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FLORAL BIOLOGY OF *ANNONA SQUAMOSA* AND *ANNONA CHERIMOLA* IN RELATION TO THE SPONTANOUS APPEARANCE OF ATEMOYA IN ISRAEL

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ABSTRACT

During the 1930's numerous atemoya seedlings appeared in Isreal. At that period Annona seedlings were used for planting and seeds were often obtained from fruit tree collections where *A. cherimola* and *A. squamosa* were planted in close proximity. Both species have protogyneous flowers; however they differ greatly in their flowering pattern.*A. cherimola* flowers open in the morning, are fully receptive for about 24 hr and shed their pollen in the afternoon. *A. squamosa* (one tree and its offspring) flowers open during the day and shed their pollen around 2 a.m. During the first part of *A. cherimola* flowering season flowers were found to open only on alternate days, with full synchronization on all trees. These flowering patterns tend to promote cross pollination between *A. cherimola* and *A. squamosa.*

RESUMEN

Durante los años treinta, mucha plantas de semillero aparecieron en Israel. En aquél entonces, se utilizaba las plantas de semillero de Anona para la plataciόn y se obtenía frecuentemente las semillas en huertos donde se había plantado la *A. cherimola* y la *A. squamosa* a poca distancia entre los árboles. Ambas especies tienen flores protogineas; sin embargo, tienen patrones de floraciόn muy diferentes. Las flores de la *A. cherimola* se abren por la mañana, son plenamente receptivas durante unas 24 horas y después dejan caer su polen por la tarde. Las flores de la *A. squamosa* (un árbol y su progenie) se abren durante el día y dejan caer su polen a eso de las dos de la tarde. Se notó que, durante la primnera parte de la florescencia de la *A. cherimola,* las flores sólo se abrían cada tercer día, con plena simcronizaciόn entre todos los árboles. Estos patrones de floracion tienden a favorecer la polinizaciόn cruzada entre la *A. cherimola* y la *A. squamosa.*

The sugar apple *Annona squamosa* L. and the cherimoya *Annona cherimola* Mill. are closely related; both belong to the section Atta Staff. of the genus (13). The two species originated in different geographical regions and under different ecological conditions: *A. squamosa* is native to the lowlands of tropical Central America, while *A. cherimola* originated in the Andean highlands of Ecuador and Peru (7, 9, 11).

Wester was the first to study the floral biology of *A. squamosa* and *A. cherimola* (17). Working in South Florida he found that both species are protogynous; no set was obtained when flowers were pollinated at the pollen dehiscence stage, while excellent set occurred if pollination took place about one day before pollen discharge. He found that good set occurred after reciprocal cross-pollinations between the two species, although most of the cherimoya fruitlets dropped before reaching maturity. Mature hybrid seeds were obtained on sugar apple mother trees and vigorous hybrid seedlings were produced in 1910 in Florida (18). Hybrid seeds from one sugar apple fruit were taken by Wester to the Philippines and sown in 1911 (18, 19, 20). The first hybrid plant fruited in 1913. Wester proposed the name "atemoya" for hybrids of *A. squamosa* and *A. cherimola* (19, 20). Hand pollination of *A. cherimola* flowers with *A. squamosa* pollen produced atemoya plants in Florida and India (2). Reciprocal crossing of of the two species was also performed successfully in Egypt (1).

Atemoya leaves are easily distinguishable from the leaves of either *A. cherimola* or *A. squamosa;* they are much larger than the leaves of *A. squamosa* and do not possess the velvety pubescence on the lower surface that is typical of *A. cherimola* (2, 6, 7, 20). The colour of the atemoya leaves is intermediate in intensity between the rather pale green of *A. squamosa* and the deep green of *A. cherimola* (7).

The atemoya, like *A. cherimola,* develops into a large, long-lived tree, in contrast to the small, short-lived *A. squamosa* tree. In warm climates the atemoya is much more productive than the cherimoya (2, 6, 7, 8, 9. 20). The best atemoyas are comparable in flavour to the best cherimoyas.

Spontaneous hybrids between *A. squamosa* and *A. cherimola* have been observed in Venezuela, Australia, Florida and Israel (6, 9, 10). We present here the known facts about the abundant appearance of atemoya in Israel, and describe the flowering behaviour of the two parents that gave rise to this large-scale spontaneous hybridization.

The history of Annonas in Israel

Both *A. squamosa* and *A. cherimola* were introduced into Palestine at the beginning of this century. The two species were frequently grown side by side, especially in experimental plots. In the 1930's and 1940's a considerable number of "productive cherimoya"seedlings were found. On close examination all of them were identified as atemoyas. Subsequent investigation indicated that similar hybrids had appeared even earlier (6,7,8,9).

During the first half of this century *A. squamosa* was a very popular fruit crop in Palestine. It was propagated exclusively by seeds, as its progeny came true to type. Off-type atemoya seedlings were observed in commercial *A. squamosa* nurseries and under bearing trees (6, 7, 8). It is not surprising that during this period hundreds of atemoya seedling trees appeared, mostly in backyard gardens. Outstanding trees were selected as hybrid annona cultivars ('Malali 1', 'Malali 2', 'Paldi', 'Kaller', 'Kaspi', 'Gefner' = 'Kabri', 'Bernitzki', 'Ubranitzki', 'Melamud', 'Kabarovski', Burshtein', 'Nordshtein', and others). These cultivars were vegetatively propagated by grafting and several of them now serve as the main

cultivars of the small (*ca.* 30 ha) *Annona* industry in Israel.

Floral biology of *A. squamosa* and *A. cherimola* in Israel

During the late 1970's and early 1980's the floral biology of the surviving trees of *A. squamosa* and *A. cherimola* in the Warbury Acclimatisation Garden, located at Rehovot, was studied, following a report by Oppenheimer of the frequent spontaneous appearance of atemoya seedlings under these trees (9).

The only surviving *A. squamosa* tree in the Warbury Garden was in severe decline and died in 1983. We studied its flowering and the flowering of four self-pollinated young seedlings of this tree. Flowers were found to open at various times during daylight, and all of them shed their pollen only during the night at about 2 A.M. Thus, at the time of pollen release there were no receptive flowers on the tree. Similar findings were reported by Nalawadi *et al.* in Dharwar, India (5). Other studies of the floral biology of *A. squamosa* are considerably at variance with our finding (1, 4, 14, 15). The discrepancies may be due to genetic variability (16), different climatic conditions, or both.

One healthy and vigorous *A. cherimola* tree was present in the Warbury Garden. Its flowering pattern was very similar to that of 'Jete' and 'Campa' cherimoya trees growing in the same region. Anthesis started in the morning (7 – 9 A.M.). The flowers were fully receptive for about 24 hours and shed their pollen in the early afternoon (3 – 4 P.M.). During the first part of the flowering season new flowers opened only on alternate days, and did not open on the day that the pollen was shed. These findings are at variance with those described in two reports from India (14, 15).

The flowering seasons of *A. squamosa* and *A. cherimola* on Israel's coastal plain coincide almost entirely, starting in the second half of May and ending in August. The synchrony of the flowering season together with the difference in their flowering patterns should promote cross-pollination whenever *A. squamosa* and *A. cherimola* are located in close proximity. We found in both species that at the time the flowers had shed their pollen their stigmata were no longer receptive, so that no self-fertilization could occur. Thus effective pollination depends on the transfer of pollen to receptive flowers.

Fruit beetles are the pollinating agents of both species in Israel (3, 12). The beetles are attracted by the freashly opened flowers and may spend many hours inside the flower during its female stage. Once the flower changes into the male stage the three petals spread out abruptly and the pollen is shed, the beetles, loaded with pollen, fly then to new receptive flowers of either species. From the time that *A. squamosa* pollen is shed, i.e., at 2 A.M., there is a period of about four hours during which only receptive flowers of *A. cherimola* are present. When *A. cherimola* pollen is shed, at 3 – 4 P.M., receptive flowers of *A. squamosa* are available for pollination, as are receptive *A. cherimola* flowers during the period when new flowers open every day. When *A. cherimola* flowers open only once every two days, i.e., early in the flowering season, no receptive flowers are present when pollen is shed.

To sum up: cross-pollination was greatly favoured when *A. squamosa* and *A. cherimola* trees were planted together in the coastal plain of Israel. Thus, the wide-spread natural hybridization and the abundant appearance of atemoyas was not accidental but inevitable.

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