Pests of Mango

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3 authors:

Poluru Venkatarami Reddy
Indian Institute of Horticultural Research
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Pests of Mango

12

Poluru Venkata Rami Reddy, B. Gundappa,
and A. K. Chakravarthy

Contents

P. Venkata Rami Reddy (✉) · A. K. Chakravarthy
Division of Entomology and Nematology, ICAR-Indian Institute of Horticultural Research, Bengaluru 560089, Karnataka, India
e-mail: pvreddy2011@gmail.com

B. Gundappa
ICAR-Central Institute for Subtropical Horticulture, Lucknow, Uttar Pradesh, India

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12.1 Introduction

Mango (*Mangifera indica* L.) (Family: Anacardiaceae) originated in the Indo-Burma region and has become naturalized and adapted throughout the tropics and subtropics. India has the richest collection of mango diversity with more than 1000 named varieties (Mukherjee 1997). Major mango producing countries are India, China, Thailand, Mexico, Pakistan, the Philippines, Indonesia, Brazil, Nigeria and Egypt. India ranks first and accounts for about 50% of the world's mango production with 2.5 million hectares producing annually 18.0 million tons. Insect pests are a major limiting factor in achieving full yield potential of mango varieties. About 400 species of insect pests are known to infest mango in different parts of the world (Tandon and Verghese 1985; Pena et al. 1998). Worldwide lists of pests of mango have been compiled by de Laroussilhe (1980), Tandon and Verghese (1985) and Veeresh (1989). Commercial cultivation of mangoes, characterized by the area expansion, changing cropping patterns, varietal replacements and increased chemical interventions, has altered the pest complex and pest community structures significantly. In addition, climate change has induced the emergence of new pests or inadvertently encourages invasives. Scales, mealybugs, thrips, mites, leaf webber, stem borer, etc., earlier considered to be minor or secondary pests, have become serious problem in the recent past (Jayanthi et al. 2014a, b).

12.2 Pests of Inflorescence and Tender Shoots

12.2.1 Leafhoppers (Hemiptera: Cicadellidae)

12.2.1.1 Occurrence and Distribution

Leafhoppers are the major pests of mango with a potential to incur cent-per-cent fruit losses. Fifteen species have been reported on mango from Asia. However, only 3–4 species are serious pests. The most predominant and widespread species are *Idioscopus clypealis* (Lethierry), *I. nitidulus* (Walker), *I. nagpurensis* (Pruthi) and *Amritodus atkinsoni* (Lethierry) (Veeresh 1989; Waite 2002). While the species of *Amritodus* are restricted to the Indian subcontinent, some species of *I. clypealis* and *I. nitidulus* occur in all other Asian countries like Cambodia, Indonesia, Malaysia, the Philippines, Myanmar, Taiwan and Vietnam (Tandon and Verghese 1985). Species distribution within the country also varies with a few species dominating a particular region. For example, *A. atkinsoni* and *I. clypealis* are more prevalent in north India, *I. niveosparsus* in Gujarat and *I. nitidulus* in south India (Veeresh 1989). Das et al. (1969) recorded *Amrasca splendens* Ghauri from Kerala. Viraktamath and Viraktamath (1985) reported three new species of mango hoppers, viz. *Busoniominus manjunathi*, *Idioscopus anasuya* and *I. jayshriae*, on mangoin Karnataka. Outside India, *I. clypealis* was reported to constitute >95% of hopper population in the Philippines (Alam 1994). In China, *I. incertus* Baker was found to be serious (Waite 2002). In Australia, *I. niveosparsus* was recorded for the first time in 1998 in Queensland in a remote seaport but not spread to commercial plantations (Waite 2002).

12.2.1.2 Biology and Nature of Damage

Hoppers have a wedge-shaped body with broad head and narrow abdomen towards the back. The hind pair of legs is well adopted for quick hops. *Amritodus atkinsoni* is dark grey in colour, has two spots on the abdomen and scutellum and is relatively bigger of all three species, measuring 4.2–5 mm, while *I. nitidulus* is slightly smaller with three spots on the scutellum and a prominent white band across its light brown wings. The smallest one is *I. clypealis*, light brown in colour with two spots on the scutellum, and measures 3.5 mm in length (Butani 1979). Adults lay eggs singly on the flowering shoots, flower buds or tender leaves. A single female lays about 100–200 eggs. The egg period varies from 4 to 7 days, nymphal period, 8–13 days with three to four instars, and the total life cycle is completed in 15–19 days. The insect has 2–3 generations in a year though the number of generations varies with place. The insect overwinters as adult. Patel et al. (1973) noted these hoppers to rest in the cracks and crevices of the bark of mango during hot noon and rainy days. The population reaches a peak during March–April, and maximum and minimum temperature and relative humidity were major abiotic factors contributing to population fluctuations (Tandon et al. 1983). The spacing of mango trees in orchards also plays an important role in breeding of the hoppers. The orchards with closer spacing and varieties of dense inflorescence attract high hopper population (Srivastava 1997; Reddy and Dinesh 2005).

Nymphs and adults congregate on panicles and tender shoots and suck the sap (Plate 12.1). *Idioscopus nitidulus* breeds on both shoots and inflorescence, while *I. clypealis* and *I. nagpurensis* breed only on inflorescence (Verghese and Devi Thangam 2011). The continued feeding results in withering and dropping of florets, thus leading to failure of fruit setting. Besides, leafhoppers excrete honey dew which attracts sooty mould and affects photosynthetic efficiency (Butani 1979). In case of severe infestation, leaves and fruits would seem shining with honey dew. Damp and shady places are more congenial for hoppers during summer.

Plate 12.1 Mango leafhoppers on a tender shoot

12.2.1.3 Management

1. Avoid dense planting and maintain tree architecture in such a way that adequate light is penetrated.
2. Regulate the number of flushes in a year by pruning and reducing the inputs.
3. Spray the botanical pesticides, like azadirachtin 1% at 3 ml/l, lemon grass oil (0.125%) and citronella oil (0.25%), if the hopper population is low (<4/panicle) (Verghese 2000).
4. If the density is beyond four hoppers/panicle, spray imidacloprid 17.8 SL at 0.3 ml/l or thiamethoxam at 0.5 g/l or lambda-cyhalothrin at 0.5 ml/l at panicle initiation stage. Spraying should be avoided when trees are on full bloom to avoid killing of pollinators (Verghese and Devi Thangam 2011).
5. Conservation of natural enemies especially the predators like coccinellids (e.g. *Coccinella septempunctata*, *C. transversalis* and *Menochilus sexmaculatus*) and spiders. Hence, conserving them would help in minimizing losses due to leafhoppers. This can be achieved by avoiding spray of broad-spectrum insecticides, and instead entomopathogens like *Metarhizium anisopliae* and botanicals should be used.
6. Significant differences in the hopper incidence among genotypes were recorded indicating the scope of host plant resistance (Nachiappan and Bhaskaran 1983; Devi Thangam et al. 2013).

12.3 Pests of Foliage and Buds

12.3.1 Thrips (Thysanoptera: Thripidae)

12.3.1.1 Occurrence and Distribution

Thrips are among an emerging group of sucking pests that infest leaves, flowers and fruits of mango. From India, the species reported on mango are *Aeolothrips collaris* (Priesner), *Anaphothrips sudanensis* (Trybom), *Caliothrips indicus* (Bagnall), *Rhipiphorothrips cruentatus* (Hood), *Selenothrips rubrocinctus* (Giard), *Haplothrips ganglbaueri* (Schmutz), *Neoheegeria mangiferae* (Priesner), *Ramaswamiahiella subnudula* (Karny) and *Scirtothrips dorsalis* (Hood). Of these, the first four species feed on the leaves, and last four infest the inflorescences (Butani 1979). Tandon and Verghese (1987) recorded for the first time *Thrips palmi* Karny infesting mango flowers in India, which caused scab-like feeding marks retarded fruit development. Outside the subcontinent, *Frankliniella bispinosa* (Morgan) and *Frankliniella kelliae* (Sakimura) were reported infesting mango blossoms and feeding on the nectaries and anthers in Florida (Pena 1993). The western flower thrips, *Frankliniella occidentalis* (Pergande), damaged flowers and fruits in Israel (Wysoki et al. 1993), while *Scirtothrips dorsalis* Hood is regarded as an important pest of mango flowers in Thailand and the plague thrips, *Thrips imaginis* Bagnall, in Australia (Waite 2002). *Thrips hawaiiensis* (Morgan), *Scirtothrips dorsalis* (Hood), *Frankliniella schultzei* (Trybom) and *Megalurothrips usitatus* (Bagnall) were recorded as pests of mango in Malaysia (Aliakbarpour and CheSalmah 2010).

12.3.1.2 Biology and Nature of Damage

A complete generation may be completed in about 20 days at 30 °C. Eggs are deposited in leaf tissue. Females lay up to about 200 eggs but average about 50 per female. The egg is colourless to pale white in colour and bean shaped in form. Duration of the egg stage is about 16 days at 15 °C, 7.5 days at 26 °C and 4.3 days at 32 °C. The larvae resemble the adults in general body form though they lack wings and are smaller. There are two instars during the larval period. Larvae feed in groups, particularly along the leaf midrib and veins and usually on older leaves. There are two instars during the pupal period. The prepupal instar is nearly inactive, and the pupal instar is inactive. Both instars are nonfeeding stages. Adults are pale yellow or whitish in colour but with numerous dark setae on the body. A black line, resulting from the juncture of the wings, runs along the back of the body. The slender fringed wings are pale. Adult longevity is 10–30 days for females and 7–20 days for males.

Thrips colonize the leaves, inflorescence, fruit and new flush and suck the sap by lacerating the tissues (Higgins 1992; Pena et al. 2002). Apart from weakening the inflorescence and reducing fruit set, thrips cause serious bronzing of the fruit surface due to the presence of air in emptied cell cavities that is more pronounced in mature fruits (Lewis 1973) (Plate 12.2). In severe infestation, the leaf tips turn brown and get curled (Aliakbarpour and CheSalmah 2010). *Thrips palmi* showed preference to lower canopy over upper canopy (Verghese et al. 1988). Populations reach a peak during hot dry weather.

12.3.1.3 Management

1. Infestation should be monitored by placing sticky traps at regular intervals.
2. Spray neem soap at 10 g/l or neem-based pesticides to prevent establishment of thrips.
3. Conservation of natural enemies that include predatory thrips, predatory mites (e.g. *Amblyseius* spp.), anthocorid bugs or minute pirate bugs (*Orius* spp.), ground beetles, lacewings, hoverflies and spiders.
4. Chemical sprays have to be taken, if the infestation is severe, with either imidacloprid (0.3 ml/l) or spinosad (0.25 ml/l) or thiamethoxam (0.05%).

Plate 12.2 Thrips damage on tender mango fruits

12.3.2 Mango Leaf Webbers (Family: Pyralidae)

12.3.2.1 Diversity and Distribution

The mango leaf webber has in the recent past become a serious pest in Uttar Pradesh, Bihar and north India. Two leaf webber species, viz. *Orthaga euadrusalis* Walker and *O. exvinacea* Hampson, have been recorded from north and south India, respectively (Butani 1979). Occurrence of leaf webber in Andhra Pradesh was reported by Kavitha et al. (2005). Hampson (1896) recorded *Orthaga euadrusalis* from India, Sri Lanka and Indonesia, and *Orthaga chionalis*, *O. melanoperalis*, *O. icarusalis*, *O. leucatma* and *O. vitialis* were reported from Sri Lanka (Rajapakse and Kulasekera 1982).

12.3.2.2 Biology and Nature of Damage

Adult moths are medium sized, and sombre-coloured females lay their eggs on leaves. The eggs are greenish dull in colour, and hatching takes place in 4–7 days. First instar larvae feed on leaf chlorophyll, and, from second instar onwards, they start webbing the leaves and feed on entire leaf, leaving behind the midrib and veins. Full-grown caterpillar measures between 2.5 and 3 cm of brownish blue colour with whitish striations dorsally. Larvae undergo five instars, and larval period varies between 15 and 33 days. The caterpillars when disturbed fall with a sudden jerk. They pupate within the web, but the last generation caterpillars in December–January secrete thread by which they hang and descend onto the ground for pupating in the soil. They spin a cocoon, on which soil gets adhered. The pupal period lasts from 16 to 18 days. The hibernating larvae pupate in March, and the adult emerges by the end of April. There are five generations in a year (Beria et al. 2008).

The caterpillars feed gregariously on tender leaf chlorophyll by scraping the leaf surface. Young larvae web together two to three leaves and feed on them by cutting the leaves from edges towards the midrib leaving behind the network of veins (Plate 12.3). Later stages feed voraciously and web the shoots and leaves together. The leaves get

Plate 12.3 Leaf webber

detached from their stalks and remain entangled in webs on the tree. Several caterpillars may be found in a single webbed cluster of leaves, and pupation takes place inside these webs in silken cocoons. As a consequence of severe feeding, clusters of webbed leaves become dry and brown. Affected trees present sickly appearance and can be observed from a distance due to brown dry clustered leaves. Though precise data on crop losses is lacking, *O. euadrusalis* has been reported to cause 25–80% damage (Srivastava et al. 1982). The pest completes several overlapping generations from July to December on mango trees. Three distinct peaks can be observed in first fortnight of August, September and October. Verma and Singh (2010) found no significant correlation between webber infestation and weather parameters.

12.3.2.3 Management

1. Prune the affected shoots, remove the leaf webs, and burn them.
2. Plough the orchard to expose the pupae for natural enemies and sunlight.
3. Spray contact insecticides, like quinalphos (2 ml/l) or lamda cyhalothrin (1 ml/l) which is effective against leaf webber infestation.

12.3.3 Mealybugs (Hemiptera: Pseudococcidae)

12.3.3.1 Occurrence and Distribution

More than 20 species of mealybugs attack mango. Of them, three species, viz. *Drosicha mangiferae* (Green), *Drosicha stebbingi* (Green) and *Rastrococcus iceryoides* (Green), are major pests in India, Nepal, Bhutan, China, Pakistan and Bangladesh, while *Rastrococcus iceryoides* is also reported from Malaysia (Tandon and Verghese 1985). Of them, giant mealybug, *D. mangiferae*, is a polyphagous insect pest, feeding on 71 plant species (Tandon 1995; Srivastava 1997). Infestation due to this pest leads to significant loss in size and weight of fresh mango incurring yield loss up to 80 per cent (Karar et al. 2012). Mango mealybug is a serious pest in Punjab, Uttar Pradesh and Bihar.

12.3.3.2 Biology and Nature of Damage

The mango mealybug (*D. mangiferae*) nymphs hatch out in the winter at end of December or beginning of January. A single female lays up to 400–500 eggs. The duration of first instar varies from 45 to 71 days, second instar 18 to 38 days and third instar for female 15 to 26 days. On mango the total duration is 77–135 days for female and 67–119 days for male (Yadav et al. 2004).

Damage is caused by feeding by nymphs and female adults throughout the developmental period. The late instar nymphs and adult female mealybugs are flat, oval and waxy white. They remain stationary and adhere to the total length of panicles and shoots (Plate 12.4). Affected panicles shrivel and get dried. Infested plants are covered by the sooty mould. Mealybug infestation on panicles results in reduction in the size and premature dropping of fruits (Singh and Mukherjee 1989). The presence of white cottony cushioned nymphs and adults is a conspicuous symptom of infestation (Mani 2016).

Plate 12.4 Mango mealybugs

12.3.3.3 Management

1. Plough the orchard in November–December.
2. Undertake banding of tree trunk with alkathene (400 gauge) of 25 cm wide 30 cm above ground level, and apply *Beauveria bassiana* product (2 g/l) or five per cent NSKE in second week of December around the tree trunk. Apply grease on lower end of alkathene band (Bindra et al. 1970; Srivastava 1980).
3. Release *Cryptolaemus montrouzieri* at ten beetles/plant in case of *R. iceryoides.* Entomopathogens were also found effective against mealybug (Haseeb and Srivastava 2003).
4. Rake up the soil around the tree trunk, and mix with chlorpyrifos dust 1.5% at 250 g/tree during the second week of December.
5. If nymphs ascended on the tree, spray carbosulfan (0.05%) or dimethoate (0.06%) (Karar et al. 2010).
6. Remove weed plants like *Clerodendrum infortunatum*, an alternate host plant of the giant mealybugs.
7. Several species of natural enemies have been observed predating upon nymphs of *Drosicha mangiferae* and *Drosicha stebbingi.* These include 11 species of coccinellids, six species of spiders, two species of mites and three species of parasitoids (Tandon 1995).

12.3.4 Midges (Diptera: Cecidomyiidae)

12.3.4.1 Occurrence and Distribution

Mango midges (Diptera: Cecidomyiidae) are important pests of mango across the world. About 16 species of gall midges attack mango in Asia (Harris and Schreiner 1992; Peña 2002). Mango midge, *Erosomya indica* Grover, has gained much attention in the recent past as it has become major pest in all mango-growing areas of the world (Abbas et al. 1985; Ahmad et al. 2005). The mango gall midge or mango blister midge, *Erosomya mangiferae* Felt, is a major pest destroying flowers and up to 70 per cent of fruit set. Similarly the leaf gall midge, *Procontarinia matteiana* (Grover), is a serious pest of mango in India, Indonesia, Kenya, Mauritius, Oman, Reunion, South Africa and the United Arab Emirates. In India, 12 species of midges are known to produce different types of galls on mango leaves.

12.3.4.2 Biology and Nature of Damage

The flies lay eggs singly on floral parts, like tender inflorescence axis, newly set fruits or tender leaves encircling the inflorescence. The eggs hatch within 2–3 days. Upon hatching minute maggots penetrate the tender parts where the eggs have been laid and start feeding on them. The floral parts finally dry up and drop. The mature larvae drop down into the soil for pupation. The larval period varies from 7 to 10 days while pupal period from 5 to 7 days. There are three to five overlapping generations from January to March; thereafter, the weather conditions turn unfavourable. Mature larvae undergo diapause in the soil instead of pupation. The midge has four larval instars.

The midge infests and damages the crop at the floral bud burst stage, young fruiting stage and on foliage. On the inflorescence, the eggs are laid in the folds between sepals and petals. The larvae make tunnels in the axis and destroy the inflorescence completely. Larval feeding prevents flower opening and consequently development of the fruit. Infested bud develops as long pointed galls, in which pupation occurs (Plate 12.5). Infested panicles have characteristic right-angled bend, with an exit

Plate 12.5 Blossom midge affected panicle

hole, from which last instar maggots emerge to pupate in the soil. The second generation then infests on very young fruits, which eventually drop before the marble stage. In most mango orchards, heavily galled leaves fall to the ground much earlier than usual, and most galled leaves remain on trees infested with anthracnose inoculum. Shoots of heavily infested mango trees have almost no inflorescence, resulting in low yields of mango fruit.

12.3.4.3 Management

1. Deep plough the orchard in November to expose pupae and diapausing larvae to sun's heat and natural enemies.
2. Monitor the larval population on white paper in April–May and dusting of chlorpyrifos (1.5%) dust on soil below the tree canopy for its control.
3. Spray dimethoate (0.06%) at bud burst stage.
4. Conservation of parasitoids of cecidomyiid pests, like *Platygaster* sp., *Systasis* sp. and *Euplemus* sp. associated with *Dasineura* sp. and *Tetrastichus* sp. associated with *Eryosomya indica*. An external parasitoid, the pteromalid, *Pirens* sp., was found attacking *Procystiphora mangiferae* (Felt.). Predators of the cecidomyiid included *Formica* sp., *Oecophila* spp. and *Camponotus* spp. (Grover 1986).

12.3.5 Scale Insects (Hemiptera: Coccidae)

12.3.5.1 Occurrence and Distribution

Over 70 scale insects are reported attacking mango. Among them, *Aspidiotus destructor* Signoret occasionally causes severe infestation (Srivastava 1997). Besides India, this armoured scale insect has been reported from Sri Lanka, China, Taiwan, Fiji Island and Mexico.

12.3.5.2 Biology and Nature of Damage

Scales undergo parthenogenic reproduction. The adult females are wingless, while the males are winged. The female leads a stationary life on the plant parts and suck the cell sap. The adult female produces numerous minute eggs in a pouch. On hatching, larvae crawl to the tender parts of the plants and shortly attach themselves at a spot (Plate 12.6). The periodical moulting takes place, and the larva loses its original form and becomes a small footless mass covered over the scale. It is difficult to differentiate male and female larva at this stage, but after one to two moults, the male insects gradually emerge as winged forms. These males mate with female and die soon. The females are fixed on the same place for the entire life span. They lose their feet, feelers, etc. and grow by feeding the sap and secrete waxy covering over the body called puparium (Rawat and Jakhmola 1970).

The scale insects suck the plant sap. In case of severe infestation, the growth and fruit setting capacity of the tree is adversely affected.

Plate 12.6 Scale insects on mango leaves

12.3.5.3 Management

1. Prune the severely affected leaves and twigs and their prompt destruction prevents the population buildup of the pest.
2. Use planting material free from scales to minimize the scale population.
3. Conserve natural enemies; major parasitoides recorded on scales are *Anagyrus pseudococci* and *Promascidia unfascitiventris*. Among predators, *Cryptolaemus montrouzieri*, *Chilocorus nigritus* and *Scymnus* sp. and larvae of midge predator, *Coccodiplosis* sp., were noticed feeding voraciously on this coccid (Tandon and Lal 1978; Mani et al. 1995).

12.3.6 Shoot Gall Psylla (Hemiptera: Psyllidae)

12.3.6.1 Occurrence and Distribution

Mango shoot gall psylla, *Apsylla cistellata* Buckton, first recorded from Dehradun, is a monophagous pest of mango. It is distributed in plains of northern India, Nepal and Bangladesh (Tandon and Verghese 1985) and in north-eastern states. It is reported from Uttar Pradesh, Bihar and Tarai regions of north India (Singh 1960; Ahsan 1983). In recent years, this pest incidence is increasing towards Lucknow (Uttar Pradesh), which is major mango-growing area (Gundappa et al. 2014).

Plate 12.7 Shoot gall psylla infestation

12.3.6.2 Bioecology and Nature of Damage

The female psylla lays average 82 eggs on either sides of the midrib of a single leaf during first week to March end. Freshly laid eggs look like a rectangular block with rounded corners. The incubation period lasts between 191 and 211 days. Freshly hatched nymph appears yellowish but change in size and colour with time. This pest undergoes six nymphal instars. Each instar moults after duration of about 1 month except 2nd nymphal instar, which moult 2–3 weeks after hatching. Therefore only one generation occurred in a year. The nymphal period is about 5–6 months. The peak adult emergence is in the first week of March (Singh 1959, 2003).

Nymphs feed inside the leaf midrib secreting chemicals (probably phenyl amino acids),which result in the formation of conical galls in place of apical and axillary buds (Plate 12.7). They enter into galls and complete their development. The gall formation directly interferes with the formation of inflorescence and thus adversely affects the yield. In due course of time, infested twigs dry, showing die-back symptoms (Singh et al. 1975; Singh and Misra 1978).

12.3.6.3 Management

1. Prune the shoots which bear galls during September to check further spread of incidence (Singh 2000).

2. Spray contact insecticide having ovicidal action during the second week of March (peak oviposition period).
3. Spray pongamia oil at 10 g/l+ dichlorovos 1 ml/or dimethoate at 1.5 ml/l or during the middle of August coinciding with the nymphal emergence time (Jayanthi et al. 2014a, b).

12.3.7 Mites (Acari: Tetranychidae and Eriophyidae)

12.3.7.1 Occurrence and Distribution

Mites are sporadic pests of mango but become serious following indiscriminate use of insecticides against other sucking pests. They colonize on leaves, buds and fruits. The bud mite, *Eriophyes mangiferae* (Sayed) is a major pest in Punjab, Delhi and Uttar Pradesh (Singh and Mukherjee 1989).

12.3.7.2 Biology and Nature of Damage

The infestation starts from April and gradually reaches a peak in June. The mango bud mite attack results in proliferation of shoots on the terminal, giving rise to a witches' broom effect. In association with the fungus, *Fusarium* sp., mite infestation results in floral and foliar galls resembling witches' broom (Ochoa et al. 1994). In Florida, *E. mangiferae* is associated with malformed mango flowers (Pena 1993), and hence there is an impression that it may be vectoring the disease that could be the real cause of the malformation.

Spider mite, *Oligonychus mangiferae* Rahman and Sapra, feeds on the upper surface of mango foliage and is a common pest in India, Egypt, Mauritius, Peru, Israel and some parts of Asia (Plate 12.8). In other countries like Australia and Central America, the tea red spider mite, *Oligonychus coffeae* (Nietner), and the avocado brown mite, *Oligonychuspunicae* (Hirst), are reported minor pests of mango (Cunningham 1989). Besides these mites, the broad mite,

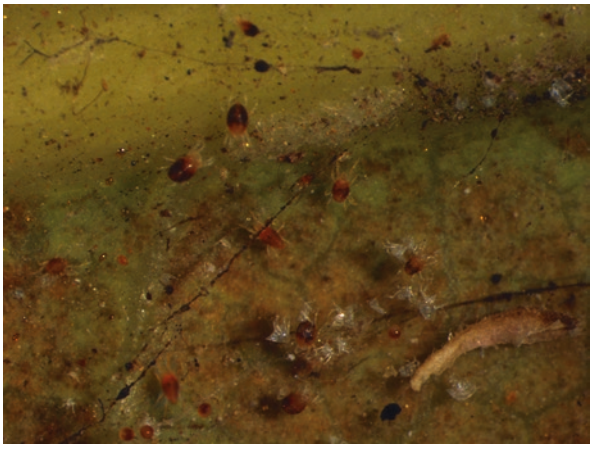

Plate 12.8 Mite infestation on mango lea

Polyphagotarsonemus lotus (Banks) of family Tarsonemidae, was reported to occasionally infest the nursery seedlings, causing stunting and crinkling of new leaves and rolling of leaf margins. Nymphs and adults suck the sap from leaves and tender shoots, resulting in leaf bronzing. On closer observation, webbing of mite colonies can be seen on leaves.

12.3.7.3 Management

Spray of acaricides, like wettable sulphur at 2.5 g/l or dicofol at 1 ml/l or spiromesifen at 1.5 ml/l, will be effective against mites.

12.4 Pests of Shoots and Stem

12.4.1 Mango Shoot Borers (Lepidoptera: Noctuidae)

12.4.1.1 Occurrence and Distribution

Mango shoots are infested by several species of borers. They include *Chlumetia transversa* Walker, *C. alternans* Moore, *Gatesclarkeana erotias* Meyrick, *Anarsia melanoplecta* Meyrick, *A. lineatella* Zeller, *Chelaria spathota* Meyrick and *Dudua aprobola* (Meyrick). Of them, the *C. transversa* is the most widespread and causes extensive damage to young plants. Besides mango, it also attacks litchi leaves. It is found all over India. It has also been reported from Bangladesh, Sri Lanka, China, Java and the Philippines (Butani 1979; Srivastava 1997).

12.4.1.2 Biology and Nature of Damage

Oval, pale yellow eggs are laid singly on tender shoot or flower panicle, which hatch in 2–3 days. The caterpillars first bore into the midribs for a few days and later tunnel into the shoot downwards. The full-grown caterpillar is pink with dirty white spots dorsally and is pale white ventrally. The caterpillar takes 10–12 days to mature, and then it leaves the tunnel and enters into the cracks and crevices of bark of the tree, dried and malformed panicles or also in the soil for pupation. Pupa undergoes diapause and adult emerges with the onset of monsoon. Pupal period is 15–18 days. Moths live up to 15 days. There are four generations in a year (Chahal and Singh 1977; Handa 2006).

The adult female lays eggs singly on the tender leaves, which hatch within 2–3 days. The newly hatched larvae bore into midribs of the leaves and feed for 2–3 days and, thereafter, bore into the tender shoots. They make tunnels downwards up to 100–150 mm in length. The damage can be noticed by the presence of excreta at the entry hole and the drying and wilting of affected shoots. The trees, which are double worked, are more susceptible to shoot borers. Incidence will be high during July–October (Bhole et al. 1987).

12.4.1.3 Management

1. Remove and destroy infested shoots
2. Spray quinalphos at 2 ml/l or profenophos at 1.5 ml/l and neem oil at 5 ml/l two times at fortnightly intervals by changing the chemical from the emergence of new flush.

12.4.2 Mango Stem Borers (Coleoptera: Cerambycidae)

12.4.2.1 Occurrence and Distribution

Stem borers of the genus *Batocera* are one of the serious pests of mango in India (Veeresh 1989). The species recorded in India include *Batocera rufomaculata* (De Geer), B. *rubus* (Linnaeus), *B. roylei* (Hope), *B. numitor* (Newmann) and *B. titana* (Thomson) (Fletcher 1914; Butani 1979). Of them, *Batocera rufomaculata* De Geer is the most destructive and frequently found borer in mango orchards. Beside mango, they attack fig, jackfruit, mango, mulberry, papaya, apple, etc. In a recent study, Reddy et al. (2014) reported that besides *B. rufomaculata*, mango is attacked by two other cerambycids, viz. *Glenea multiguttata* Guerin-Meneville and *Coptops aedificator* (Fabricius), and one buprestid in Karnataka. In Pakistan, the scolytid, *H. mangiferae*, was reported to be associated with sudden death disease of mango (Masood et al. 2009).

12.4.2.2 Biology and Nature of Damage

The pest has annual life cycle with one generation per year. Adults are stout, dark brown beetles with a body length of 50–55 mm in case of males and 55–60 mm in females. Adults emerge with the onset of monsoon and start mating. Female beetle lays eggs singly on the main trunk of relatively older mango trees between June and August. A single beetle lays up to 200 eggs, which hatch in 7–13 days. Eggs are shiny white in colour, oval shaped, 5–7 mm long. Full-grown grubs are 85–95 mm long, stout, yellowish ivory in colour with well-defined segmentation. Pupation takes place in the tunnel and lasts for 20–25 days. Total life cycle takes 170–190 days, and adult longevity is 60–100 days.

Generally more than 15-year-old trees or those already weakened from other causes, either pathological or environmental, are more vulnerable to attack by stem borers (Waite 2002). After hatching from the egg, the neonate larva initially feeds under the bark. The larvae tunnel through the sapwood and make tunnels of about 2–3 cm width, which interfere with sap flow and affect foliage and production (Plate 12.9). The tunnels may either be in the peripheral region or may go deep down into the core of the tree. The size of the tunnel gradually increases as the grub develops. The damage in the early stage is not perceptible, but it can be noticed by the oozing of sticky fluid from several places of the tree trunk and branches. Normally the attack goes unnoticed till a branch or two starts shedding leaves and drying up. A hole with dripping sap and frass on the bark are symptoms visible in advanced stages of infestation. The damage results in yellowing of branches followed by drying and dieback of terminal shoots and branches ultimately leading to the death of the whole tree. Varietal preference of borer is evident with *Alphonso*, *Langra* and *Jehangir* being the most susceptible (25–50% damage) and *Himayuddin* and *Banganapalli* the least susceptible ones (Palaniswamy et al. 1979; Reddy et al. 2015). Rootstock and spacing are other factors supposed to influence the borer infestation levels (Reddy et al. 2015).

Plate 12.9 Borer damage on mango trunk

12.4.2.3 Management

1. Prune the affected branches.
2. Stem wrapping with a nylon mesh during May–August helps in capturing freshly emerging adult beetles (Reddy et al. 2014).
3. A formulation called 'sealer cum healer' has been developed by Indian Institute of Horticultural Research, Bengaluru, which when applied on the stem along with an insecticide (dichlorovos) and a fungicide (Copper oxychloride) helps to protect trunks from egg laying by adults (Shivananda et al. 2012).
4. Remove the grubs from the infected trunk holes by using iron wire/hook and kill them.
5. Plugging the holes with cotton dipped in dichlorovos 76% EC or petrol kills the active larvae inside the stem.
6. Spray trunk portion with chlorpyrifos 20 EC at 3 ml/l or imidacloprid 17.8 SL at 1 ml/l or thiamethoxam at 1 g/l five times at weekly intervals by changing the chemicals after the onset of monsoon to prevent the infestation (Upadhyay et al. 2013).

12.5 Pests of Fruits

12.5.1 Fruit Flies (Family: Tephritidae)

12.5.1.1 Occurrence and Distribution

Fruit flies are serious pests of mangoes in most parts of the world and cause economic losses (Veeresh 1989; Verghese et al. 2011). They are also the major constraint in the export of fresh mango fruits to foreign counties. There are several species of Tephritidae associated with mango across the globe. All *Dacus* species attacking mango have recently been placed under the genus *Bactrocera.* There are 325 species of fruit flies occurring in Indian subcontinent of which 205 are from India alone (Kapoor 2005); of them six to seven species are found infesting mango fruits in India. They include *Bactrocera dorsalis* (Hendel), *B. Zonata* (Bezzi), *B. correcta* (Bezzi) and *B. Caryeae* (Kapoor). Of them, *B. dorsalis*, commonly called the Oriental fruit fly, was earlier considered to be the most important and dominant species complex (Plate 12.10). It is reported from India, Sri Lanka, Myanmar, Nepal, Bhutan, Thailand, Vietnam and Cambodia in Asia. The insect is distributed throughout India; in the north it overwinters in pupal dormancy, but in the south, it is active throughout the year. *B. dorsalis* occurs on a wide range of fruit crops including guava, custard apple, banana, papaya, peaches and plums (Tandon 1995). *Anastrepha* species are endemic to the western hemisphere, and their range extends from Southern United States to northern Argentina and Caribbean islands. *A. oblique* (Macquarat) is the most common fruit fly pest in the Americas (Aluja 1994).

12.5.1.2 Biology and Nature of Damage

Female fly punctures the skin of mature fruits with ovipositor and inserts white banana-shaped eggs (6–10/batch) in clusters into mesocarp. On hatching (after 1–2 days), the maggots tunnel into the fruit and feed on the pulp. The larvae pupate in soil (5–10 cm), and flies start emerging from April onwards with maximum population during May to July, which coincides with fruit maturity. The adults emerge after 10–12 days and may live for a few months. Affected fruits bear tiny

Plate 12.10 Oriental fruit fly, *Bactrocera dorsalis*

ovipositional marks on the skin. Maggot feeding leads to rotting, and the pulp exhibits bad odour. Premature dropping is also noticed in orchards. All commercial varieties of mango are susceptible. However, *Langra*, *Dashehari* and Bombay Green are least susceptible (Jothi et al. 1994).

12.5.1.3 Management

1. An integrated management strategy involving crop sanitation, male annihilation technique and bait sprays has been standardized at Indian Institute of Horticultural Research, Bengaluru, to manage fruit flies. It consists of the following components (Verghese and Shivananda 2014).
2. Collect and destroy fallen fruits at regular intervals to minimize the further spread of infestation. Since pupation takes place in soil, deep ploughing during November–December exposes pupae to hot sun and predators.
3. Erect methyl eugenol bottle traps at 6/acre throughout fruiting period, which attracts male flies. Bait splashes on the trunk, and branches with 10% jaggery + deltamethrin (1 ml/l) attract female flies. Spraying deltamethrin 2.8 EC (1 ml/L),when fruits are at lemon size, gives protection.
4. **Postharvest disinfestation of fruits:** Immerse mango fruits, within 24 h after harvest, in hot water at 48 °C ± 1 °C for 60 min. This process gives 100% mortality of eggs in the fruit without affecting the quality. For export to Europe or Japan, vapour heat treatment and to the USA, gamma irradiation (400 Gy) are mandatory.

12.5.2 Stone Weevil (Family: Curculionidae)

12.5.2.1 Occurrence and Distribution

The stone weevil, *Sternochetus mangiferae* (Fabricius), is the most widely distributed and the most serious and specific pest of mango. It is also of quarantine significance. The infestation ranges from 50% to 70% in susceptible varieties. The pest is more common in south India where late varieties suffer the most. The pest is also reported to occur in Australia (Australian Northern Territory, New South Wales and Queensland).

12.5.2.2 Biology and Nature of Damage

Eggs are laid singly in depressions along the fruit surface. On hatching, the grubs enter the nut or stone. Initially damage is caused by feeding on the outer coat of the stone in a zig-zag fashion. After hatching, the larvae burrow through the pulp to the young developing seed. Consequently, complete stone is destroyed leaving behind black mass. Damaged stones lose their viability, and the fruits are unsuitable for consumption and processing. Generally, only a single larva completes the development in each fruit, but as many as five larvae have been found (Hansen et al. 1989). Extent of damage can be up to 60–65% in susceptible varieties like *Neelam*, *Totapuri* and *Banganapalli*. Weevils hibernate in cracks and crevices of the tree trunk and under the fallen leaves (Shukla and Tandon 1985). Verghese et al. (2005) reported

an association between stone weevil infestation and fruit drop. Similarly, in Hawaii, Follett (2002) found that stone weevil infestation could increase fruit drop in mango during early fruit development.

Females begin oviposition 3–4 days after mating, when the fruit is about marble size. This occurs about mid-March and reaches a peak during the first week of April. The oviposition period varies from 3 to 5 weeks. Eggs are laid singly in depressions along the fruit surface. Females oviposit on fruits and lay eggs mostly on the sinus of the fruit or sometimes on the stalks. The female makes a boat-shaped cavity in the skin (epicarp) into which an egg is deposited, which is covered with a brown exudate. The wound creates a sap flow, which solidifies and covers the egg with a protective opaque coating. The eggs hatch in 5–7 days. After hatching, the larva burrows through the flesh of the fruit and into the seed. Adults are capable of surviving long, unfavourable periods. During non-fruiting periods, weevils diapause under loose bark on mango tree trunks and in branch terminals or in crevices near mango trees. A few adults live through two seasons with a diapause period in between.

12.5.2.3 Management

1. Collection and destruction of fallen fruits.
2. Cleaning the stem and branch junctions with hard broom to disturb the resting weevils.
3. Spraying with deltamethrin at 1 ml/l when fruits are at marble stage.
4. Insecticide sprayings meant for management of other pests should also be directed to the trunk during off-season to kill adult weevils.

12.5.3 Mango Pulp Weevil, *Sternochetus frigidus* (Fabricius)

12.5.3.1 Occurrence and Distribution

Pulp weevil, *Sternochetus frigidus* (Fabricius), attacks both wild and cultivated species of *Mangifera*. Unlike stone weevil, the pulp weevil usually infests the fruit pulp but not the nut or stone. It has restricted distribution in India and is reported from Assam, Manipur, Meghalaya, Tripura and West Bengal. Adults of *S. frigidus* and *S. mangiferae* are similar. They can be distinguished from the pronotum of *S. frigidus*, which is parallel sided in the basal half, and the elytra is only one quarter as long as it is broad and the pro-femora is slender, not clavate (Srivastava 1989).

12.5.3.2 . Biology and Nature of Damage

Eggs are laid on the fruit surface when they are of minimum of 6 cm diameter. The newly hatched larva tunnels through the fruit pulp to the kernel, avoiding the gum-laden tissues because contact with them may cause its death. No external symptoms are noticed till the adult emerges out of the fruit. Pupation takes place inside the fruit, and the weevils leave the ripe fruit through a hole in the peel.

12.5.4 Fruit Borers (Family: Pyralidae)

12.5.4.1 Occurrence and Distribution

Unlike other fruits, mango is relatively least vulnerable to fruit borers except for a few sporadic and localized borer pests. Among them, the red-banded caterpillar, *Deanolis albizonalis* (Hampson), is the major borer pest of mango fruits. It is synonymous to *Autocharis albizonalis* (Hampson) and *Noorda albizonalis* (Hampson). This pest was reported for the first time in India as early as 1955 (Sengupta and Behura 1955), and the severe incidence of *D. albizonalis* was later reported from coastal districts of Andhra Pradesh (Sujatha and Zaheeruddin 2002). It is widely distributed in mango-growing areas of the West Bengal and east coast of Andhra Pradesh causing 10–52% damage of fruits from pin-headed stage to full maturity. All major belts in south India are free of the borer. It is likely to spread across major mango-growing areas, unless strict stringent domestic quarantine is put into regulation (Krishnamoorthy et al. 2014). *Citripestis eutraphera* (Meyrick) is another mango fruit borer (Plate 12.11), geographically distributed in Java, Indonesia, India and Northern Territory in Australia. However, in India, the only official record of *C. eutraphera* is from Andaman Islands (Bhumannavar 1991) on local endemic mango species, *Mangifera andamanica* L. It was also reported as major pest on cashew, *Anacardium occidentale*, another member of Anacardiaceae family from Andaman Islands (Jacob et al. 2004). Jayanthi et al. (2014a, b) recorded its occurrence in Karnataka and Kerala indicating the geographical expansion of the pest. Castor capsule borer, *Conogethes punctiferalis* (Guenee) and *Hyapsila leuconeurella* Ragonot are occasionally found boring mango fruits and are considered to be of minor importance (Butani 1979).

12.5.4.2 Biology and Nature of Damage

On hatching, larvae enter the fruit by boring holes on the apex or narrow tip of the fruit and tunnel through the flesh and skin and then feed on seed. The infestation causes fruit spoilage and premature fruit drop. Fruits of all stages are susceptible. The first sign of

Plate 12.11 Mango fruit borer, *Citripestis eutraphera*

infestation is the presence of a sap stain running from the caterpillar's entry hole and collecting on the drip point at the fruit apex. The sap darkens over time and becomes very noticeable (Fenner 1997). The larvae usually enter through one hole, typically laid in the lower half of the fruit (Krull 2004). First and second instar caterpillars feed just beneath the skin surface, while later instars feed on the seed itself (Kalshoven 1981; Waterhouse 1998). Krull (2004) observed in Papua New Guinea that mango fruits of all sizes were attacked, but marble-sized fruits were preferred sites for oviposition. *Banganapalli*, *Langra*, *Fazil*, etc. are the most susceptible cultivars.

12.5.4.3 Management

1. Collection and destruction of affected and fallen fruits minimize the damage.
2. Larval parasitoids, viz, *Apanteles* sp., *Angitia trochanterata*, and *Bracon brevicornis*, have been reported.

Table 12.1 List of insect species considered minor pests on mango

S. No.	Common name	Scientific name	Nature of damage
1.	Blossom feeders and webbers	*Asura ruptofascia* Hampson, *Celama analis* Will and Westwood, *C. fasciatus* Walker, *Cosmostola laesaria* Walker, *Gymnoscelis imparatalis* Walker, *Eublemma* spp.	Webbing and feeding on the inflorescence
1.2.	White grub beetles	*Holotrichia consanguinea* (Blanchard)	Voracious feeding on leaves during night times
		Anomala sp.	
3.	Slug caterpillar	*Latoia lepida* (Cramer)	Feeding on leaves
4.	Leaf-cutting weevil	*Deporaus marginatus* (Pascal)	Characteristic cutting and feeding on leaves
5.	Leaf minor	*Acrocercops syngramma* Meyrick	Mining leaves
6.	Leaf-mining weevil	*Rhynchaenus mangiferae* Marshall	Skeletonization of leaves
7.	Mango blackfly	*Aleurocanthus mangiferae* Quaintance	Suck sap from leaves
8.	Leafhopper	*Amrasca splendens* Ghauri	Suck sap from leaves leading to hopper burn
9.	Painted bug	*Coptosoma nazirae* Atkinson	Suck sap from leaves, flowers
1.10.	Bark-eating caterpillar	*Indarbela quadrinotata* (Walker)	Feed on bark and make holes on stem
		I. tetraonis (Moore)	
11.	Termite	*Odontotermes* spp.	Affects stem and branches by building mounds
12.	Red ant	*Oecophylla smaragdina* Fabricius	No direct damage but cause nuisance to workers. Also considered as biocontrol agent against sucking pests
1.13.	Fruit-sucking moths	*Eudocima maternal* (Linn.)	Suck sap from fruits
		E. fullonica (Clerck)	
14.	Castor capsule borer	*Conogethes punctiferalis* (Guenee)	Larvae bore the fruits

3. Clean cultivation as weed plants serves as alternate hosts.
4. Use light trap at 1/ha to monitor the activity of adults.
5. Spraying of indoxacarb 14.5 SC at 0.5 ml/l or dimethoate 30 EC at 2 ml/l at fruit set will check the pest incidence.

12.6 Minor Pests

Besides the above-mentioned pests, mango trees are occasionally attacked by a variety of other insect pests not considered economically significant (Butani 1979). They are listed below (Table 12.1).

12.7 Conclusions

With the onset of variety and location-specific commercial cultivation, there have been significant shifts in the pest community structure over the years on mango. Indiscriminate use of broad-spectrum insecticides has taken a toll of natural enemies, leading to a spurt in sucking pests like thrips, mites, mealybugs, etc. Climate change-driven shift in crop phenology is another factor, which contributed to the complexity of pest problems in mango. Growing mangoes to meet international standards demand residue-free product, and hence there is a need to strengthen good agricultural practices, and research in this direction is essential. The IPM module developed for mango fruit fly management would serve as a model to evolve strategies for other pests. Host plant resistance and semiochemicals are underutilized components of IPM and deserve immediate attention. Orchard ecosystem supports a large fauna of native natural enemies, and they should be conserved.

References

Abbas SR, Verghese A, Fasih M (1985) Studies on the mango inflorescence midge, *Erosomyia indica* Grover. II Int Symp Mango 231:593–596

Ahmad W, Nawaz MA, Saleem A, Asim M (2005) Incidence of mango midge and its control in mango growing countries of the world. II Int Conf Mango Date Palm 231:98–102

Ahsan MF (1983) Incidence of the mango shoot-gall psyllid, *Apsylla cistellata* Buckton at Shibganj. Univ J Zool 2:61–68

Alam SN (1994) Population dynamics, varietal reactions and microbial control of different species of mango leaf hoppers. MSc thesis, University of the Philippines, Los Banos

Aliakbarpour H, CheSalmah MR (2010) Diurnal activity of four species of thrips (Thysanoptera: Thripidae) and efficiencies of three nondestructive sampling techniques for thrips in mango inflorescences. J Econ Entomol 103:631–640

Aluja M (1994) Bionomics and management of Anastrepha. Annu Rev Entomol 39:155–178

Beria NN, Acharya MF, Kapadia MN (2008) Biology of mango leaf webber, *Orthaga exvinacea*. Annal Plant Prot Sci 16:218–219

Bhole SD, Jadhav VS, Dumbre RB, Dalvi CS (1987) Seasonal incidence and chemical control of mango nursery pests in the Konkan region. J Maharashtra Agric Univ 12(3):387–388

Bhumannavar BS (1991) Record of *Citripestis eutraphera* Meyrick (Pyralidae: Lepidoptera) on *Mangifera indica* in India. J Bombay Nat Hist Soc 88(2):299

Bindra OS, Varma GC, Sandhu GS (1970) Studies on the relative efficacy of banding materials for the control of mango mealy bug, *Drosicha stebbingi* (Green). J Res Punjab Agric Univ 7(4):491–494

Butani DK (1979) Insects and fruits. Periodical Expert Book Agency, Delhi

Chahal BS, Singh D (1977) Bionomics and control of mango shoot borer, *Chlumetia transversa* Walk. (Noctuidae: Lepidoptera). Ind J Hort 34(2):188–192

Cunningham I (1989) Pests. In: Bagshaw, Journal Mango Pests and Disorders (ed) Department of Primary Industries Information Series, Q189007, pp 10–21

Das NM, Remamony KS, Nair MRGK (1969) Biology of a new jassid pest of mango. *Amrasca splendens* Ghauri. Ind J Entomol 31:288–290

de Laroussilhe F (1980) Le Manguier. G.P. Masoneuve & Larose, Paris

Devi Thangam S, Verghese A, Dinesh MR, Vasugi C, Kamala Jayanthi PD (2013) Germplasm evaluation of mango for preference of the mango hopper, *Idioscopus nitidulus* (Walker) (Hemiptera: Cicadellidae) :The first step in understanding the host plant resistance. Pest Manag Hort Ecosyst 19:10–16

Fenner T (1997) Red-banded mango caterpillar: biology and control prospects. Northern Territory Department of Primary Industry and Fisheries, Darwin, 2 pp

Fletcher T. B. (1914) Some South Indian insects and other animals of importance considered especially from an economic point of view. Printed by the superintendent, Government Press, Madras, 565 pp

Follett PA (2002) Mango seed weevil (Coleoptera: Curculionidae) and premature fruit drop in mangoes. J Econ Entomol 95(2):336–339

Grover P (1986) Integrated control of midge pests. Cecidol Int 7:1–28

Gundappa, Shukla PK, Rajkumar B, Verma S, Misra AK (2014) Incidence of shoot gall psylla, *Apsylla cistellata* Buckton on mango in India. In World mango conference, Islamia University of Bahawalpur, Pakistan, p 72

Hampson GF (1896) The Fauna of British India including Ceylon and Burma. Moths, Taylor and Francis, London, vol 4, pp 70–77,356

Handa S (2006) Seasonal incidence of mango shoot borer in different cultivars of mango and efficacy of different insecticides and neem oil for its control. Agric Sci Dig 26(4):306–308

Hansen JD, Armstrong JW, Brown S (1989) The distribution of the mango weevil, *Cryptorhynchus mangiferae* (Coleoptera: Curculionidae) in Hawaii. Proc Hawaiian Entomol Soc 29:31–39

Harris KM, Schreiner H (1992) A new species of the gall midge (Diptera: Cecidomyiidae) attacking mango foliage in Guam, with observations on its pest status and biology. Bull Entomol Res 82:41–48

Haseeb M, Srivastava RP (2003) Field evaluation of entomogenous fungus, *Beauveria bassiana* (Bals.) Vuill. against mango mealy bug, *Drosicha mangiferae* Green. J Ecophysiol Occup Health 3(3):253–258

Higgins CJ (1992) Western flower thrips (Thysanoptera: Thripidae) in greenhouses: population dynamics, distribution on plants and association with predators. J Econ Entomol 85:1891–1903

Jacob TK, Veenakumari K, Bhumannavar BS (2004) Insect pests of cashew in the Andaman Islands. Cashew 18(4):25–28

Jayanthi PDK, Verghese A, Shashank PR, Kempraj V (2014a) Spread of indigenous restricted fruit borer, *Citripestis eutraphera* (Meyrick) (Pyralidae: Lepidoptera) in mango-time for domestic quarantine regulatory reforms. Pest Manag Hort Ecosyst 20(2):227–230

Jayanthi PDK, Verghese A, Arthikruba A, Sowmya BR, Bhatt RM (2014b) Emerging pests of mango under changing climate scenario, Technical bulletin no. 18. Indian Institute of Horticultural Research, Bengaluru

Jothi DB, Tandon PL, Verghese A (1994) Hot water immersion as a quarantine treatment for Indian mangoes infested with the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera : Tephritidae). FAO. Plant Prot Bull 42(3):158–159

Kalshoven LGE (1981) The pests of crops in Indonesia. PT IchtiarBaru – Van Hoeve, Jakarta, 701 pp

Kapoor VC (2005) Taxonomy and biology of Indian fruit flies. Isr J Entomol 35-36:459–475

Karar H, Arif MJ, Sayyed HA, Ashfaq M, Khan MA (2010) Comparative efficacy of new and old insecticides for the control of mango mealy bug (*Drosicha mangiferae*) in mango orchards. Int J Agric Biol 12(3):443–446

Karar H, Arif MJ, Ali A, Hameed A, Abbas G, Abbas Q (2012) Assessment of yield losses and impact of morphological markers of various mango (*Mangiferae indica*) genotypes on mango mealybug (*Drosicha mangiferae* Green) (Homoptera: Margarodidae). Pak J Zool 44(6):1643–1651

Kavitha K, Lakshmi KV, Anitha V (2005) Mango leaf webber *Orthaga euadrusalis* Walker (Pyralidae: Lepidoptera) in Andhra Pradesh. Insect Environ 11:39–40

Krishnamoorthy A, Reddy PVR, Verghese A (2014) Borer pests: status and challenges. Indian Institute of Horticultural Research, Bengaluru, pp 14–15

Krull SME (2004) Studies on the mango-ecosystem in Papua New Guinea with special reference to the ecology of *Deanolis sublimbalis* Snellen (Lepidoptera: Pyralidae) and to the biological control of *Ceroplastes rubens* Maskell (Homoptera, Coccidae). PhD thesis, Justus-Liebig-UniversitatGieben, 190 pp

Lewis T (1973) Thrips, their biology, ecology and economic importance. Academic, New York

Mani M (2016) Fruit crops: mango. In: Mani M, Shivaraju C (eds) Mealy bugs and their management in agricultural and horticultural crops. Springer, New Delhi, p 385

Mani M, Krishnamoorthy A, Pattar GL (1995) Biological control of the mango mealybug, *Rastrococcus iceryoides* (Green) (Homoptera: Pseudococcidae). Pest Manag Hortic Ecosyst 1(1):15–20

Masood A, Saeed S, Sajjad A, Ali M (2009) Life cycle and biology of mango bark beetle, Hypocryphalus mangifera Stebbing: as a possible vector of sudden death disease of mango in Pakistan. Pak J Zool 14:281–288

Mukherjee SK (1997) Introduction: botany and importance. In: Litz RE (ed) *The mango: botany, production and uses*. CAB International, Wallingford, pp 1–19

Nachiappan RM, Bhaskaran R (1983) Biochemical constitution of inflorescence of certain varieties of mango in relation to mango leafhoppers. South Ind Hortic 31:160–165

Ochoa R, Aguilar H, Vargas, C (1994) Phytophagous mites of Central America: an illustrated guide. Centro Agronómico Tropical de Investigación y Enseñanza, Technical series 6. Turrialba, Costa Rica

Palaniswamy MS, Sundra PC, Babu, Subramanian TR (1979) Studies on the biology of mango stem borer, *Batocera rufomaculata* De Geer (Coleoptera: Cerambycidae). South Ind Hort 27(3–4):100–106

Patel AK, Patel SR, Shah AH (1973) Studies on sex ratio, longevity and seasonal incidence of mango leafhopper, *Amritodus atkinsoni* in South Gujarat. Ind J Entomol 37:150–153

Pena JE (1993) Pests of mango in Florida. Acta Hortic (341):395–406

Peña JE (2002) Integrated pest management and monitoring techniques for mango pests. VII Int Mango Symp 645:151–161

Pena JE, Mohyuddin AI, Wysoki M (1998) A review of the pest management situation in mango agroecosystems. Phytoparasitica 26:129–148

Pena JE, Sharp JL, Wysoki M (2002) Tropical fruit pests and pollinators: biology, economic importance, natural enemies and control. CABI Publishing, New York

Rajapakse RHS, Kulasekera VL (1982) Some observations on insect pests of cinnamon in Sri Lanka. Entomon 7(2):221–223

Rawat RR, Jakhmola SS (1970) Bionomics of the mango-Coccid (*Rastrococcus iceryoides* Green; Homoptera: Coccidae). Ind J Agric Sci 40(2):140–144

Reddy PVR, Dinesh MR (2005) Evaluation of mango exotic collections for resistance to hopper, *Idioscopus niveosparsus* Lethierry India. J Plant Gen Res 18(1):69–70

Reddy PVR, Chakravarthy AK, Sudhagar S, Kurian R (2014) A simple technique to capture, contain and monitor the fresh-emerging beetles of tree borers. Curr Biotica 8(2):191–194

Reddy PVR, VarunRajan V, Thangam D, Chakravarthy AK (2015) Stem borers in mango: species diversity and damage patterns. 4th congress on insect science, PAU Ludhiana, 16–17 April 2015, pp 150–151

Sengupta GC, Behura BK (1955) Some new records of crop pests from India. Ind J Entomol 17:283–285

Shivananda TN, Verghese A, Hegde RM, Kumar NKK, Singh AS (2012) Management of mango trunk borers using sealer cum healer. Technical bulletin no. 72/12, IIHR, Bangalore

Shukla RP, Tandon PL (1985) Bio-ecology and management of the mango weevil, *Sternochetus mangiferae* (Fabricius) (Coleoptera: Curculionidae). Int J Trop Agric 3:293303

Singh SM (1959) Studies on mango shoot gall psyllid, *Apsylla cistellata* Buck. I. Descriptions of developmental stages and biology and habits. Ind J Entomol 21:273–281

Singh SM (1960) Studies on mango shoot gall in *Tarai* region of UP. Its causes and control. II distribution, nature, extent, intensity of damage and binomics of the pest. Hortic Adv (Hortic Res Inst Saharanpur) 4:97–114

Singh G (2000) Physiology of shoot gall formation and its relationship with juvenility and flowering in mango. VI Int Symp Mango (509):803–810

Singh G (2003) Mango shoot gall: its causal organism and control measures. Indian Council of Agricultural Research, New Delhi, 94 pp

Singh HS, Kishore K (2014) Status and strategies for red banded mango caterpillar, *Deanolis albizonalis* (Hampson) – an emerging pest of in eastern India. J Appl Zool Res 25(1):11–20

Singh G, Misra PN (1978) The mango shoot gall psyllid *Apsylla cistellata* Buckton and its control. Pesticides 12:15–16

Singh J, Mukherjee IN (1989) Pest status of phytophagous mites in some northern states of India. In: Proceedings of the first Asia-Pacific conference of entomology. Chiang Mai, Thailand, pp 192–203

Singh G, Kumar A, Everrett TR (1975) Biological observations and control of *Apsylla cistellata* Buckton (Psyllidae: Homoptera). Ind J Entomol 37:46–50

Srivastava RP (1980) Efficacy of Alkathene bands to prevent ascent of mango mealy bug nymphs on mango trees. Ind J Entomol 42(1):122–129

Srivastava RP (1997) Mango insect pest management (No. Ed. 1). International Book Distributing Co, Lucknow

Srivastava RP, Tandon PL, Verghese A (1982) Evaluation of insecticides for the control of mango shoot gall psyla, *Apsylla cistelata* (Buckton) (Psyllidae, Homoptera). Entomon 1:281–284

Sujatha A, Zaheeruddin SM (2002) Biology of pyralid fruit borer, *Deanolis abizonalis*: a new pest of mango. J Appl Zool Res 13:1–5

Tandon PL (1995) Integrated insect pest management in mango. In Proceedings national symposium on integrated pest management and environment organized by Plant Protection Association of India and FAO at Madras, 2–4 February 1995

Tandon PL, Lal B (1978) The mango coccid, *Rastrococcus iceryoides* (Green) (Homoptera:Coccidae) and its natural enemies. Curr Sci 47:467–468

Tandon PL, Verghese A (1985) World list of insect, mite and other pests of mango, Technical document, vol 5. Indian Instistute of Horticultural Research, Bangalore

Tandon PL, Verghese A (1987) New insect pests of certain fruit crops. Ind J Hortic 44:120–121

Tandon PL, Lal B, Rao GSP (1983) Prediction of mangohopper *Idioscopus clypealis* (Leth.) population in relation to physical environmental factors. Entomon 8:257–261

Upadhyay SK, Chaudhary B, Sapkota B (2013) Integrated management of mango stem borer *(Batocera rufomaculata* Dejan*)* in Nepal. Glob J Biol Agric Health Sci 2(4):132–135

Veeresh GK (1989) Pest problems in mango – world situation. Acta Hortic (231):551–565

Verghese A (2000) Status and management of the mango stone weevil *Sternochetus mangiferae* (Fab.) (Coleoptera: Curculionidae) in India. Pest Manag Hort Ecosyst 6(1):15–21

Verghese A, Devi Thangam S (2011) Mango hoppers and their management. Extension folder no: 71-11, ATIC series: 31-11. Indian Institute of Horticultural Research, Bangalore

Verghese A, Tandon PL, Rao GSP (1988) Spatial distribution pattern and sampling plan for the blister midge, *Erosomyia indica* Grover (Cecidomyiidae: Diptera) in India. Insect Sci Appl 9(4):515–518

Verghese A, Nagaraju DK, Kamala Jayanthi PD, Madhura HS (2005) Association of mango stone weevil, *Sternochetus mangiferae* (Fabricius) (Coleoptera: Curculionidae) with fruit drop in mango. Crop Prot 24:479–481

Verghese A, Uma S, Jayanthi PD, Mouly R, Helen M (2011) Evidence of a random ovipositional strategy by female fruit fly *Bactrocera dorsalis* (Tephritidae: Diptera) with reference to host quantum. Curr Sci 100(2):246–248

Verghese A, Shivananda TN, Jayanthi PDK (2014) Integrated Pest Management (IPM) of mango fruit fly, Bactrocera spp. IIHR extension folder. Indian Institute of Horticultural Research, Bengaluru

Verma R, Singh S (2010) Seasonal activity of mango leaf webber, *Orthaga eudrasalis* walker. Insect Environ 16(1):22

Viraktamath S, Viraktamath CA (1985) New species of *Busoniomimus* and *Idioscopus* (Homoptera: Cicadellidae: Idiocerinae) breeding on mango in south India. Entomon 10:305–311

Waite GK (2002) Pests and pollinators of mango. In: Pena JE (ed) Tropical fruit pests and pollinators: economic importance, natural enemies and control. CABI Publishers, Wallingford, p 103

Waterhouse DF (1998) *Deanolis sublimbalis* (chapter 4.6) in biological control of insect pests: South-East Asian prospects, ACIAR monograph No. 51. Australian Centre for International Agricultural Research, Canberra. 548 pp

Wysoki M, Ben-Dov Y, Swirski E, Izhar Y (1993) The arthropod pests of mango in Israel. Acta Hortic (341):452–466

Yadav JL, Singh SP, Kumar R (2004) The population dynamics of the mango mealy bug (*Drosicha mangiferae* G.) in mango. Progress Agric 4(1):35–37