Interrelationship between avocado flowering and honeybees and its implication on the avocado fruitfulness in Israel

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SUMMARY

Introduction

The average yield of the avocado (Persea americana Mill.) in Mediterranean climate countries, and particularly that of the early blooming cultivars', is known to be low. This stems, to a great extent, from low pollination rates and from insufficient cross-pollination. Low pollination rates, which occur during periods of low honeybee activity on the avocado bloom, is mainly associated with the early blooming cultivars, while insufficient cross-pollination affects cultivars that prefer out-crossing over selfing, where there is an absence of a neighboring pollen-donor (pollenizer) tree. In this work we investigated the interrelationship between avocado bloom and honeybees, and its influence on the avocado productivity problem.

Methods

The daily flowering course of the main avocado cultivars in Israel was studied, including the course of pollen dehiscence and nectar secretion. The relationship between this course and the daily course of honeybee visitation to the avocados was studied as well. The attractiveness of avocado bloom to honeybees was measured, employing original methods, and was compared to that of its main competing plant species, which were identified under field conditions. Honeybee mobility in the orchard was recorded, for ranges of one to twenty rows, and was related to bee density and to wind direction and velocity. The rates of avocado cross-, close- and total-pollination were measured, and were related to flowering stage, to bee density and to the distance from a pollenizer tree and from the plot‘s edge. Yield-per-tree values were recorded during four consecutive seasons, and were related to flowering per tree records and to the previous measures. The contribution to avocado pollination of pollen-transfer through the beehive, as well as of fly activity, was also investigated.

Results

A negative linear correlation between flowering times and the daily average temperature was found for all cultivars. That is to say: that the lower the daily average temperature drop there was a corresponding delay in the the flowering times. These flowering times' regression slopes were steeper in the early blooming cultivars than in the late blooming ones. This means that the former cultivars' daily flowering course, and hence also their daily pollination, is more sensitive to temperature fluctuations than that of the later cultivars. The daily male and female flowers' overlapping periods between opposite flowering-group cultivars was found to last longer in the morning, when the female bloom of A-type cultivars overlaps the male bloom of B-types, than in the afternoon, when the B-types are in the female bloom stage. The length of this inter-cultivar bisexual overlapping period was almost constant under wide range of temperatures. However,

the duration of the within-cultivar overlapping period did change with temperature: in the early-blooming cultivars it became longer when temperatures were higher, and became shorter in the late-blooming ones. In the late-blooming B-type cultivar 'Nabal' this period disappeared altogether in hot days, with average temperatures of 23ºC and above.

The honeybees' daily activity course on the avocado bloom formed a bimodal curve, responding well to the avocado flowering, pollen dehiscence and nectar secretion daily course. The two daily maximum bee-activity peaks on the bloom of A-type cultivars appeared in between the two maximum bee-activity peaks on the B-type cultivars: they appeared after the morning peak and before the afternoon peak of bee activity on the B-type bloom. Thus, in the morning the bees moved from B-type male flowers to A-type female flowers, and *vices versa* in the afternoon, maximizing cross-pollination probability. On the average, about 40% of the bees on the tree moved to an adjacent row in 10 min. This honeybee mobility increased with wind velocity, from 25% to 64% of the bees in 10 min. at wind velocity of 0 to 6 Beaufort, respectively. The honeybees preferred the upwind direction to the other directions, and preferred the downwind direction the least. This preference was more significant under higher wind velocity, and at high wind velocity of 6 Beaufort about 100% of the bees moved in 10 min. to an upwind adjacent row, while only 33% moved to the downwind adjacent one. Bee mobility to a range of many rows was found to decrease with the increasing distance in a hyperbolic curve, which asymptotically approached the value of 2% cross-bees at a distance of 10 rows (and more) from the pollenizer trees.

The avocado flower is pollinated mainly by field-worker bees, since avocado pollen transfer through the hive was found to be inefficient. The major avocado pollinators are honeybees that collect both nectar and pollen. Bees collecting only nectar also contribute significantly, though the pollen-only collectors make a small contribution, and only to close pollination of A-type cultivars. The seasonal average contribution to avocado pollination of flies was found to be 3% in A-type cultivars and about 12% in B-types. The daily pollination curve of A-type cultivars is a monotonously growing line, which is convex for trees that are close to a pollenizer (B-type) tree and concave for trees that are far from it. The daily pollination curve of B-type cultivars is a typical maximum curve, which climbs up at the beginning of the female flowering period and goes down towards the end of the period. The farther the pollenizer tree (A-type cultivar) the earlier and the steeper is its curve’s fall. Close-pollination, among flowers within the tree, was found to be more efficient than cross-pollination between flowers of different cultivars. Both pollination types were more effective in A-type cultivars than in B-type ones. Exceptional low pollination efficiency was measured in the 'Fuerte' B-type cultivar. Cross-pollination rates were found to significantly depend on both bee density and the distance from the pollenizer, while close-pollination rates related only to bee density. Hence, the daily total-pollination rate depended mostly on bee density and, to a lesser extent, on the distance from the pollenizer. Honeybee activity, and specifically the activity of cross-bees, was found to be higher in the plot margins (in the two marginal rows of the plot) than inside the plot, and so were also pollination rates (cross- and total-pollination). This relative "margin preference" of the honeybees was high at a low bee density and decreased when bee density increased.

A computer model was developed, which receives input of orchard structure and of the daily maximum bee density, wind velocity and wind direction, and computes (in one-min. steps) the daily cross-, close- and total-pollination rates of the avocado flowers in the orchard. The model was checked against 'Hass' pollination data, with 'Ettinger' as the pollen donor, and was found to fit well with field measurements.

Citrus species were found to be the main avocado competitors for nectar, or for pollen-and-nectar collecting honeybees, in the "Kuren Valley" of the Western Galilee. Wild flowers of the Papilionaceae (Fabaceae) and the Cruciferae (Brassicaceae) were the main competitors for the pollen collectors. Since avocado fruit setting mainly depends on visits by nectar-and -pollen collecting bees, its main competitor was the citrus bloom. Only small amounts of nectar were collected by the honeybees from the early-blooming avocado cultivars, while the nectar of late-blooming cultivars constituted the main honey component of the season. Small amounts of avocado pollen were also collected during most of the blooming period, though for a number of days, at midseason, it represented about 50% of the honeybee pollen sources.

Avocado relative-attractiveness to honeybees was very low at the beginning of the blooming season, competing with citrus species and with the early blooming wild flowers. However, it increased gradually throughout the blooming period, and was high at its end, while competing with Umbelliferae and Compositae wild flowers. The low relative-attractiveness of the avocado flowers, which appears to contradict their large pollen and nectar amounts, may be the result of the flower structure, and of its nectar sugar constituents, which are of low preference for the honeybees. Also, the avocado pollen-grain structure was found to be incompatible for packing into the honeybee pollen load. These incompatibilities between the avocado flower features and the honeybee needs may be attributed to their separate evolutionary history in distant regions of the world.

Flower density was found to be negatively affected by the previous season yield. It increased noticeably where orchard density decreased, as well as in the plot marginal rows. The 'Hass' cultivar yield was found to be mostly affected by honeybee density and by the distance from 'Ettinger' trees (but not from the ‘Fuerte’), and less so by flower density. 'Hass' yield increased with the decrease of distance from the ‘Ettinger’ and with the increase of both honeybee and flower densities. On the other hand, the 'Reed' yield was found to depend on bee activity, as well as on its flower density, but not on the distance from a pollenizer cultivar. A yield increase appeared also in the plot margins, and was more obvious for lower bee densities. A significant alternating flowering and yield, at the individual tree level, was observed. However, this effect was randomly distributed throughout the plot, and its influence on the successive years’ yield was not significant. It appeared that the (average) yield potential of the ‘Reed’ cultivar is about 12 ton/acre, and the 'Hass' yield presumably averaged the same. This yield potential, which may be reached in well-treated plots during years with no climatic catastrophes, demands honeybee activity of (at least) 20-40 bees per tree during (at least) 10 days of the blooming season. The 'Hass' also needs a distance of 1-3 rows (at the most) from an adequate pollenizer cultivar, like the 'Ettinger'.

Discussion

The avocado reproductive strategy and its ecological implications are:

One. The avocado presents typical adaptations for a very low pollination probability environment: it has a long blooming season, bearing abundance of flowers of a very high P/O (pollen per ovule) ratio, with relatively few fruits.

Two. The avocado has a sophisticated mechanism, which significantly enhances cross-pollination probability, and at the same time ensures enough close-pollination within the tree. Namely: its protogynic synchronic flowering course, of trees of two complimentary flowering types, which also presents a daily period of a bisexual flowers' overlap within the tree and within a cultivar.

Three. The avocado reproductive system fits a very sparse stand of trees, which reduces cross-pollination probability to a very low level. Its partial self-incompatibility maximizes the success of cross-pollination, by preferring the few out-cross pollen grains, and hybrid fruits, over the many selfed-ones. However, at the same time ensures that enough close-fruits remain on the tree.

Four. The avocado flowering, nectar secretion and anther dehiscence daily course maximize pollination, and mainly cross-pollination rates, by controlling the daily course of bee activity on its bloom.