovary and fertilize it. He speculated, although he believes it to be unlikely, that the climate in Southern Florida is such that the type of self fertilization described by Davenport may occur.

We were presented with a series of slides of avocado flowers both in the male and female stages, male flowers before and after anther dehiscence, bees visiting flowers while carrying pollen loads, bees with pollen nested between their antennae, their chest and neck areas and the lower dorsal abdomen. Ish-Am indicated that the apparent similarity between the pistillate (female) and the staminate (male) stages could be significant for both bee behavior and flower pollination. He showed that the pollen loads of mustard and Valencia orange were much larger when compared to their avocado counterpart. The avocado pollen grain is relatively large, 42 microns in size, and is perfectly spherical with many protrusions on the surface. The bee finds this round shape uninviting and difficult to maneuver about. The bee appears to struggle to embed the grain in the pollen load and needs a lot of honey to cement the pollen grains in the load. The load, under a scanning microscope at 1000 magnification, appears to be highly disorganized when it is compared to the mustard pollen load. It has honey as a cementing medium and weighs significantly less than the pollen load of mustard. The avocado pollen load weighs as much as one third of the mustard's pollen load weight, and about half the weight of the Valencia's.

The sugar content of the avocado flower is another deterrent when compared to other flower nectars available to the bees. Honeybees prefer, and can only utilize directly, hexose (six-carbon) type sugars such as fructose and glucose. Avocado nectar composition is mostly all sucrose. Hass nectar is almost 100% sucrose while mustard nectar contains less than 15% sucrose and Valencia nectar contains less than 20%. The bee needs to expend valuable energy to manufacture enzymes that will help convert the sucrose into hexose. One interesting exception, he pointed out, is the Reed nectar. He speculated that since the Reed nectar contains only 70% sucrose that might be the reason bees appear to prefer the Reed over other avocado varieties *(please refer to next article, Ed.).* Ish-Am made a mention of another type of sugar called perseitol, unique to avocado that seems to be involved in sugar transport in the avocado tree, and also appears in its nectar in small quantities

The bee remains, with all the setbacks, the best pollinating agent we have. It is hairy and is able to carry as many as one thousand pollen grains available for pollination distributed on the various regions of its body. These pollen grains by the way, should not be confused with those pollen grains that are in the pollen load and therefore not viable for germination. Although the bee is too large for the small circular avocado flower it is an effective pollinator for the avocado and succeeds in delivering numerous pollen grains to the stigma.

Ish-Am presented in vivid microscope photography the way pollen grains are held on the anther after dehiscence. The pollen grains are apparently attached to the open valved anther with a very mild electrical charge. Wind or shaking do not release these pollen grains. When a bee approaches and a hair, for example, touches a cluster of pollen grains on an anther, there is a discharge and the grains disburse. A photograph of pollen grains on bee hairs revealed a compressed cluster with grains squeezing each other like inflated balloons pressed together. The explanation for this is that the bee, during its flight, generates static electricity as a result of wing flapping. This electricity is positively charged and the charge holds the pollen grains with a stronger force than when the grains are held on the anther. Upon arrival at the stigma, the stigma acts as a strong ground and it causes an electrical discharge and some of the pollen grains are transferred onto the stigma. Dr. Art Schroeder, who attended Ish-Am's seminar in Santa Barbara, finds the subject fascinating. He envisions, and he is not alone in the world on this track, a charged pollen collecting machine that would be used to collect large amounts of pollen. This pollen will be stored for mechanical application at a later date when environmental conditions or other considerations are more favorable. Pollen collected for upon-demand application will eliminate the need for:

1. Bees that do not find, as described above, avocado nectar as a preferable food source.
2. By curtailing the need for honeybees, the high expense of placing them in strategic locations in the grove will be reduced.
3. It will allow for more potent pollen sources, which may not be necessarily commercially viable varieties, but could be cultivated mainly for their pollen, and

4. The most important of all is the availability of viable pollen, upon request to be introduced to the blooming trees during the period of severe competition from other more attractive flowers, nectar and pollen sources. (The above speculations are Reuben Hofshi's and do not necessarily reflect either Dr. Schroeder's or Dr. Ish-Am's opinions).

IS THE AVOCADO FLOWER A "HONEY BEE FLOWER"?

Property	Bee Flowers	Fly Flowers	Avocado
color	violet, blue, yellow	white, yellow	cream-yellow
odor	honey-sweet	rank	bitter-sweet
form	bilabiate	circular	circular
nectar position	quite deep	exposed	exposed
nectar concentration	medium	high	high
nectar quantity	medium	low	medium
pollen quantity	medium-high	low	medium
no. of ovules	few or many	few	one

The 'heavy blooming and hardly no pollination period', according to Ish-Am's data, extends to almost 66% of the total Hass blooming period and 68% of Ettinger's. In terms of total bloom it is even higher, with as much as 85% of the bloom occurring during this light to no bee activity period. Ish-Am monitored the bloom of Ettinger, Hass, Valencia and mustard in the months of April and May 1992. His graphs show, unequivocally, that during the avocado bloom period, coinciding with the mustard and Valencia bloom, there were no fruitlets set on the avocado trees. Bee counts were almost non existent on the Hass and very minimal on the Ettinger. As soon as the mustard and Valencia bloom diminished, and even though avocado bloom was also in its tail end, a dramatic increase in bee activity was immediately registered. Within three days of the onset of increased visitations both cultivars had an immense increase in fruitlet counts. Apparently most of the set came from this relatively short period of diminishing bloom and sugar (as compared to the total bloom period). Different hives had pollen pellets from distinct sources and in varying percentages. It was during this late period that avocado pellet counts at the hive entrance increased dramatically and constituted as much as 47% of the total pellet count.

The honeybee brings pollen grains to the stigma and they in turn germinate with pollen tubes that race to the ovule in hope of fertilizing the ovary. Ish-Am showed, quoting Shoval that it took over 20 pollen grains per Hass stigma to affect good fertilization, while 6 grains were the minimum for fertilization to occur. As the number of grains diminished so did the efficacy of the pollen to fertilize the ovule. Since bees deposit only a few grains per visit, more than one visit is needed to achieve the 20 grains goal.

Combining bee hives together with pollen donor trees, particularly for varieties that require other pollen donors for at least some of their fruit set, is a common sense notion. He clearly showed that adequate pollen donor trees need to be planted at least one row for every three rows of pollinated variety, or two rows for 6 pollinated rows. The pollen donor variety needs to be carefully tested for bloom synchrony and pollen potency, whereas its nectar type is of a lesser importance.

Ish-Am, working with bee density, explained that by increasing the number of bee hives from 1 to 3 or 4 hives per acre, the number or bees per tree increases as a result of competition among bees. Additional bees mean more visitations, increase in bee mobility, a higher cross-pollination rate, and thus more successful pollination and fertilization. The conclusion he arrived at agreed with Vithanage in Australia that is by increasing bee density you set more fruit of greater size.

The bee hives should be placed, before or at onset of the blooming period, in clusters of several hives sufficient to service 10 acres, with the preferred density of 2 to 3 hives per acre. The hives' distribution between adjacent hive groups should be 200 yards and at a maximum of 300 yards. These hives should contain no less than 20,000 bees each and a super of the same bee count. A number of 80,000 to 100,000 bees per acre would be great. His data indicate that an average count of 40 bees per medium size tree is a good number. He recommends for farmers, as a management tool, to count bees on average size trees on fair days, during full female bloom, three times a week. When the bee per tree count falls below 25 he recommends adding hives. Only when the bee count exceeds 55 per tree does he find the number of hives to be satisfactory.

THE EFFECT OF BEE NUMBERS PER TREE ON A FAIR DAY DURING FULL FEMALE BLOOM

BEES PER TREE	SELF FRUITLETS	CROSS FRUITLETS	ADDING HIVES
0	none	none	may not be helpful
1-4	none	none	recommended
5-9	few	none	recommended
10-25	many	few on first row	recommended
26-55	many	on first and second row	may be helpful
more than 55	many	up to the fourth row	not needed

The hives should be located at the center of the grove or, if it is not feasible, at the long edge of the orchard. In the case where pollen donor trees are available, the hives should be placed in a location in front of the pollen donor trees and the trees to be pollinated are located upwind from there. The idea behind this, according to the experts, is that bees fly upwind because they can coast downwind when fully loaded. More importantly, said Ish-Am, is the fact that bees have a keen sense of smell and they travel upwind so they can find the location on of the pre-scouted food source by smell They have limited eye sight and smell is their main source of information for food location. Worker bees during any particular flight tend to collect food from only one species' flowers. The area from which the bees collect food during the flight seldom exceeds three adjacent trees.

Increased bee mobility is desired and could be influenced by an increase in wind velocity and, as mentioned above, by higher density and mobility in the upwind direction. Scout bees, which are the collectors of information regarding food sources, are thought to be the main vector for cross-pollination at a distance greater than three rows.

The bees, in order to dissolve the mostly crystallized sugar in the nectaries, need water. They spit some water on the concentrated sugar and thus dissolve and dilute the sugar which is then ingested. They, through an elaborate process of dilution and dehydration of liquids, similar to the panting of dogs, bring the sugar concentration in their stomach to a 40-50% range. Ish-Am recommends placing shallow water basins at least by the bee hives so that water could be easily located by the bees. Tom Glenn, who has a queen bee breeding business in Fallbrook, suggested using basins with floating water plants which will both provide the bees with purified water and a dry platform for them to land on and drink without the risk of drowning.

Ish-Am presented very convincing data that avocado pollen transfer does not take place in the bee hive in any measurable way. The small amount of pollen found on bees departing the hive is thought to be the result of pollen spreading during self cleaning in the hive. He concluded that honeybees efficiently clean avocado pollen from their bodies and that this may be another aspect of the low suitability of honeybees for avocado pollination. He stressed that pollen of some plants, like apples, almonds and mustard, unlike avocado, transfers successfully through the hive. This in-the-hive pollen transfer contributes a high percentage of cross-pollination in these plants.

On the question of the use of bee attractants and sugar he felt that the results that he was familiar with did not justify the expense. Also the attempt, following Russian research, to condition the bees to visit avocado flowers, to starve the bees for pollen or to train them to collect only avocado pollen resulted in failure and very weak hives. As Dr. Ish-Am put it, this is just a step in the right direction for higher productivity in avocados. Select pollen donor trees have to be placed in strategic locations downwind from the trees that need to be cross-pollinated, with large numbers of strong bee hives placed below them for upwind travel. Providing that other environmental and cultural variables remain within an acceptable norm, a significant increase in production could be attained. The pollination issue is one limiting factor in the equation of higher productivity that is being resolved in such a manner that a discriminating farmer can make an educated choice. Together with the work of Dr. Carol Lovatt on boron application, which potentially can reduce the need for large numbers of pollen grains, Dr. Michael Clegg on RAPD genetic markers and other international research, we might some day soon find ourselves able to put together an integrated pollination program.

Acknowledgments

Thanks to Gad Ish-Am's lectures and insights, I now feel enlightened in regards to one significant variable of avocado productivity. I thank Ish-Am for taking the time to review this article for accuracy and completeness and for providing pertinent materials. I also thank Ben Faber for his review and moral support.

Glossary

1. Pollinizer or pollen donor: The plants that donates the pollen (functions as a male). Dr. Ish-Am prefers to use the term pollinizer. To avoid confusion I have used the term pollen donor. In my view, both 'pollinator' and 'pollinizer' could be understood to be the pollinating agent and not pollen donor.

2. Pollinator: The pollinating agent (eg. bee)
3. Pollinated: The plant that accepts the pollen (functions as a female)
4. Pollination: The process of pollen transfer from anther to stigma.
5. Fertilization The process of pollen tube penetration into the ovule and fusion of male and female gametes.