*J. Appl. Hort., 2(1):39-43, January-June, 2000*

# Mango pollinators in Israel

**A. Dag and S. Gazit**

*The Kennedy-Leigh Centre for Horticultural Research, The Hebrew University of Jerusalem, Rehovot 76100, Israel*
*E-mail: dagarnon@agri.huji.ac.il*

## Abstract

Effective insect pollination is essential for good fruit set and yield in mango (*Mangifera indica* L.). Insects visiting mango bloom were collected for 3 years (1994-1996) in 10 commercial orchards located in all major mango-growing areas in Israel. Forty-six distinct species or types (not identified to the species level) were found; most belonged to the orders Diptera (26), Hymenoptera (12) and Coleoptera (6). The following species played a significant role in mango pollination in most orchards: two blow flies (*Chrysomya albiceps* Wiedemann and *Lucilia sericata* Meigen); the honeybee (*Apis mellifera* L.) and the housefly (*Musca domestica* L). Found in only one or two orchards, in medium to large numbers, were: the hover fly *Episyrphus balfeatus* De Geer, the wasp *Bembecinus tridens* Fabricius, and two beetles–*Cantharis atropoveolatus* and *Omophlus syriacus* Mulsant. The effectiveness of 12 pollinators was assessed in one orchard. Blow flies were found to be as effective as the honeybee, whereas the housefly was less so. Yield of small caged 'Keitt' mango trees was minuscule (1 kg/tree), whereas open-pollinated trees carried a good crop of 61 kg/tree. The introduction of three pollinators — the honeybee, the bumblebee (*Bombus terrestris* L.) and the housefly — resulted in higher yield.

**Keywords**: *Mangifera indica* L.; mango; pollinators, fruit set, yield

## Introduction

Mango (*Mangifera indica* L.) originated in India and has been cultivated there from time immemorial. Although, the Indian subcontinent is the world's leading mango producer, the crop is now produced in more than 100 tropical and warm subtropical countries. World mango cultivation covers about 2.7 million ha (Galan Sauco, 1999). In 1960, the total mango-growing area in Israel was only 40 ha; today it is close to 2000 ha (Homsky, 1997).

The climate in most mango-growing regions in Israel is Mediterranean-subtropical: warm to hot, with dry summers, and cool, rainy winters. Annual precipitation varies greatly between regions, from 650 to 700 mm in the northern coastal plain, to only 20 to 30 mm in the southern Arava desert. All mango orchards are irrigated during the dry season.

The greenish-white, strongly scented mango inflorescence is a large, highly branched panicle, with a large number of hermaphroditic and staminate flowers. The hermaphrodite flower has five stamens, inserted on the outer margin of a disc, and a single pistil with one ovule. The floral disc is four- to five-lobed, located above the base of the petals. Of the five stamens, usually only one is fertile. The staminate flower is similar but lacks a pistil (Singh, 1960; Mukherjee, 1997).

The stigma is already receptive when the flower opens in the morning; receptivity is lost 2 to 3 days later. Dehiscence takes place a few hours after anthesis (Singh, 1960; Davenport and Nunez-Elisea, 1997). The number of pollen grains per anther fluctuates between 400 and 2000 (Free, 1993). The nectar is produced by the sepal glands and it accumulates at the floral disc. The nectar is easily available to short-tongued insects (Diptera and Coleoptera) as well as to those with medium (honeybee) and relatively long proboscises (Lepidoptera) (Jiron and Hedstrom, 1986).

Pollination is essential for fruit set in mango (Singh, 1960). Pollen is transferred mainly by insects visiting the flowers for nectar (Anderson *et al.*, 1982; Eardley and Mansell, 1994). Wind-pollination has been reported to be significant for mango (Mallik, 1957; Free and Williams, 1976) but the flower characteristics—a tiny stigma and a minuscule amount of pollen—rule out the possibility of its major role in mango pollination (Popenoe, 1917; Scholefield, 1982).

A large number of insect species, belonging mainly to the orders Hymenoptera, Diptera, Coleoptera and Lepidoptera, have been found on mango blooms in India, Australia, Costa Rica, Florida, South Africa, Jamaica, the Canary Islands and Kenya (Spencer and Kennard, 1955; Free and Williams, 1976; Anderson *et al.*, 1982; Jiron and Hedstrom, 1986; Singh, 1988, 1997; Eardley and Mansell, 1993, 1994; Galan Sauco *et al.*, 1997).

The aim of this work was to identify the main mango pollinators in Israel and to assess the relative effectiveness of the most prevalent ones.

## Materials and methods

***Pollinator survey:*** Studies were carried out in 10 commercial mango orchards, located in the country's main mango-growing regions (Fig. 1): Yotvata in the Arava valley; Besor in the southern coastal plain; Rehovot, Bet Dagan, Benei-Dror and HaCfar-Hayarok

in the central coastal plain; Maoz Hayim in the Bet Shean Valley; and Ravid, Kineret and Genosar near the Sea of Galilee. Foraging insects were collected on mango bloom into glass flasks containing cotton wool with $CCl_4$ (Ish-Am and Eisikowitch, 1993). The density of each insect type was estimated. Identification was carried out at the Department of Zoology, Tel Aviv University, by R. Casher (Hymenoptera) and A. Fridberg (other orders). Of the 46 distinct types collected (Table 1), only 25 could be identified to the species level.

***Pollen identification:*** A scanning electron microscope (SEM) was used to determine mango pollen distribution on the body of several important pollinators.

***Visiting rate and effectiveness:*** Visiting rate (flowers per minute) was determined for 12 species; the percentage of visits involving contact with the reproductive organs was also recorded. This study was performed in Rehovot during 3 days in May 1996.

***Caged trees:*** Sixteen small 'Keitt' trees were enclosed before the beginning of flowering, in eight hemispherical cages of 15-mesh screen (two per cage), at The Volcani Center in Bet Dagan. Four trees in two cages served for each of the following pollination treatments:

a. A small honeybee hive (three brood frames out of five populated frames) was placed in each cage.

b. A *Bombus terrestris* colony (ca. 50 bees) was placed in each cage.

c. Several thousand *Musca domestica* pupas were placed every week, during the flowering period, in each cage.

d. No pollinators were introduced.

Four uncaged trees, exposed to the natural pollinators in the orchard, served as controls.

At harvest, mature fruits were counted on each tree.

## Results and discussion

In our country-wide survey (Fig. 1) of visitors to mango blooms in Israel, we found 46 distinct species or types (Table 1); most of them belonged to three orders: Diptera (26), Hymenoptera (12) and Coleoptera (6). The predominant insect species visiting mango blooms in Israel were: two blow flies (*Chrysomya albiceps* and *Lucilia sericata*), the housefly and the honeybee. The following species predominated in one or two orchards only: the hover fly *Episyrphus balfeatus*, and two beetle species: *Omophlus syriacus* (Alleculidae) and *Cantharis atropoveolatus* (Cantharidae). The pollinating effectiveness of 12 species is presented in Table 2. Based on these two studies (Tables 1 and 2), the following appear to be significant mango pollinators in Israel:

***Diptera:*** Blowflies (Calliphoridae) were present in most mango orchards in medium to large numbers and were effective pollinators. Hence, *Chrysomya albiceps* and *Lucilia sericata* should be considered major mango pollinators in Israel. Blowflies have also been found to be important mango pollinators in other countries (Anderson *et al.*, 1982; Jiron and Hedstrom, 1986; Singh, 1988, 1997; Free, 1993; Galan Sauco *et al.*, 1997).

Hoverflies (Syrphidae) were found in medium to large numbers in only two orchards. They are considered effective mango pollinators in several countries (Anderson *et al.*, 1982; Jiron and Hedstrom, 1986; Singh, 1988, 1997). However, the two species observed (*Metasyrphus corollae* and *Eristalinus aeneus*) were less effective than the Calliphoridae flies. Hence, they should be considered of only secondary importance in Israel.

The ubiquitous housefly (*Musca domestica*) was found in small to medium numbers in almost all orchards. However, its effectiveness as a pollinator was much lower than that of the blow flies (Table 2). It is apparently of secondary importance in Israel, as in other countries (Singh, 1960, 1988; Jiron and Hedstrom, 1986; Eardley and Mansell, 1994; Galan Sauco *et al.*, 1997).

We encountered a very effective Sarcophagidae pollinator (Table 2), which was identified only to the family level. Nevertheless, being only an occasional visitor on mango bloom (Table 1), it does not appear to play a significant role in mango pollination in Israel.

***Hymenoptera:*** Honeybee (*Apis mellifera*) hives were placed in one mango orchard (Yotvata), and within 1 km of the other mango orchards surveyed, for pollination of other fruit crops. In almost all orchards, honeybees were found to be prevalent visitors on mango bloom; in two orchards, it was the dominant visitor and in seven orchards it was one of the main ones. In only one orchard (Kineret), no honeybee was observed during 2 days of the study; their absence appeared to be the direct result of large-scale activity of a bee-eater (*Merops apiaster*) in the area. Our observations indicate that the mango bloom is not very attractive to honeybees as compared to citrus, litchi and wildflower blooms. Avocado bloom was found to be less attractive. The cold winter in Israel has a deleterious effect on early mango bloom (Dag *et al.*, 1999) and good fruit set usually occurs only during the second half of the flowering season. At that time, citrus and wildflowers are at the end of their bloom and the bees do go in large numbers to the mango blooms. Hence, the honeybee should be considered an effective pollinator of mango in Israel. In the absence of large population of other effective pollinators (Yotvata), placing hives in the orchard is essential. However, taking into account both its abundance and effectiveness (Tables 1 and 2), the honeybee ranks only third in importance, after the two blowfly species.

Wasp species (*Bembecinus tridens*), from the Sphecidae was found to be an important visitor on mango bloom in one orchard. In Australia, another

species of the same family has been found to be an effective mango pollinator (Anderson *et al.*, 1982).

***Coleoptera*:** Two beetle species were found in large numbers on mango bloom (Table 1). *Cantharis atropoveolatus* was found in one orchard. It carried large amounts of mango pollen on its body and appeared to play an important role in pollination. *Omophlus syriacus* was found in two orchards, where it may also serve as a significant pollinator.

**Table 1. Insects found on mango bloom in Israel and their mean density: + = occasional visitor, ++ = consistent visitor, +++ = frequent visitor. The survey was conducted in 10 orchards in the main mango-growing areas of Israel, during three flowering seasons (1994, 1995 and 1996)**

| Order: Family | Insect Species | Yotvata | Besor | Reho-vot | Bet Dagan | HaCfar-Hayarok | Benei-Dror | Maoz Hayim | Kineret | Ravid | Genosar |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Diptera:** | | | | | | | | | | | |
| Calliphoridae | *Lucilia sericata* Meigen | + | +++ | +++ | + | +++ | +++ | +++ | | ++ | |
| | *Chrysomya albiceps* Wiedemann | + | +++ | +++ | +++ | + | +++ | +++ | | ++ | |
| | *Pollenia* sp. | | | + | ++ | ++ | | | ++ | | |
| Muscidae | *Musca domestica* L. | | ++ | ++ | + | ++ | ++ | + | ++ | + | ++ |
| | *Musca vitripennis* Meigen | | + | | | | | | | | |
| | *Coenosia attenuata* Stein | + | | | + | | | + | | | |
| | *Fannia* sp. | | + | | | | | | | | |
| | *Autumnalis* sp. | | | | | + | + | | | | |
| Syrphidae | *Episyrphus balfeatus* De Geer | | | | | | | +++ | + | + | |
| | *Eristalinus aeneus* Scopoli | + | | | + | | | + | | | |
| | *Metasyrphus corollae* F. | + | | | | | | + | | | |
| | *Eristalinus taeniops* Wiedemann | | + | | | + | | | | | + |
| | *Syritta pipiens* Norway | | + | | | | | | | | |
| | *Scaeva albomaculata* Macquart | ++ | | | | | | | | + | |
| Chloropidae | *Thaumatomya notata* Meigen | | | + | | | | + | | | |
| Anthomyiidae | ? | | + | | | | | + | | | |
| | ? | | | | | | | | | + | |
| Tabanidae | *Tabanus* sp. | | | | | | | | | + | |
| Miliciidae | *Desmometopa nigrum* Zetterstedt | | | | + | | | | | | |
| Tachinidae | *Drino imberbis* Wiedemann | + | + | | + | | | + | | + | |
| Sarcophagidae | ? | | | + | + | + | + | | | | + |
| Fanniidae | ? | | + | | | | | | | | |
| Rhinophoridae | ? | | | | | | | | + | | + |
| Sepsidae | *Sepsis thoracica* Robineau-Desvoidy | + | + | | | | | | | | |
| Conopidae | *Thecophora* sp. | | | | | | | | | | + |
| Otitidae | *Physiphora demandata* F. | | | | + | | | | | | |
| **Hymenoptera:** | | | | | | | | | | | |
| Apidae | *Apis mellifera* L. | +++ | ++ | ++ | ++ | ++ | ++ | +++ | | ++ | ++ |
| Andrenidae | ? | + | | | | | | | | | |
| Halictidae | ? | | | | | | | + | | | |
| | *Halictus* sp. | | | | | | | | | | ++ |
| | *Lasioglossum* spp. | | | | + | | | | | | ++ |
| Braconidae | *Aptanteles* sp. | | + | | | | | + | | + | |
| Sphecidae | *Oxybelus* sp. | + | | + | | | + | | | | |
| | *Bembecinus tridens* Fabricius | | | | | +++ | | | | | |
| Ichneumonidae | ? | | | + | | | | | | | |
| Formicidae | *Tapinoma sinorothi* Krausse | | | | | | | + | | ++ | |
| | *Solenopsis* sp. | + | | | + | | | | | | |
| | *Messor* sp. | | | + | | | | | | | |
| **Coleoptera:** | | | | | | | | | | | |
| Coccinellidae | *Coccinella septempunctata* L. | | | | + | | | | | + | + |
| Cantharidae | *Cantharis atropoveolatus* | | | | | | | | +++ | + | |
| Malachiidae | *Malachius coccineus* Walte | | | | + | | | | | | |
| Alleculidae | *Omophlus syriacus* Mulsant | | | | | +++ | +++ | | | + | |
| | *Cteniopus gibbosus* Bandi | | + | + | | | | | | | |
| Scarabaeidae | ? | + | | | | | + | | | | |
| **Neuroptera:** | *Chrysoperla carnea* Stephens | | | | | | | | | | |
| Chrysopidae | | | | | + | | | | | | |
| **Heteroptera:** | | | | | | | | | | | |
| Miridae | ? | | | | | | | | | + | |

**Table 2. The effectiveness of 12 mango pollinators. Determination was performed in 1996, at the Faculty of Agriculture Farm in Rehovot**

| Insect order | Insect species | Visits observed (no.) | Rate of effective Visits[a] (%) | Flowers per minute ± S.E. | Choice of food |
|---|---|---|---|---|---|
| Diptera | [b]*Lucilia sericata and Chrysomya albiceps* | 209 | 95 | 9.7±50 | Nectar |
| | *Pollenia* sp. | 91 | 93 | 7.7±4.1 | Nectar |
| | *Musca domestica* | 163 | 68 | 5.5±3.3 | Nectar |
| | *Metasyrphus corollae* | 37 | 100 | 4.5±1.8 | Nectar |
| | *Drino imberbis* | 107 | 94 | 7.3±4.4 | Nectar |
| | *Eristalinus aeneus* | 22 | 54 | 2.1±1.4 | Nectar |
| | Sarcophagidae ?[c] | 107 | 89 | 13.6±8.3 | Nectar |
| Hymenoptera | *Apis mellifera* | 31 | 80 | 8.9±3.3 | Nectar |
| | *Messor* sp. | 39 | 77 | 7.6±3.2 | Nectar |
| | *Halictus* sp. | 13 | 8 | - | Nectar |
| Coleoptera | *Cteniopus gibbosus* | 76 | 46 | 6.6±3.1 | Nectar and pollen |

[a] The visitor touched the flowers' reproductive organs
[b] These two blow fly species are similar in appearance and cannot be differentiated at a distance
[c] Genus and species unknown

Most of the insect species found on mango blooms in Israel (Table 1) have not been recorded in similar surveys conducted in other countries (Anderson *et al.*, 1982, Jiron and Hedstrom, 1986; Singh, 1988, 1997; Eardley and Mansell, 1993, 1994). This reflects the fact that the insect fauna in Israel differs markedly from that of those distant countries. For example, the *Trigona* found in Australia is absent in Israel; the small carpenter bees, *Braunsapis facialis* and *Braunsapis bouyssoui,* which were found to be effective mango pollinators in South Africa, are also absent. However, at the genus and family levels there is a much greater similarity between the fauna of mango pollinators in Israel and other countries. For example, *Chrysomya* flies are involved in mango pollination in Israel and several other countries as well, and in almost all countries Calliphoridae, Syrphidae and Muscidae flies are important pollinators (Anderson *et al.*, 1982; Eardley and Mansell, 1994; Singh, 1997). Cantharidae beetles have been active on mango bloom in both Israel and Costa Rica (Jiron and Hedstrom, 1986).

The great difference in the fauna of mango bloom visitors in five countries is presented in Table 3. The total number of species found fluctuates from 25 in India to 46 in Israel and 80 in Australia. It is surprising that in India, where mango originated and has been grown extensively for thousands of years, the number of species is smallest. However, this may be due to the survey having been limited to one place. Extensive use of insecticides during the bloom period in India to control mango hoppers and other pests may also be responsible (Singh, 1988). The difference in the relative abundance of species from different orders also appears to reflect differences in insect fauna. For example, no butterflies (Lepidoptera) were found on mango bloom in Israel, whereas a large number of butterfly species have been found in Costa Rica and Australia.

**Table 3. Number of distinct pollinators found on mango blooms in five countries, and their distribution per order**

| Country (source) | Species collected (no.) | Distribution per order (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Hymenoptera | Diptera | Coleoptera | Lepidoptera | Neuroptera | Heteroptera |
| Israel (Table 1) | 46 | 27 | 58 | 13 | - | 2 | 2 |
| South Africa (Eardley and Mansell, 1994) | 49 | 51 | 39 | 2 | 8 | - | - |
| Costa Rica (Jiron and Hedstrom, 1986) | 26 | 15 | 48 | 7.5 | 29 | - | - |
| Australia (Anderson *et al.*, 1982) | 80 | 31 | 25 | 4 | 24 | 1 | - |
| India (Singh, 1988) | 25 | 12 | 40 | 28 | 8 | - | - |

Almost all insect species observed on mango flowers collected only nectar (Table 2). Only the beetle *Cteniopus gibbosus* also collected pollen. Reports on the feeding behaviour of mango visitors indicate that pollen is rarely collected (Anderson *et al.,* 1982; Eardley and Mansell, 1994, (reflecting the fact that the mango flower has a meager amount of pollen (Singh, 1960; Free, 1993).

***A pollinator trial:*** A preliminary pollinator trial was conducted with caged 'Keitt' trees (Table 4). When no pollinators were present, the yield was negligible, demonstrating the need for pollinators in this productive cultivar. With the introduction of pollinators into the cages: the honeybee, the bumblebee and the housefly, yield was much higher, although, because of very high variability, the pronounced increase was not found significant. The fact that the bumblebee was apparently more effective than the honeybee is of interest, and may result from its greater ability to work well in enclosures (Free, 1993).

**Table 4. Yield (fruit per tree) of 'Keitt' mango trees caged with three pollinators in comparison to caged trees with no pollinators and exposed trees. The experiment was conducted at The Volcani Center, Bet Dagan, 1995**

| Treatment | Fruit per tree (no.) |
|---|---|
| No pollinators | 1.2 b |
| Housefly | 8.7 ab |
| Honeybee | 18.5 ab |
| Bumblebee | 49.5 ab |
| Exposed | 61.6 a |

Values follows by different letters are significantly different ($P < 0.05$) by Tukey Kramer test

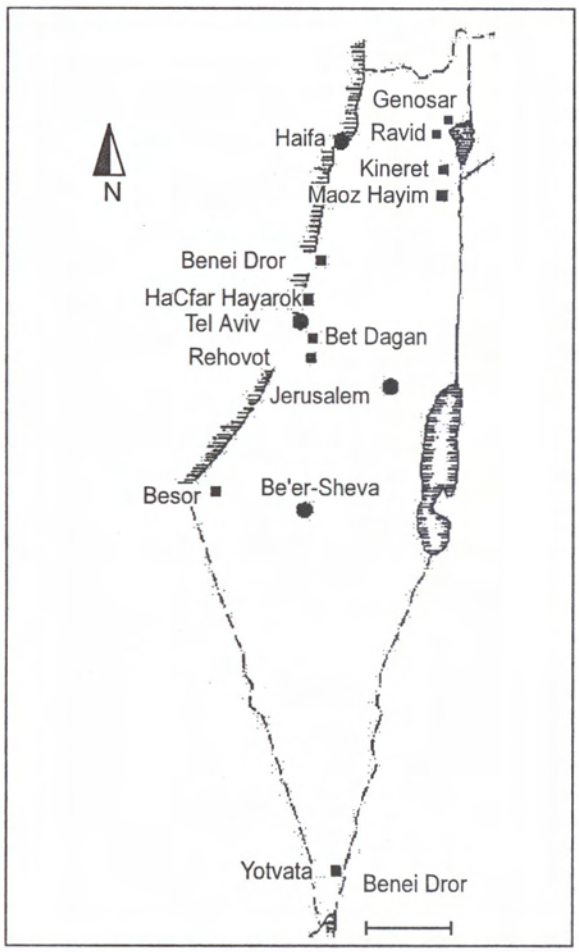


**Fig. 1. Map of Israel with the location of the 10 mango orchards included in the pollinator survey.**

**Practical conclusions:** At this stage, the honeybee and bumblebee are the only pollinating agents that may be supplied on demand for pollination in mango orchards in Israel. The high rental fee for bumblebee colonies makes them less economically attractive. Increasing the density of honeybee hives may compensate for the mango bloom's low attractiveness (McGregor, 1976). Several species of flies, particularly *Chrysomya albiceps* and *Lucilia sericata*, may serve as very effective mango pollinators, and are less likely than honeybees to abandon the mango orchard for more attractive blooms. However, their consistent appearance in large numbers in mango orchards is not assured; in several orchards they were absent, or present in only very small numbers. We need to develop the necessary know-how to achieve large populations of one or more of these fly species during the mango fruit-setting season. It would probably be less expensive than covering the costs for honeybees.

## References


Anderson, D.L., M. Sedgley, J.R.T. Short and A.J. Allwood, 1982. Insect pollination of mango in northern Australia. *Aust. J. Agric. Res.*, 33:541-548.

Dag, A., D. Eisenstein and S. Gazit, 1999. Effect of temperature regime on pollen and the effective pollination of 'Kent' mango in Israel. *Scientia Hort.* (in press).

Davenport, T.L. and R. Nunez- Elisea, 1997. Reproductive physiology, p. 69-146. In: R.E. Litz (ed.). *The Mango: Botany, Production and Uses.* CAB Int. Wallingford, U.K.

Eardley, C.D. and M.W. Mansell, 1993. Preliminary report on the natural occurrence of insect pollinators in mango orchard. *S. A. Mango Growers' Assoc. Yearbook*, 13:127-128.

Eardley, C.D. and M.W. Mansell, 1994. Report on the natural occurrence of insect pollinators in a mango orchard. *S. A. Mango Growers' Assoc. Yearbook*, 14:65-66.

Free, J.B. 1993. *Insect Pollination of Crops.* Academic Press, London, U.K.

Free, J.B. and I.H. Williams, 1976. Insect pollination of *Anacardium occidentale* L., *Mangifera indica* L., *Blighia sapida* Koenig and *Persea americana* Mill. *Tropic. Agric.*, 53:125-139.

Galan Sauco, V. 1999. *El cultivo del mango.* Edic. Mundi-Prensa, Madrid.

Galan Sauco, V., D. Fernandez Galvan, J.C. Hernandez Conde and A. Morales Navarro, 1997. Preliminary studies on fruit-set of mango cultivar Tommy Atkins under greenhouse cultivation in the Canary Islands. *Acta Hort.*, 455:530-537.

Homsky, S. 1997. The mango industry in Israel–an overview. *Acta Hort.*, 455:7-14.

Ish-Am, G. and D. Eisikowitch, 1993. The behavior of honey bees (*Apis mellifera*) visiting avocado (*Persea americana*). *J. Apic. Res.*, 32:175-186.

Jiron, L.F. and I. Hedstrom, 1986. Pollination ecology of mango in the neotropic region. *Turriabla*, 35:269-277.

Mallik, P.C. 1957. Morphology and biology of the mango flower. *Indian J. Hort.*, 14:1-23.

McGregor, S.E. 1976. *Insect Pollination of Cultivated Crop Plants.* USDA Agr. Handbook 496.

Mukherjee, S.K. 1997. Introduction: botany and importance, p. 1-19. In: R.E. Litz (ed.). *The Mango: Botany, Production and Uses.* CAB Int. Wallingford, U.K.

Popenoe, W. 1917. *The Pollination of the Mango.* U.S. Dept. Agr. Bull. 542.

Scholefield, P.B. 1982. A scanning electron microscope study of flowers of avocado, litchi, macadamia and mango. *Scientia Hort.*, 16:263-272.

Singh, G. 1988. Insect pollinators of mango and their role in fruit set. *Acta Hort.*, 231:629-632.

Singh, G. 1997. Pollination, pollinators and fruit setting in mango. *Acta Hort.*, 455:116-123.

Singh, L.B. 1960. *The Mango.* Leonard Hill, London, U.K.

Spencer, J.L. and W.C. Kennard, 1955. Studies on mango (*Mangifera indica* L.) fruit set in Puerto Rico. *Trop. Agriculture, Trin.*, 32:323-329.