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Review Article

Classical biological control initiatives for the impending invasive pests of India

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ABSTRACT: Invasive insect pests, diseases and weeds caused extensive damage to several crops in India. Recent insect invasives include *Heteropsylla cubana* Crawford, *Liriomyza trifolii* (Burgess), *Hypothenemus hampei* (Ferrari), *Aleurodicus dispersus* Russell, *Aceria guerreronis* Keifer, *Bemisia argentifolii* Bellows and Perring, *Paracoccus marginatus* Williams and Granara de Willink and *Leptocybe invasa* Fisher and La Salle. Classical biological control through the introduction of parasitoids from the native range of the invasives have shown tremendous control of *P. marginatus* and *L. invasa.* An assessment was made on the possibilities of invasion by several insect pests and the weeds. The Madeira mealy bug, *Phenacoccus madirensis* Green; cassava mealy bug, *Phenacoccus manihoti* Mat.-Ferr.; coconut leaf beetle, *Brontispa longissima* Gestro; giant whitefly, *Aleurodicus dugesii* Cockerell; tomato pinworm, *Keiferia lycopersicella* (Walshingham); eucalyptus leaf gall, *Ophelimus maskelli* (Ashmead); Quince borer *Coryphodema tristis* Drury; sunflower maggot, *Strauzia longipennis* and light brown apple moth, *Epiphyas postvittana* are to name a few, who pose threat to Indian agriculture. The classical biological control options available for the management of these pests are discussed in case of the invasions.

KEY WORDS: Classical biological control, invasive pests, quarantine.

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INTRODUCTION

Biotic invaders are species that establish in a new environment in which they proliferate, spread, and persist to the detriment of the environment. They are the most important ecological outcome of the unprecedented alterations in the distribution of the earth's biota brought about largely through human transport and commerce. These species are aggressive invaders outside their natural range that directly affect resource management schemes, such as land use, watersheds and native biodiversity. Alien invasives have been recognized as the second largest threat to biological diversity and other natural resources after habitat destruction due to fire, water or other natural calamities. Problems caused by such invasive species in agricultural ecosystems especially, through accidental introductions of pests are manifold. These alien pests find the new habitat ideal and conducive for breeding and establishment without any restriction through natural regulating factors like natural enemies that keep the species under check in its native range. Managing such invasive species can be ideally attempted through classical biological control involving introduction of effective exotic natural enemies from the native home range of the given species in order to re-establish the lost balance between the pests and the natural enemies.

In the last 15 years at least six species of insects and mite pests have invaded India. These include the subabul psyllid, *Heteropsylla cubana* Crawford in 1988, the American serpentine leaf miner, *Liriomyza trifolii* (Burgess) in 1990-91, the coffee berry borer, *Hypothenemus hampei* (Ferrari) in 1990, the spiralling whitefly, *Aleurodicus dispersus* Russell in 1994, the coconut mite, *Aceria guerreronis* Keifer in 1998 and the silver leaf whitefly, *Bemisia argentifolii* Bellows Perring in 1999. Recently, the papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink and eucalyptus gall wasp, *Leptocybe invasa* Fisher & LaSalle caused extensive damage. Local flare-ups also cause considerable damage to the economy like the recent increase of the cotton mealybug *Phenacoccus solenopsis* Tinsley and the sugarcane wooly aphid, *Ceratovacuna lanigera* Zehntner. Several alien weeds have also invaded India and those of importance are *Salvinia molesta* D. Mitchell Linn., *Eichhornia crassipes* (Mgrt.) Solms., *Chromolaena odorata* Linn., *Lantana camara* Linn., *Parthenium hysterophorus* Linn., *Mikania micrantha* Kunth. and the thorny weed, *Mimosa diplotricha* (*invisa*) Mart (giant sensitive plant) resulting in huge alterations in local flora. A list of invasive weeds of quarantine importance is presented in Table 1.

Table 1. Invasive weeds of quarantine importance to India

1. *Abutilon theophrasti*	22. *C. solstitialis*	43. *Lolium rigidum*
2. *Agrostemma githago*	23. *Chondrilla juncea*	44. *Matricaria perforatum*
3. *Alectra sp.*	24. *Cichorium endivia*	45. *Mimosa pigra*
4. *Allium vineale*	25. *C. pumilum*	46. *Orobanche cumana*
5. *Ambrosia artemisiifolia*	26. *C. spinosum*	47. *Phalaris paradoxa*
6. *Ambrosia maritima*	27. *Cordia curassavica*	48. *Polygonum cuspidatum*
7. *Ambrosia psilostachya*	28. *Cuscuta australis*	49. *P. perfoliatum*
8. *Ambrosia trifida*	29. *Cynoglossum officinale*	50. *Proboscidea lovisianica*
9. *Ammi visnaga*	30. *Desmodium tortuosum*	51. *Raphanus raphanistrum*
10. *Apera-spica-venti*	31. *Echinochloa crus-pavonis*	52. *Rumex crispus*
11. *Arceuthobiumoxycedri*	32. *Echium plantagineum*	53. *Salsola vermiculata*
12. *Avena sterilis*	33. *Emex australis*	54. *Senecio jacobaea*
13. *Baccharis halimifolia*	34. *Emex spinosa*	55. *Solanum carolinense*
14. *Bromus diandrus*	35. *Froelichia floridana*	56. *Striga hermonthica*
15. *Bromus rigidus*	36. *Helianthus californicus*	57. *Thesium australe*
16. *Bromus secalinus*	37. *H. ciliaris*	58. *T.humiale*
17. *Cardus pycnocephalus*	38. *H. petiolaris*	59. *Vicia villosa*
18. *Cenchrus tribuloides*	39. *H. scaberrimus*	60. *Viola arvensis*
19. *Centaurea diffusa*	40. *Heliotropium amplexicaule*	61. *Xanthium spinosum*
20. *C. maculosa*	41. *Ipomoea coccinea*	
21. *C. melitensis*	42. *Leersia japonica*	

(Source: DPPQ&S. GOI)

Large-scale movement of plant material such as vegetables, fruits, ornamentals, planting material, seeds, etc. between nations entails the danger of accidental introduction of insect pests, nematodes, plant pathogens and weeds. Dominance of the invasive species in the new found habitat would cause immense damage to the native fauna and flora thus upsetting the natural balance of the invaded habitat. An ideal way of managing such invasive species, whether insects, mites or weeds, would be to intentionally introduce and establish effective natural enemies from the native home range of the invasive species. This method is often referred to as Classical Biological Control (CBC) in recognition of its relatively early first use in 1880s. In fact the spectacular success of cottony cushion scale, *Icerya purchasi* Mask control in California by exotic predator, *Rodolia cardinalis* Mulsant and *Cryptochaetum iceryae* (Willston) greatly influenced both the entomologists and administrators to promote classical bio-control during the turn of the 20th century for invasive pests. The recent successes in the CBC of *P. marginatus* using *Acerophagus papayae* Noyes & Schruff and also the management of the dreaded eucalyptus gall wasp *Leptocybe invasa* using *Quadrastichus mendeli* Kim & La Salle has energised us in using this important tool for the management of invasives in the country.

A range of invasives are still playing havoc in the country which has to be attended to. To mention a few are; the *Erythrina* or the Indian coral tree gall wasp, *Quadrastichus erythrinae* Kim and the weed *Mimosa diplotricha* Mart. (giant sensitive plant). As per the recent documentation of the invasive species by some of the organizations like the Invasive Species Specialist Group (ISSG), International Network for Bar coding Invasive and Pest Species (INBIPS) and Global Invasive Species Programme (GISP), more than 575 invasive threats are being notified. Surrounding Indian region at least 10-12 species of dreaded insects are waiting to invade. Our preparedness for management of the same only can help to thwart the menace and also the huge economic loss associated with the invasion. Weed invasions are also of prime importance as they alter the native biodiversity and cause imbalance to it. According to an estimate, about 40% of the species in the Indian flora are alien, of which 25% are invasive. The major adventive weeds of importance are from Asteraceae, a list of 61 weed species of quarantine importance has been given in the documents of Directorate of Plant Protection and Quarantine, Government of India, out of which 3-4 species have already invaded India and are slowly establishing in various ecosystems (Table 1).

Several of invasive species of insects are already present and are devastating the ecosystem. The prime example is of *Quadrastichus erythrinae* Kim which was introduced to our country during 2005-07 and till now no sincere effort has been made to combat this species. The farmers in coffee and tea orchards are now depending on other fast growing shade plants to replace the Indian coral tree because of the gall wasp incidence. In this paper an effort is made to consolidate the alien invasive insect threats to India (Table 2) and available options for CBC.

Erythrina gall wasp, *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae)

The wasp, *Q. erythrinae* Kim (Hymenoptera: Eulophidae) was noticed as a serious pest of *Erythrina* in Singapore and Mauritius. The pest is reported to damage five species of *Erythrina* (Fabaceae) in Taiwan by formation of gall-enlargement and malformation, leading to severe defoliation and even death of trees. *Erythrina* spp., popularly known as coral tree, are grown throughout the tropics as windbreak for soil and water conservation and for planting around homesteads. *Erythrina stricta* Roxb. a quick-growing species with showy red flowers, is grown as a standard for trailing black pepper (*Piper nigrum* L.) and vanilla (*Vanilla planifolia* Andr.) throughout south India. Its leaves are used as a favourite fodder in sheep and rabbit rearing. Severe incidence of *Q. erythrinae* has been noticed on *E. stricta* in the plains of Thiruvananthapuram District, Kerala since April, 2005 (Fizal *et al*., 2006). Interestingly, during the same period the pest was also reported from Hawaii infesting three different species of *Erythrina*. Symptoms and nature of damage observed on *E. stricta* were similar to those described earlier. Female wasp thrusts eggs into tender tissues of shoots using the exerted ovipositor. Apodous, creamy white larvae develop individually in chambers formed inside the meristematic tissue. Proliferation of tissues in the attacked portion results in gall formation. Galls are formed on the entire developing stem, petiole and leaf lamina with characteristic enlargement and malformation. The mean thickness of galled petioles was 3.1 times more than that of normal. In the case of tender stem, infestation resulted in enhancement of mean thickness twice. Multiple galls with layers of larval chambers are formed in the affected portion. Infected leaves fail to attain the normal size and shrivel with thick galls on them. Petioles and tender stem enlarge in thickness and present a curly appearance with knot-like galls on them. From a single abscised infested leaf, up to 271 wasps emerge. Similarly, a five centimetre long piece of galled petiole and tender stem produced up to 51 and 64 wasps, respectively (La Salle *et al*., 2009, Prinsloo and Kelly, 2009). Sex ratio of wasps emerging from galls was highly skewed towards males, with 2.7 males emerging for each female. Severely infected branches appear stunted and bushy, and finally dry up. As the newly emerging leaves are converted into galls, there is severe reduction in the number and size of leaves besides complete cessation of growth. Such trees present a scrawny appearance with malformed and crinkled shoot. Sustainable control of the pest can probably be achieved by CBC using natural enemies from the homeland of the gall wasp.

A few parasitic wasps belonging to Encyrtidae, Eupelmidae and Pteromalidae were reared from galled *Erythrina* twigs in Taiwan. Pruning of infected branches results in trees putting forth fresh growth which again get affected by the pest, further debilitating the trees. Pruning and burning of the affected shoots in an entire locality on a community basis may yield result. Application of systemic pesticides may be tried as a short-term emergency measure. In Hawaii though pruning failed to contain the damage, bark injection of the systemic pesticide imidacloprid had some effect in protecting new growth. Spread of the pest to hill tracts of South India where plantation crops are grown was extensive. Some parasites have recently been identified for CBC in several countries and results are to be assessed for the introduction of the same to India.

Twelve species of chalcidoids, mostly eulophids are found in association with erythrina galls in East, West and South Africa (Prinsloo and Kelly, 2009). In addition they identified five new tetrastichine species, namely, *Quadrastichus ingens, Q. gallicola, Q. bardus, Aprostocetus nitens* and *A. tritus* , in association with erythrina galls. Two more parasitoids, *viz., Eurytoma erythrinae* Gates & Delvare (2008) (from South Africa, Tanzania and Ghana) and *Aprostocetus exertus* La Salle *et al*., (2009) (from Tanzania) have been described recently. The potential of these species as biocontrol agents of *Q. erythrinae* are being tested in Hawaii (Ronald *et al*., 2008).

The Madeira mealybug, *Phenacoccus madeirensis*, Green (Hemiptera: Pseudococcidae)

The *P. madeirensis*, is of Neotropical origin and is widespread in tropical South America, but was originally described from Madeira (Green 1923). It is now common in temperate areas of USA, well established in Micronesia, and is one of the most common species in tropical Africa (Williams and Granara de Willink 1992, Ben-Dov, 2010c). It is continuing to expand its geographical range; Williams (2004) recorded it from Pakistan in 1997 and mentioned interceptions at U.S. plant quarantine facilities from the Philippines in 1999 and Vietnam in 1997. It was reported from Taiwan by Yeh *et al*. (2006). *P. madeirensis* is highly polyphagous, feeding on members of 44 plant families, including many herbaceous crops, fruit trees, and ornamentals (Ben Dov, 2010c) with potential to spread further in South-east Asia infesting cassava (*Manihot esculenta* Crantz), brinjal, oats, cotton, *Coleus*, *Hibiscus*, potato, *Capsicum* and many other crops including *Citrus* spp. The *P. madeirensis* was recorded on mango seedlings in Naha, Okinawa in 1993 (Kinjo *et al.*, 1996, Kondo, 1996). It has a wide geographical distribution in Europe, Africa, North and South America, Mexico, USA and Central America including the Caribbean islands.

Anagyrus loecki Noyes & Menezes (Hymenoptera: Encyrtidae) is a parasitoid of *P. madeirensis*, *A. loecki* is an arrhenotokous parasitoid with an average lifetime fecundity of 78 progeny. The developmental rate of the mealybug parasitoid increased with temperature between 15° and 30°C. The lower development threshold of female parasitoids was estimated to be 11°C and the thermal constant was 22.7 degree-days. The upper developmental threshold appeared to be above 30°C. The survival rate of the parasitoid larvae was above 94%. Provision of diluted honey significantly extended the longevity of *A. loecki*, especially at lower temperatures. Third-instar immature bugs and pre-reproductive adult mealybugs were the most preferred and suitable host stages. These host stages were able to support the development of a higher number of progeny, a female-biased sex ratio, the shortest developmental time and the highest survival rate. *A. loecki* exhibited a type II functional response, meaning that the parasitism rate decreased exponentially with increase in *P. madeirensis* density. *A. loecki* has the potential to be an effective biological control agent of *P. madeirensis* in greenhouse ornamental production (Chong, 2005).

Cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr. (Hemiptera; Pseudococcidae)

Cassava (*Manihot esculenta*) is one of the two most important food crops in sub-Saharan Africa. This region accounts for most of the root harvest worldwide, followed by Asia and Latin America. *Phenacoccus manihoti*, commonly known as cassava mealybug was first discovered in Africa in the early seventies and it originated from central South America (Neuenschwander 2003). It was accidentally introduced from South America into Africa, spreading rapidly over most of the cassava belt, causing heavy losses of up to 80 per cent of root yield (Williams and Granara de Willink, 1992). It is now threatening the staple food of 200 million people who depend upon cassava for over 50 per cent of their caloric intake.

P. manihoti is oligophagous, feeding on members of nine plant families, but, it strongly prefers cassava as a host (Neuenschwander 2003). It was first found in Southeast Asia (Thailand) in 2009, seriously damaging cassava, and has probably spread to Laos and Cambodia (Winotai *et al*., 2010). It is highly invasive and its entry into India can be restricted only by strict quarantine.

The parasitoid, *Epidinocarsis lopezi* De Santis (*Anagyrus lopezi* De Santis) has been established in eleven countries and is spreading rapidly. Its impact is dramatic and chances of success very high. A *lopezi* was first released in a major CGIAR campaign in East Africa in the early 1980s where it demonstrated that it could control the mealybug as effectively as it did back home. It helped to avert a major food crisis.

Norgaard (1988) analyzed the impact of the biological control of the cassava mealybug based on extrapolation of data from a few West African countries over the entire continent the percentage yield loss saved due to the presence of A. *lopezi* was assumed to rise to a maximum of only 60%. This was attributed to a lower likelihood of A. *lopezi* becoming established when the mealybug populations begin to decline. In Africa, classical biological control of this mealybug has been very successful using A. *lopezi* (Hymenoptera: Encyrtidae). Thailand recently imported and released *A. lopezi* (Winotai *et al*., 2010).

Coconut leaf beetle, *Brontispa longissima* Gestro (Coleoptera: Chrysomelidae)

Brontispa longissima is believed to be endemic to Indonesia and possibly also to Papua New Guinea. In the 20th century *B. longissima* was accidentally introduced into several other countries in South East Asia and Pacific, and as a result has now become widespread. However, the pest was not recorded from continental Southeast Asian countries until the late 1990s when it was first detected in the Mekong delta of Vietnam. The pest was introduced into Maldives through imported ornamental palms from Indonesia or Malaysia. The pest was first noticed in Thailand in February 2004 and several months later in Myanmar, followed by the Philippines in 2005. Singapore and parts of Indonesia have also reported damage by the pest. With no significant physical barriers such as mountain ranges or seas, it is expected that the pest will continue its spread westward and may enter India.

B. longissima is very destructive, 9 mm long beetle damaging the new leaf of coconuts and other palms. In Indonesia, Malaysia, and Pacific Islands it also occurs on other palms. Many local varieties have been described: *var. longissima* with brown elytra, originallly described in Wolan of the Aru Islands, and now common in Java; *var. froggatti* sharp with black elytra, from new Britain and Salomon Islands; *var. selebensis* Gestro with a spindle-shaped, black marking on the suture of the elytra, originally from South and North Sulawesi, later also found near Bogor. *B. longissima* attacks coconut palms aged two to three years old. Lower infestation is noticed in older palms. No damage is reported in coconut palm aged eight to nine years old due to the difficulties of the pest to penetrate unopened leaves to lay the eggs. In contrast, the less compact leaves are more susceptible to *Brontispa* attacks (Tjoa, 1953, Waterhouse and Norris, 1987). The pest has entered all the countries bordering India except Sri Lanka and Bangladesh. Hence, it is imperative that the quarantine is put on high alert and if introduced we should be ready with suitable control measures.

Muniappan *et al.* (1980) reported the natual enemy diversity of *B. longissima* in Guam. Among the natural enemies used in biological control, information about predators against chrysomelid beetles is still limited. Waterhouse and Norris (1987) reported some earwigs preying on *B. longissima*. However, no research has been done to study the basic aspect of the predator and to develop them as a potential biological agent against *B. longissima.* The parasitoid complex of *B. longissima* comprises three egg parasites, *Haeckeliana brontispa* Ferriere, *Trichogrammatoidea nana* Zehntner (Hymenoptera: Trichogrammatoidae) and a species of *Ooencyrtus* (Hymenoptera: Chalcidoidea), and a parasitoid of the larvae and pupae, *Tetrastichus brontispa* Ferriere (Hymenoptera: Eulophidae) (Lever, 1969). In Java, a complex diversity of parasitoids occurs: (1) a strain of the trichogrammatid *H. brontispa*, with one wasp developing per *Brontispa* egg, and found on about 15 percent of *Brontispa* eggs in the field (Kalshoven, 1981) or 17 percent (Tjoa, 1953); (2) the encyrtid *Ooencyrtus podontiae* Gah. occurring on about 10 percent of the eggs (Kalshoven, 1981; Tjoa, 1953) and (3) the eulophid *Tetrastichus brontispa* Ferr., found in 60-90 percent of the pupae and 10 percent of the larval eggs (Kalshoven, 1981; Tjoa, 1953), develop in 18 days; about 20 specimens emerge from one *Brontispa* pupa. Hyperparasitoids have not been found. The same group of parasitoids could also be observed in 1940 in East Java near Kediri. *Tetrastichus* (= *Tetrastichodes*) which is a very distinctive parasitoid, is also found in other parts of Java, in Bali and Papua (Kalshoven, 1981). *Tetrastichus* is the most effective parasitoid *of Brontispa*. Control of the beetle was achieved in Celebes by introducing this parasitoid from Java (Lever, 1969). The larval parasitoid, *Asecodes hispinarum* Boucek was introduced into a few countries in the region and the parasitoid has been successful in managing the pest and is presently adopted by other countries where *Brontispa* is a problem (Lu *et al*., 2005).

Giant Whitefly, *Aleurodicus dugesii* Cockerell (Hemiptera: Aleyrodidae)

The giant whitefly, *Aleurodicus dugesii,* is native of Mexico. It was first discovered in San Diego County in October 1992 and is now found in many parts of the world. This giant whitefly can severely infest many ornamental plant species of nurseries, landscapes, and home gardens. Severely affected plants include begonia, hibiscus, giant bird of paradise, orchid tree, banana, mulberry, *Xylosma,* aralia, and various vegetables. Certain varieties of citrus and avocado are also affected. In California, it has been reported to attack more than forty-three plant genera and thirty-five plant families (Lasalle *et al*., 1997). The giant whitefly was first discovered in the U.S. in Texas in 1991, later found in California (1992), Florida (1996) and Indonesia (2007) (Martin, 2004). The giant whitefly adult is about three times larger than *A. dispersus.*

This is the second Neotropical species of *Aleurodicus* to invade the region; the first was a spiraling whitefly, *A. dispersus*, which began radiating westwards across the Pacific in the 1980s and is now widespread in Southeast Asia (Yu *et al*., 2007). *A. dugesii* is likely to spread through the region in a similar way (Bellows and Meisenbacher 2000, Heu *et al*., 2004). The giant whitefly is a polyphagous species of Central American origin that prefers woody dicotyledonous hosts, including fruit trees and *Hibiscus* sp. It spread into the south-eastern United States in 1990s, reaching California by 1992 (Gill, 2002) and later Hawaii in 2002 (Heu *et al*., 2004). Like *A. dispersus*, it lays its eggs on leaf underside in spirals of white wax, and the immature stages produce long, glassy wax filaments that make infested leaves appear bearded. Adults of *A. dugesii* (3.0–4.5 mm long) are much larger than those of *A. dispersus* (1.8–2.5 mm), have grey patterns on the forewing, and are very sedentary, whereas the forewing of *A. dispersus* has only one pale grey patch and the adults fly readily when disturbed. The *A. dugesii* whitefly can damage fruit trees and other crops by sap depletion and by fouling with sooty mold

(Martin, 2004), and the conspicuous nature of the infestation on ornamental plants is likely to cause public concern.

In California and Hawaii, the giant whitefly was successfully controlled by parasitoids, *Idioporus affinis* LaSalle & Polaszek (Hymenoptera: Pteromalidae), *Encarsiella noyesii* Hayat (Hymenoptera: Aphelinidae), and *Entedononecremnus krauteri* Zolnerowich and Rose (Hymenoptera: Eulophidae) (Heu *et al*., 2004, Zolnerowich and Rose, 1996), hence, there is potential for classical biological control of the giant whitefly in Southeast Asia if it becomes serious. In California, its preferred host is *Hibiscus* sp. (Malvaceae) and could present a threat to cotton (also a member of Malvaceae), although it is yet to be recorded on cotton.

In Florida, the nonstinging parasitic wasp *E. krauteri* was released to combat the giant whitefly. Releases have been made in all counties where the whitefly has been noticed. In order to avoid the long wax filaments this parasite has the unique habit of placing eggs into the whitefly larval stages from the upper leaf surface. Hence, the parasitoid requires considerable time to synchronise with the whitefly population so as to cause a reduction in whitefly numbers.

Tomato pinworm, *Keiferia lycopersicella* (Walshingham) (Lepidoptera: Gelechiidae)

The *Keiferia lycopersicella* is a microlepidopteran moth. In the early 1920s much of the damage to tomatoes in Mexico and California was considered to be due to the eggplant leafminer (*Gnorimoschema glochinella* Zeller) but, the damage was actually inflicted by the *K. lycopersicella*. It persisted in the literature as the eggplant leafminer until redescribed as a new species (Busck, 1928) collected from tomatoes. It was later synonymized with *Eucatoptus lycopersicella* Walshingham. Capps (1946) provided a key, with descriptions, that defines the species along with larval morphology.

K. lycopersicella are found in the warm agricultural areas of Mexico, California, Texas, Hawaii, Cuba, Haiti and the Bahamas. Also, they have been reported from greenhouses in Delaware, Mississippi, Missouri, Pennsylvania and Virginia. Fields near greenhouses may become infested, but the species does not overwinter in colder regions (Thomas, 1933).

Opaque to pale yellow eggs are laid singly or grouped in two's and three's on the host foliage. The eggs turn orange before hatching. The first instar larvae spin a tent of silk over themselves and tunnel into the leaf. Further feeding results in a blotch-like mine usually on the same leaf. The third and fourth larval stages feed from within tied leaves, folded portions of a leaf, or enter stems or fruits. Mature larvae abandon the host and form a loose pupal cell of sand grains near the soil surface. The adult emerge from this pupal cell two to four weeks later. Although the life cycle is lengthy, generations overlap and infestations quickly mount to damaging proportions. Seven or more generations can be expected per year (Elmore and Howland, 1943).

Plants of Solanaceae are the preferred hosts of pinworms. Tomato, *Lycopersicon esculentum* L., is infested most commonly, but eggplant, *Solanum melongena* L. var *'esculentum'* Nees, and potatoes, *Solanum tuberosum* L. are also attacked. Weeds such as *S. carolinense* L., *S. bahamese* L., *S. xanthii* Gray, and *S. umbelliferum* Esch. are suitable hosts. Damage to tomatoes are due to feeding of larvae on leaves, stems and fruit. Initial injury is slight and appears as a small leaf mine. Later injury includes leaf folding and leaf tying. Mature larvae may abandon the leaf and bore into the fruit leaving a small "pin" size hole. Secondary damage results when plant tissues become infected by pathogens and the plant dies or the fruit rots. Approximately 60 to 80 percent of tomato fruits may become infested in a single season (Elmore and Howland, 1943).

Natural enemies include *Apanteles dignus* Muesebeck, *Apanteles scutellaris* Muesebeck, *Horogenes blackburni* (Cameron), *Panhormius pallidipes* Ashmead and the egg parasitoid *Trichogramma pretiosum* Riley. Poe *et al*. (1975) reported that the main cause of pinworm epidemic in Florida (1972) was because of extensive use of chemical insecticides. Pena *et al*. (1986) opined that the farmers were using calendar based insecticides which killed the natural enemies. Poe *et al*. (1975) reported two parasitoids *A. dignus* and *A. scutellaris* that reduced 50-60% of pinworm incidence.

Eucalyptus leaf gall, *Ophelimus maskelli* (Ashmead) (Hymenoptera: Eulophidae)

Ophelimus maskelli is an invasive species of the Mediterranean region and occurs naturally on eucalyptus in New South Wales, Australia. This gall inducer was discovered in several southern European countries, where it was erroneously reported as *O. eucalypti*. Heavy galling by *O. maskelli* results in premature shedding of leaves. *Eucalyptus camaldulensis* Dehnh. and *E. tereticornis*, are more susceptible to attack by *O. maskelli.*

Originally described as *Pteroptrix maskelli* by Ashmead in 1900, this organism was reclassified within the primitive genus *Ophelimus* as part of the extensive revision of Australasian Chalcidoidea by Boucek (1988). The biology and taxonomy of *Ophelimus* is little studied and poorly known. *Ophelimus* is a very large genus with lots of undescribed species and no one has produced a key to species (Protasov *et al*., 2007a). Specimens found spreading around the Mediterranean previously identified as *O. eucalypti* (e.g. Viggiani and Nicotina, 2001) are actually *O. maskelli* (Tilbury and Jukes, 2006; Protasov *et al*., 2007a).

Ophelimus maskelli population build up is very rapid. It produces three generations per year in Israel, and can damage two thirds of the entire leaf volume. The impact of high wasp populations on the canopy of *E. camaldulensis* is serious. Heavily damaged trees are revealed by the desiccation of large parts of their crowns. The adult wasps cause health problems to people during mass emergence, industrial areas surrounded by ornamental eucalyptus trees suffer greatly from clouds of wasps during peak emergence periods (Protasov *et al.*, 2007a).

Closterocerus chamaeleon (Girault) (Hymenoptera; Eulophidae) was introduced into Israel for biological control of *O. maskelli* (Ashmead). *C. chamaeleon* appears to be a widespread species in Australia, occurring in northern Queensland to Victoria and Western Australia. It was reared from galls on *E. camaldulensis* Dehnh. *C. chamaeleon* is a uniparental species and at 25°C the entire development is completed in 3 weeks. Galls containing late 2nd or 3rd instar larvae and pupae of *O. maskelli* are suitable for successful development. *C. chamaeleon* is efficient and has shown to lower the population density of its host within a year of its release. The parasitoid is active throughout the winter when development of its host is virtually arrested. The fast spread of *C. chamaeleon* was demonstrated by its capacity to occupy areas 120 km away from the release point within a year. Green sticky traps are a reliable practical devices for monitoring and sampling of both *O. maskelli* and *C. chamaeleon* (Protosov *et al.,* 2007b).

Apart from gall wasps, several insects of Australian origin described below have become a major constraint in eucalyptus production in several countries and may threaten an estimated 80 lakh ha of plantation jeopardizing the productivity of paper and rayon industry due to raw material shortage.

Quince borer, *Coryphodema tristis* Drury (Lepidoptera: Cossidae)

Coryphodema tristis is native to South Africa and is a well known pest of fruit trees, vines and some native trees. It is a wood-boring insect with a wide host range covering Combretaceae, Malvaceae, Myoporaceae, Rosaceae, Scorphulariaceae, Ulmaceae and Vitaceae. Larvae tunnel the main stem and branches producing frass at the region of tunnel. A female can lay 104 to 316 eggs in her lifetime and adult live for 6 days only, the fully grown larvae measure 2-4 cm. The insect takes two years to complete its life cycle (Solomon Gebeyehu *et al*., 2005).

Australian weevil, *Gonipterus scutellatus* Gyllenhal (Coleoptera: Curculionidae)

It was noticed for the first time from California in March 1994, feeding on eucalyptus in the Simi Valley of Ventura County (Selman, 1994; Davidson 1995). Female lays the hard brown egg capsules on shoots and the young leaves, each female lays about 20-30 capsules, and each capsule contains nine eggs. After incubation for two weeks, the neonates emerge from the egg and start chewing the leaf then feeding on the leaf surface; later instars consume the entire leaf blade. Adults live about two to three months during summer and they are the strong fliers (Clausen, 1978; Luck, 1981; Tooke, 1953).

The Eucalyptus tortoise beetle, *Trachymela sloanei* Blackburn (Coleoptera: Chrysomelidae)

It was identified for the first time in the United States by Garrison in 1968. The grub and adult feed on a wide variety of eucalyptus (Selman, 1985) with preferred host of *E. globules* and *E. viminalis* (Anon., 1977). The unchecked populations can upsurge, causing severe damage to eucalyptus plantations (Lawrence and Britton, 1991; Selman, 1994). Females lay over 3000 eggs in her lifetime (about 270 days) in crevices or fissures or under bark. There are four larval instars, pupation occurs in the duff and litter or soil around the base of the host tree and adults emerge at about 35 days after oviposition. The time to complete the life cycle from egg to adult is eight to twelve weeks (http://www.ohric.ucdavis.edu).

Spotted gum lerp psyllid, *Eucalyptolyma maideni* Froggatt Carpintero, the redgum lerp psyllid, *Glycaspis brimblecombei* Moore and the plant bug, *Thaumastocoris peregrines* Carpintero are some of the invasive species infesting eucalyptus (Carpintero and Dellapé, 2006).

False codling moth, *Thaumatotibia leucotreta* (Meyrick) (Lepidoptera: Tortricidae)

Thaumatotibia leucotreta is a significant pest of fruit trees and field crops in portions of Africa (CIE 1976, Zhang, 1994). This pest is commonly known as *Cryptophlebia leucotreta* (Komai, 1999). *T. leucotreta* is a native of the Ethiopian region (Israel), a polyphagous pest which can feed on more than 70 host plants within 40 families. It was first found in Israel during 1984 on macadamia nuts, in 2003, it was still present but with a limited distribution on cotton and castor bean which are minor crops for Israel. In 2009, an incursion of *T. leucotreta* was detected in the Netherlands on *Capsicum chinense*. It is a polyphagous pest and many of its host plants are economically important crops (Daiber, 1979; 1980). The pest attacks many cultivated and wild fruit species, such as avocado (*Persea americana*), cacao (*Theobroma cacao*), carambola (*Averrhoa carambola*), citrus species (particularly *C. sinensis* and *C. paradisi* but, *C. limon* is considered to be an unsuitable host), coffee (*Coffea* spp.), guava (*Psidium guajava*), litchi (*Litchi sinensis*), macadamia (*Macadamia ternifolia*), peach (*Prunus persica*), pepper (*Capsicum* spp.), persimmon (*Diospyros kaki*), pomegranate (*Punica granatum*). It is also a pest of field crops such as beans (*Phaseolus* spp.), cotton (*Gossypium hirsutum*), castor (*Ricinus communis*) and maize (*Zea mays*). The insect has been recorded in several Northern European countries (e.g. the Netherlands, Sweden and the UK) and well distributed throughout the African continent.

Damage is caused by larvae feeding inside fruits, nuts, maize ears or cotton bolls. Feeding damage can also lead to the development of secondary infections by fungi or bacteria. Eggs (whitish, about 0.9 mm long) are laid on the fruit surface, singly or in small numbers. Shortly after hatching, young larvae enter the fruit and feed internally. Young larvae are whitish with a dark brown head, and usually develop through 5 instars. Mature larvae are about 15 mm long, pinkish-red with a brown head. Fully grown larvae emerge from the fruit and pupate in the soil, in a cocoon of silk and soil fragments. Adult moths (7-8 mm long; 15-20 mm wingspan) have variegated brown and grey forewings with a white spot in the centre, while hindwings are light brown to grey. *T. leucotreta* are weak flyers but present all year-round with overlapping generations. It is a polyphagous pest and many of its host plants are economically important crops (citrus, avocado, fruit trees, maize, capsicum,) (1979, 1980). Biological control with the egg parasitoid *Trichogrammatoidea cryptophlebiae* Nagaraja is partly successful.

Cocoa pod borer, *Conopomorpha (Acrocercops) cramerella* Snellen (Lepidoptera: Gracillariidae)

In Southeast Asia, the greatest threat to cocoa production is from a small insect called the cocoa pod borer and losses due to this pest is approximately 40,000 MT annually. The cocoa pod borer insect is approximately 1 cm long resembling a mosquito. The lifecycle of the insect is intrinsically linked to the cocoa pod. The female lays eggs on the surface of developing cocoa pods. After a few days, the eggs hatch and larvae burrow into the pod. For two weeks, the larvae feed on the pulp and placenta that surround the developing beans inside the pod. The larvae then emerge leaving a long silk thread as they move to the ground. The pod is susceptible to secondary infections and rot due to the holes left. Although the larvae do not eat the beans, they do hinder the beans development.

Cocoa pod borer was first detected in Sabah Malaysia in August 1980 is the most important insect pest of cocoa. Cocoa was free of this pest till 1986, when it was detected in about 700 ha of cocoa in Melaka. Subsequently, the pest was detected in other major cocoa growing areas. The larvae of the insect bore into the cocoa pod and feed on the pulp and funicles, which causes cocoa beans to clump and stop development. This may make them difficult to remove from the pods, and leads to malformed small and low quality beans. Although, overall economic loss is difficult to ascertain, crop loss in badly infested holders can be very severe and losses up to 30% are not uncommon. *C. cramerella* mainly attacks cocoa but has also been recorded from *Nephelium lappaceum* (rambutan) and *Cynometra cauliflora*. *C. cramerella* is restricted to rambutan and cocoa (Bradley, 1986). The pest is distributed in Asia, Brunei, Indonesia, Malaysia, Philippines, Australasia and Pacific islands, Australia, Irian Jaya, New Britain, Papua New Guinea and Samoa. In India, cocoa is grown in 32,360 hectares with a production of 10,000 tons and it is expected to go up to 16,000 tons in the current year. The pest is of utmost quarantine importance to India. *Trichogramma* sp. are major biocontrol agents for management of the pest in addtion to pheromnes.

Sunflower maggot, *Strauzia longipennis* (Wiedemann) (Diptera: Tephritidae)

Strauzia longipennis, a North American pest of sunflower, was reported in 2010 from Germany and is known to be invasive. Host range includes *Helianthus annuus* (sunflower), and other *Helianthus* species like

H. maximilianii and *H. tuberosus* (Jerusalem artichoke) and on other plants of Asteraceae (e.g. *Ageratina altissima, Ambrosia trifida, Smallanthus uvedalia).* This fly is the only tephritid species found feeding in stalks of cultivated sunflower. The bright yellow adult has a wing span of about 13 mm and a body length of 8 mm. The eyes are bright green and the wings have broad dark bands forming a fairly distinct F pattern near the wing tip. Eggs are 1 mm long, white, and elongate. The larvae are yellow white, tapered from anterior to posterior, and approximately 9 mm long and 2.5 mm wide at maturity (Knodel and Charlet, 2007).

Adults emerge in mid-June, are active diurnally and remain in fields until late July. Eggs are deposited singly in stem tissue near the apical meristem. Larvae feed on the stem, creating large tunnels in the stalk pith and develop through three instars in approximately six weeks (Westdal and Barrett, 1960). Fully developed larvae emerge from the stalk beginning in mid-August and overwinter as pupae in soil at the base of the sunflower plant (Westdal and Barrett, 1960). Secondary fungal infections are often associated with tunnelling by the larvae within the stalk (Westdal and Barrett, 1962). This fly occurs in most areas of the United States and in many of the Canadian provinces**.** Depending on the number of larvae, injury may vary from a short tunnel to complete destruction of the pith. Large infestations can weaken the stalk and eventually lead to plant breakage. Natural enemies (e.g. parasitoids like *Coptera strauziae* Muesebeck (Hymenoptera: Diapriidae) helps to keep the populations under economic threshold (http://www.eppo.int/).

The West Indian fruit fly, *Anastrepha obliqua* (Macquart) (Diptera: Tephritidae)

Anastrepha obliqua was described originally by Seín in 1933 as a variety of *A. fraterculus* (Wiedemann). The type species was from Rio Piedras, Puerto Rico. It was first reported from Florida in the early 1930s as an unnamed species known widely by its synonym, *A. mombinpraeoptans* Seín, or as a variety of the continental Neotropical species, *A. fraterculus* (Wiedemann) (Berg, 1979; Weems 1980) and is one of several closely related species of *Anastrepha*. *A. obliqua* adults are difficult to separate from those of *A. fraterculus, A. sororcula* Zucchi*, A. zenildae* Zucchi*, A. turpiniae* Zucchi, *A. suspensa* Zucchi and several other species of the *fraterculus* group. The body is predominantly yellow to orange-brown, and the setae are red-brown to dark-brown. All these fruitflies are known to be invasive and are absent in India.

As in most other *Anastrepha* spp., the adults of *A. obliqua* are easily separated from those of other tephritid genera by a simple wing venation character; vein M, the vein that reaches the wing margin just behind the wing apex, curves forwards before joining the wing margin. Furthermore, most *Anastrepha* spp. have a very characteristic wing pattern; the apical half of the wing has two inverted 'V'-shaped markings, one fitting within the other and a stripe along the forward edge of the wing, which runs from near the wing base to about half-way along the wing length. Head: yellow except ocellar tubercle brown. Antenna not extended to ventral facial margin. Thorax: mostly yellow to orange-brown, Wing: 5.7-7.5 mm long. Vein M strongly curved apically Abdomen: tergites yellow to orange-brown, without dark-brown markings. Larva measure 7.5-9.0 mm long; 1.4-1.8 mm wide it is very difficult to distinguish larvae of *Anastrepha* species by morphological characteristics. The key by Steck *et al.* (1990) and the interactive key by Carroll *et al*. (2004) are the best tools for larval identification. Descriptions of *A. obliqua* larvae are provided by Berg (1979), Steck *et al*. (1990) and White and Elson-Harris (1994).

The pre-oviposition period varies from about a week in summer and up to 2-3 weeks in winter. Eggs are laid singly, generally in mature green fruits except for some varieties of mangoes, which may be attacked when they are very small. The larval stage lasts 10 to 13 days in summer, slightly longer in winter, and the pupal stage occupies about the same length of time. Possibly six or seven generations develop annually.

The main native hosts are *Spondias* spp. (Anacardiaceae), but these are only of local interest. Mangoes (*Mangifera indica*), also Anacardiaceae, are the economically important host, on which the species has extended its range (Hernandez-Ortiz, 1992). *Citrus* spp. and guavas (*Psidium guajava*) are only occasional hosts. Like other *Anastrepha* spp., *A. obliqua* has been recorded incidentally on a wider range of fruits, both tropical and temperate, but these records are incidental occurrences (Couturier *et al*., 1996).

The major parasitoids of the larvae include *Aceratoneuromyia indica* (Silvestri)*, Biosteres longicaudatus* (Ashmead) that occur in 2.7% of larvae (Borge and Basedow, 1997). Others include *Doryctobracon areolatus* (Szepligeti)*, D. crawfordi* (Wharton & Marshall)*, D. trinidadensis* Gahan*, Opius bellus* Gahan and *Utetes anastrephae* (Viereck) and pupal parasitoids like *Pachycrepoideus vindemmiae* (Ohashi *et al*., 1997).

Western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysonoptera: Thripidae)

The western flower thrips (*Frankliniella occidentalis* (Pergande)) is an important pest insect in agriculture. This species of thrips is native to North America, but, has spread to other continents including Europe, Australia, and South America via transport of infested plant material. It has been documented to feed upon over 500 different species of host plants, including a large number of fruit, vegetable, and ornamental crops. The adult male is about 1 millimeter long; the female is slightly larger, about 1.4 millimeters. Most western flower thrips are females and reproduce by arrhenotokous parthenogenesis. Males are rare. They are variable in color, with some color types more abundant in certain seasons. Colors vary from red to yellow to brown. Each adult is elongated and thin, with two pairs of long wings. The eggs are oval or kidney-shaped, white, and about 0.2 millimeters long. The nymph is yellowish in color with red eyes.

The life cycle of the western flower thrips varies in length due to temperature, with the adult living up to 2-5 or more weeks, and the nymph stage lasts 5 to 20 days. Each female lay 40 to over 100 eggs in the plant tissues, often in the flower, but, sometimes in the fruit or foliage. The newly hatched nymph feeds on the plant for two of its instars, then falls off the plant to complete its other two instars. The major damage is caused by the adult ovipositing in the plant tissue. The plant is also injured by feeding, which leaves holes and areas of silvery discoloration when the plant reacts to the insect's saliva. Nymphs feed heavily on new fruit just beginning to develop from the flower. The western flower thrips is also the major vector of tomato spotted wilt virus and is a year-round pest, being less destructive in wet weather.

Various species of the worldwide anthocorid genus *Orius* are used in biological control against thrips, and these bugs are evidently important as predators in many natural populations. A majority of natural enemy records for *F. occidentalis* are from greenhouses. *Neoseiulus cucumeris* Oudemans is one of the most widespread mites used in attempts at the biological control. Control with hymenopterous parasites seems to have been less effective, although the polyphagous eulophid, *Ceranisus menes* Walker, has been used in several countries with varying levels of success (Loomans *et al*., 1995). Fungal pathogens like *Metarhizium anisopliae* Metsch. and nematodes, such as *Steinernema feltiae* Filipjev are also being used commercially. Predators include *Amblyseius barkeri* Huges, *A. limonicus* Huges, *A. mckenziei* and bugs *Geocoris pallens* Stäl, *Hypoaspis aculeifer* Canestrini, *H. miles, Macrolophus caliginosus* Wagner, *M. rubi* (Goldarazena *et al*., 2000). Parasitoids include *Ceranisus americensis* Girault, *C. lepidotus, C. menes* (Hymenoptera: Eulophidae) *Dicyphus tamaninii* Wagner (Miridae), *Grandjeanella multisetosa*, *Thripinema nicklewoodii* Siddiqui, *Typhlodromips lailae* Schicha and *Typhlodromips montdorensis* Schicha.

***Rhagoletis pomonella* Walsh (Diptera: Tephritidae)**

Rhagoletis pomonella is a serious pest of apple (*Malus domestica,* Borkh), but also recorded on Chickasaw plum (*Prunus angustifolia*), peach (*Prunus persica* Marst) and Siberian crabapple (*Malus baccata* Linn.); larvae have also been found in pear (*Pyrus communis* Linn.), but no adults emerged (Bush, 1966). The original native host of *R. pomonella* is hawthorn (*Crataegus* spp.) Bush (1969) suggested that the populations on apples were initially founded by a few flies that emerged early and that within a few generations a race of early emerging flies with a preference for ovipositing on apples evolved in sympatry with the original hawthorn race. Similar variation is still evident in the response of both host races to host volatiles (Linn *et al*., 2005). During the relatively short period since the colonization of apple, the apple and hawthorn populations have diverged genetically to form distinct apple and hawthorn races (Bush, 1969; McPheron *et al*., 1988; Feder *et al*., 1989; 1990a; 1990b; Berlocher *et al*., 1993; Berlocher and McPheron, 1996). The two host races are also clearly differentiated by heritable preference for fruit volatiles of their natal hosts and active avoidance of non-natal host odours (Linn *et al*., 2003; Dambroski *et al*., 2005, Forbes *et al*., 2005).

In New England (USA), *R. pomonella* utilizes the hips (fruits) of Japanese rose (*Rosa rugosa* Thumb) and *R. carolina* (as *R. virginiana*) as alternative hosts (Prokopy and Berlocher, 1980). Recently, *R. pomonella* has adapted to attacking apricot (*Prunus armeniaca* Linn.), chokeberry (*P. virginiana*), crabapple (*Malus* spp.), mahaleb (*P. mahaleb*), pyracantha (*Pyracantha coccinea* M.Roem), ornamental hawthorn (*Crataegus monogyna* and *C. mollis*), plum (*Prunus americana*), river hawthorn (*C. douglasii*), sweet cherry (*Prunus avium*) and sour cherry (*P. cerasus*) in Utah (USA) where it has not been reported from cultivated apple (Jorgensen *et al*., 1986; McPheron *et al*., 1988; Messina, 1989; Alldred and Jorgensen, 1993), and there is also a record from apricot in New York (USA) (Lienk, 1970). Ornamental hawthorns (*Crataegus* spp.) may also be attacked by the hawthorn race. *R. pomonella* which is recorded in *Amelanchier, Aronia* and *Cotoneaster* spp. (all Rosaceae) (Bush, 1966).

In most cases *R. pomonella* has only one generation a year, but diapause is facultative (Feder *et al*., 1997) and emergence without diapause by a small proportion of apple maggot pupae has been documented in the field. Females lay their eggs singly beneath the skin of the fruit. The larvae hatch 3-7 days later and tunnel into the fruit pulp. They complete their development within the fruit, taking anywhere from 2 weeks to several months to mature. Very rarely will larvae exit from hanging fruit. The infested fruit usually drops to the ground. Larvae remain in the dropped fruit until reaching maturity when they make an exit hole in the skin of the fruit and wriggle to the ground. Larval emergence from fruit may continue into early December. Larvae then enter the soil where pupation occurs. They enter the soil to a depth of 2-5 cm, usually beneath the host plant. Pupae stay dormant over winter, and may persist in the soil for several years. Adult emergence is in late June or July and they may feed on insect honeydew and bird dung, reaching sexual maturity 7-10 days after emergence. As the flies mature and mate they respond more to oviposition-site stimuli, i.e. fruit shape and fruit odour (Prokopy and Papaj, 2000; Linn *et al*., 2003). After mating, a single female fly is capable of laying more than 200 eggs in her lifetime. Adults usually die after 3-4 weeks, but may live up to 40 days under field conditions.

Natural enemies include: predators like *Amara aenea* (De Geer), parasitoids like *Biosteres melleus* Gahan, *Opius lectus* Gahan, *O. rhagoleticola* Sochtleben on larvae and *O. downesi* Gahan, *O. lectoides* Gahan, *Diachasma alloeum* (Muesebeck), *D. ferrugineum* (Gahan), *Phygadeuon wiesmanni* Sachti, *Pterostichus melanarius* (Illiger), *Pteromalus sp.* and *Tetrastichus* sp. attack pupae. Up to 90% of larvae may be parasitized in *Crataegus* fruits (Gut and Brunner, 1994) in Washington State, USA. However, in a comparative study of parasitism levels in *Crataegus* and apple in Michigan, USA, Feder (1995) found only 46% and 13% parasitism, respectively. Allen and Hagley (1989) stated that predators' impact was very low.

Mulberry moth – *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae)

Hyphantria cunea the mulberry moth attacks a wide range of forest and fruit trees. The origin of the pest is North America, Canada and Mexico region where it infests a wide range of plant species (88 species in North America, 230 in Europe and 317 in Japan), Larvae are Brownish-grey, attains 40 mm when fully developed, and has 12 small warts surmounted by characteristic tufts of hair. There are two forms, those with red heads and those with black head. Emergence from overwintered pupae begins in late April or early May, and is completed in 4-6 weeks. Mass flight lasts for 7-10 days. The sex ratio is usually 1:1, females live for 4-8 days and males live 1-2 days less. Adults emerge in the evening and rest initially on branches, twigs and leaves before flying to preferred food plants (Yaroshenko, 1975). They are able to fly several kilometres. Females each lay 293-1892 eggs within 1-2 days, on the lower surface of the leaves on the upper and outer parts of trees

H. cunea is liable to be carried on vegetative host-plant material as well as on packing materials and in vehicles. The ability of the larvae to withstand starvation for up to 2 weeks ensures their survival and dissemination to different areas. Mass migrations due to exhausted food plants or the search for new sites often end in urban areas where the pest invades wood piles, houses, roads and vehicles (Giovanni *et al*., 1986). Transportation of *H. cunea* also occurs often in wood logs where it inhabits cracks or holes in the bark (Shu and Yu, 1984).

H. cunea was first recorded in Europe in 1940 and was widespread in Eastern Europe by the time a biological control programme was initiated in 1952. Introductions of a number of the more important parasitoids from North America were attempted and continued into the 1960s. However, none of them are known to have become established (Greathead, 1976; Clausen, 1978), and subsequent biological control attemps have focused on the the use of *Bacillus thuringiensis* sprays. Other natural enemies include: *Brachymeria lasus* (Walker), *B. tibialis* (Walker), *Compsilura concinnata* (Meigen), *Conomorium patulum* (Walker), *Cotesia hyphantriae* (Riley), *Cotesia ordinaria* (Ratzeburg), *Psychophagus omnivorus* (Walker), *Rogas hyphantriae* Gahan, *Campoplex validus* (Cress), *Carcelia bombylans* Robineau-Desvoidy, *Casinaria nigripes* (Graverhorst), *Exorista fasciata* (Fallen), *E. japonica* (Townsend), *E. larvarum* (Linn.), *E. segregata*, *E. xanthaspis* (Ashmead), *Glyptapanteles porthetriae* (Muesebeck), *Hyposoter fugitivus* (Say), *H. pilosulus* (Provancher) *and H. seve, Brachymeria lasus* and *B. tibialis.* In addition several species of *Trichogramma* and predatory beetles are also recorded.

Japanese beetle *Popillia japonica* Newm. (Coleoptera – Scarabaeidae)

The Japanese beetle, *Popillia japonica* Newman, is a widespread and destructive pest of turf, landscape, and ornamental plants in the United States. It is also a pest of several fruit, garden, and field crops, and has a total host range of more than 300 plant species. Adult Japanese beetles feed on foliage, flowers, and fruits. Leaves are typically skeletonized or left with only tough network of veins. The larvae, are white grubs, primarily feed on roots of grasses often destroying turf in lawns, parks, and golf courses. Currently, the Japanese beetle is the most widespread pest of turfgrass and costs the turf and ornamental industry approximately $450 million each year in management alone (Potter and Held, 2002). The beetles are particularly attracted to certain species of Aceraceae, Anacardiaceae, Betulaceae, Clethraceae, Ericaceae, Fagaceae, Gramineae, Hippocastanaceae, Juglandaceae, Lauraceae, Leguminosae, Liliaceae, Lythraceae, Malvaceae, Onagraceae, Platanaceae, Polygonaceae, Rosaceae, Salicaceae, Tiliaceae, Ulmaceae and Vitaceae. The grubs feed on roots of a wide range of vegetable crops, ornamental plants and tender grasses. Maize is one field crop seriously damaged in North America. The beetles feed on the maturing silk, preventing pollination; this results in malformed kernels and reduced yield.

Popillia japonica is found in China, Russia, Portugal, Canada and the USA (CABI 2004). It probably entered the USA as grubs with iris bulbs before 1912 when plant materials were first examined. Since then it has spread to many states (at least 30) in the southern region, (Johnson and Lyon, 1991).

A detailed account of the biology of *P. japonica* is provided by (Potter, 1998; Vittum *et al*., 1999; Potter and Held, 2002; Jackson and Klein, 2006). After mating on host plants during the day females fly to suitable sites for oviposition. Areas with moist, loamy soil covered with turf or pasture grasses are preferred (Fleming, 1972a; Allsopp *et al*., 1992).

Eggs are laid singly or in small clusters (2-4 eggs) in the upper 7.5 cm of soil. The cycle of feeding, mating and oviposition is repeated every few days. The average lifespan of a female is 30-45 days, during which she may lay 40-60 eggs. Eggs are about 1.5 mm long, pearly white and oblong. They absorb water from the soil, becoming spherical and nearly doubling in size within a week. The external surface of the chorion is marked with small hexagonal markings. The larvae are most abundant in well-kept lawns and golf courses, and less often in pastures. As the grub feeds just below the surface, it cuts off and consumes the grass roots. Early symptoms include thinning, yellowing, and wilting, culminating in large patches of dead, brown grass that appears in late summer or early autumn because of water stress, There is one generation per year, even in the most southern areas, but at the northern edge of its range, a few individuals may need 2 years to complete the life cycle (Fleming, 1972b; Vittum, 1986; Vittum *et al*., 1999).

Virgin females produce a volatile sex pheromone (Ladd, 1970), identified and called Japonilure (Tumlinson *et al*., 1977). The beetles normally feed in groups, usually starting near the top of a plant and working downward (Fleming, 1972a; Rowe and Potter, 1996). The adults are attracted to feeding-induced plant volatiles, resulting in aggregation on damaged plants (Fleming, 1972b; Loughrin *et al*., 1996).

Several indigenous, generalist, predators, especially ants and ground beetles, help to suppress Japanese beetle populations by feeding on eggs and grubs (Terry *et al*., 1993; Zenger and Gibb, 2001). Parasitoids like *Campsomeris annulata* Fab., *Campsomeris marginella modesta* (Smith), *Dexia ventralis* Aldrich, *Erythrocera genalis* (Aldrich), *Hamaxia incongrua* Walker and *Heterorhabditids* sp. *Tiphia asericae* Allen & Jaynes, *T. biseculata* Cam., *T. brevilineata* A & J, *T. burrelli* Parker, *T. communis* A & J, *T. koreana* Roh., *T. matura, T. notoplita* and several species of *Tiphia* are recorded and Predatory carabids like *Craspedonotus tibialis* Schaum, also feed on grubs. Both adults and larvae are fed upon by various birds including starlings, crows, grackles, and gulls. Moles, skunks, raccoons and armadillos, feed on the grubs, but cause considerable damage to the turf or pastures. Grubs are susceptible to several naturally-occurring fungal pathogens including *Metarrhizium anisopliae* and *Beauveria bassiana*, entomo-pathogenic nematodes including *Steinernema* and *Heterorhabditis* species, bacteria pathogens such as *Paneibacillus popilliae*, the protozoan, *Ovavesicula popilliae*, and the rickettsia *Rickettsiella popilliae.* Unfortunately, humans are also susceptible to the rickettsia. (Fleming, 1968; Fleming, 1969; Potter and Held, 2002; Jackson and Klein, 2006).

Light brown apple moth *Epiphyas postvittana* (Lepidoptera:Tortricidae)

Light brown apple moth *Epiphyas postvittana* is native to Australia. *E. postvittana* has a very wide host range, with 73 listed from Australia (Danthanarayana, 1975; Geier and Briese, 1981), and over 250 from New Zealand (Thomas, 1989). Danthanarayana *et al*. (1995) have suggested that the better performance of *E. postvittana* on herbaceous rather than woody plants suggests that it primarily evolved as a feeder on the former. Mo *et al*. (2006) reported development of this species on *Citrus* spp. Larval nests are typically seen as leaves webbed together, or attached to fruit. Fruit surface feeding is common on apples, older skin damage has a cork-like appearance. Vectoring of *Botrytis cinerea* DeBary by larvae has been shown in grapes, with up to13% of berry damage (by weight) (Bailey *et al.,* 1997). *E. postvittana* has colonized a wide range of orchard and other habitats in both Australia and New Zealand. It is present in pine forests on understorey perennial weeds, on willows and other plants. *E. postvittana* is a small, bell-shaped moth, whose caterpillars feed on a very wide range of plants. The eggs, larvae and pupae can be associated with plant material and readily transported. Light brown apple moth adults are sexually dimorphic and variable in wing pattern and colour, although a lighter diamond-shaped area extending from behind the head to approximately one-third of the body length is typically visible at rest.

Natural enemies of the moth include species of tachinid fly, *Trigonospila brevifacies* Hardy and ichneumonid wasp. These are parasitoids which deposit their eggs on or within the bodies of the moth larvae. The parasitoid larva hatches and kills the pest larva. Historically, the most abundant parasitoid has been the braconid wasp, *Dolichogenidea tasmanica* (Cameron) and it is still the most common natural enemy found with the moth in New Zealand. This wasp like the moth is native to Australia and was probably imported along with it. Other common parasitoids include the braconid wasp *Glyptapanteles demeter* (Wilkinson) and the bethylid wasp *Goniozus jacintae* Farrugia. The combination of these parasitoids has played a role in reducing moth damage. Other natural enemies include *Apanteles demeter* Wilkinson, *Australoglypta latrobei* Gauld, *Dolichogenidea tasmanica* (Stephen *et al.*), *Brachymeria lasus* (Walker), *B. phya* (Walker), *B. teuta*, *Eriborus epiphyas* (Paull & Austin), *Glabridorsum stokesii* (Cameron), *G. jacintae*, *G. mandibulatus*, *Trichogrammatoidea bactrae fumata* Nagaraja, *T. carverae* Oatman & Pinto, *T. funiculatum, Trigonospila brevifacies*, *Voriella uniseta* Malloch and *Xanthopimpla rhopaloceros* Krieger.

Briese *et al*. (1980) reported resistance to a nucleo-polyhedrosis virus (MacCollom and Reed, 1971), which was probably one of the first examples of virus-resistance in insects. The virus genome has been sequenced (Caradoc-Davies *et al*., 2001; Hyink *et al*., 2002).

Tomato fruit fly – *Neoceratitis cyanescens* (Bezzi) (Diptera: Tephritidae)

Neoceratitis cyanescens is native to Madagascar; it has been introduced to Mauritius, Réunion and Mayotte islands. It is oligophagous on both wild and cultivated Solanaceae species, particularly tomato, where attacks on fruit may cause severe damage to yield and quality of production. Once introduced, populations of *N. cyanescens* have the potential to build up rapidly in habitats where fruiting wild and cultivated hosts are present throughout the year.

The adults of the tomato fly are easily recognised by the characteristic pattern of brown bands on their wings and the posterior half of the scutellum, which is entirely black. The eggs are white and elongated, slightly curved and approximately 1 mm long. The yellowish larva is a maggot: its slender anterior part has blackish mouth-hooks, whereas the posterior part ends bluntly. At the end of development, it reaches approximately 7-8 mm long. The brown puparium is barrel-shaped and 4-5 mm long (Quilici and Brévault, 1999; Carrol *et al*., 2002). The distribution of the tomato fly extends from sea level up to an altitude of 1500 metres, depending on the availability of host-plants (Etienne, 1972, 1982). Male flies frequent non-host plants, but some are observed on host fruit in the early morning (Brévault and Quilici, 2000a). *N. cyanescens* is oligophagous and attacks host-plants within the Solanaceae family. Green tomato fruits (formed 10 to 24 days after flowering) are the most susceptible (Brévault, 1999). The development and survival of *N. cyanescens* females from egg to complete ovarian maturity were studied as a prerequisite to understand temporal and geographical patterns of fruit fly occurrence (Brévault and Quilici, 2000b). The fastest development of pre-imaginal instars is recorded at 30°C (22 days) and the slowest at 15°C (98 days). At 25°C, egg hatching occurs after 3 days of incubation in the fruit, whereas larval and pupal developments last for 9 and 14 days, respectively.

Natural enemies include parasitoids like *Acerato-neuromyia indica* (Silvestri), *Dirhinus giffardii* (Silvestri), *Muscidifurax uniraptor* (Kogan & Legner), *Psyttalia distinguenda* (Granger), *P. insignipennis* (Granger) and *Tetrastichus giffardianus* Silvestri. Several arachnids may prey upon the adults during resting, foraging, mating and egg laying activities. The egg and larval stages are relatively well protected inside the host-fruit, although they may be attacked by parasitoids. Others have reported that *Psyttalia insignipennis* (Granger) or *P. distinguenda* parasitoids attacking *N. cyanescens* in Réunion (Etienne, 1973; Wharton *et al*., 1999).

Papaya fruit fly – *Bactrocera papayae* (Diptera: Tephritidae)

This fruit fly attacks many species of edible fruits and fleshy vegetables. It can also cause considerable damage to fruit and coffee berries. It is present in Papua New Guinea (PNG), but data is scarce to establish a comprehensive host list for that country. It has been occasionally bred from carambola, cashew, papaya, pomelo, mango and guava. Very few infestations of coffee berries have been observed so far in PNG, even though *B. papayae* is commonly trapped in the Highlands.

B. papayae is a highly invasive species. It has a high dispersive ability, a very large host range and a tolerance for both forest and non-forest habitats. It has a high economic impact, affecting production, control costs and market access. The species is native to and widespread in south-east Asia (Thailand, Peninsular Malaysia, East Malaysia, Singapore, Indonesia and Kalimantan). It invaded Papua New Guinea from Asia through Irian Jaya in 1992. For a long time it had been trapped only in the Western and West Sepik Provinces, but was later detected in Port Moresby (May 1998), Morobe Province (September 1998), and the Highlands (Eastern Highlands, Simbu, Western Highlands) (November 1998). A polyphagous pest species, it has been recorded in Asia attacking 193 host species in 114 genera and 50 families (Allwood *et al*., 1999) in Australia it was bred from 35 host species (Hancock *et al*., 2000a). It was eradicated from Queensland by implementing a programme using male annihilation and protein bait spraying.

In Malaysia this species is a pest of papaya and it also caused heavy attack on mango and ripe banana (White and Elson-Harris, 1994). *Terminalia catappa, Psidium guajava, Syzygium samarangense* and *Averrhoa carambola* were found to be favoured hosts in southern Thailand and Peninsular Malaysia (Clarke *et al*., 2001). Mango was the main host recorded during the Queensland outbreak (Hancock *et al*., 2000b). Cashew, arecanut, citrus, garcinia, annonas and breadfruits are most susceptible (Allwood *et al*., 1999; Drew and Hancock, 1994; Hancock *et al*., 2000a; Yong, 1994).

B. papayae is genetically similar to several other pest members of the dorsalis species complex (Yong, 1995; Khalid Mahmood, 1999; Nakahara *et al*., 2000). It is known to hybridize with *Bactrocera carambolae* Drew & Hancock in both laboratory and field cage experiments (Wee and Tan, 2000). However, Khalid Mahmood (1999) concluded there was no gene flow between these two species in Malaysia, suggesting that any hybrisization under natural conditions is, at most, very limited. He also recorded differences between *B. papayae* and the morphologically very similar *B. philippinensis.* The males of *B. papayae* are strongly attracted to methyl eugenol (Wee and Tan, 2000; Tan, 2000; Wee *et al*., 2002). Competition from related species, such as *Bactrocera dorsalis* (Hendel) and *B. philippinensis*, might be inhibiting its spread northwards within Asia; in Papua New Guinea, where no similar species occurs, *B. papayae* has spread rapidly. *Toxotrypana curvicauda* Gerstaecker is another invasive fruitfly on papaya (Martin *et al*., 2000) but its host range is limited to Caricaceae and Asclepidaceae (Mason, 1922; Landolt, 1994).

Parasitoids appear to have little effect on the populations of most fruit flies and Fletcher (1987) noted that 0-30% levels of parasitism are typical. To date there are no records of biological control success for any *Bactrocera* or *Dacus* spp. (Wharton, 1989). Laboratory studies have indicated that *B. papayae* can be attacked by the braconid *Biosteres longicaudatus* (Ashmead) (Petcharat, 1997a) and some field trial of this as a possible biocontrol agent have also been carried out in Thailand (Petcharat, 1997b). *B. longicaudatus, Fopius arisanus* (Sonan), *F. vandenboschi* (Fullaway), *Psyttalia incisi, P. makii* and two unnamed *Psyttalia* species were recorded from *B. papayae* in Thailand and Malaysia by Chinajariyawong *et al*. (2000).

Rusty tussock moth – *Orgyia antiqua* (L.) (Lepidoptera: Lymantriidae)

The polyphagous rusty tussock moth is a generalist feeder for which about 50 coniferous and hardwood host species have been recorded. Distributed in Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Ontario, Prince Edward Island and Quebec. The larvae emerge in the late spring and feed until late July or early August. They first attack current-year foliage, which quickly turns brown. Later in the season, they feed on both older and current-year needles of conifers. Defoliation occurs first in the upper crown, then in the outermost portion of the branches and finally in the lower crown and farther back on the branches.

Rusty tussock moths are relatively easy to identify; they are fairly long (about 30 mm), very hairy, with black heads, dark grey backs and yellow bellies. Their bodies have four to seven tufts of dense, short, yellowish white hair, which are perpendicular to their bodies and radiate from orange tubercles. The caterpillars also have two long black pencil tufts projecting forward from the first thoracic segment and a similar one back from the rear of the body. The female moths are wingless. Several hundred eggs are laid on the outside of the female’s empty cocoon, usually attached to a host-plant (Waring *et al.*, 2003). The species over-winters in the egg stage. The larvae hatch early in the spring, as soon as foliage starts to appear (de Worms, 1979). They are easily recognized by their horn-like tufts of hair-like setae. There are 4 toothbrush-like tufts along the back, and hair pencils that project from the sides at the front and at the back. The body is dark grey to black, and there are red tubercules along the sides and back. They have defensive glands at the back, and wipe their setae against them to charge them with toxins (Wagner, 2005). They grow to about 30–40 mm, females being considerably larger than males (de Worms, 1979). In the UK, caterpillars can be found between May and early September (Waring *et al.*, 2003). The larvae pupate in a crevice inside a silk cocoon. The larvae are polyphagous and feed on a wide range of deciduous trees and shrubs, such as birch (*Betula*), *Crataegus*, Lime (*Citrus*), *Prunus*, *Quercus*, *Rubus*, *Salix*, *Tamarix* and *Vaccinium* (Porter, 1997; Wagner, 2005).

Natural enemies like nuclear polyhedrosis virus is reported and is effective in bringing down the pest populations.(Mills and Schoenberg, 1985).

Glassy-winged sharpshooter, *Homalodisca coagulata* (Say) (Hemiptera: Cicadellidae)

The *Homalodisca vitripennis*, is a large leafhopper species native to the southeastern United States, was first detected in California in 1989 (Sorenson and Gill, 1996). It is one of the main vectors of the bacterium, *Xylella fastidiosa* Wells. a plant pathogen that causes a variety of plant diseases, including phony peach disease of peach and Pierce's disease (PD) of grape (Wells *et al*., 1987; Turner, 1949; Hewitt *et al*., 1946; Alderz and Hopkins, 1979; Davis *et al*., 1980). *H. coagulata* vectored a serious PD epidemic in 2000, in Temecula, California (Blua *et al*., 2001), The glassy-winged sharpshooter is about 12 mm in length, mostly brown-colored on the dorsal side, with ivory and black markings under the abdomen. They have large smoky-brown wings with red markings and are very good flyers, making them able to transmit plant diseases. The face and legs are yellow-orange. Nymphs are wingless and grey; having a body shape similar to the adults. The female glassy-winged sharpshooter lays her eggs in groups of three to 28 eggs just under the epidermis layer of several well-chosen leaves. Preferred plants for oviposition may include sunflower and citrus. As the female lays her eggs, she covers them with a white material scraped from deposits on her fore wings. This white powder is termed brochosomes, consisting of intricately structured hydrophobic particles. *H. coagulata* has a wide host range, feeding on more than 150 plants ranging from herbaceous annuals to woody perennials (CDFA 2006). In Georgia, Hoddle *et al*. (2003) and Turner and Pollard, (1959) used yellow sticky board traps to determine that 100 species of plants in 30 families hosted *H. coagulata* for oviposition and feeding, with a pronounced attraction to peach in the spring and the fall.

A parasitic wasp, *Gonatocerus triguttatus* Girault, was introduced into California in an effort to control the early spring generation of *H. coagulata*. The tiny wasp from Texas and Northern Mexico is an egg parasite, laying its eggs within the eggs of the sharpshooter (Triapitsyn and Phillips, 2000). Research is also underway to promote the use of entomopathogens such as *Hirsutella* sp., a fungus that is known to affect sharpshooters in the southeastern United States.

The Queensland fruit fly, *Bactrocera tryoni* (Froggatt)

Queensland fruit fly is an insect pest of fruit and vegetable crops in Australia and is capable of affecting the majority of commercial fruit crops (with the exception of pineapple and strawberry) (Hooper and Bateman, 1982). It is has been also recorded in over 60 native fruit species (Hooper and Drew, 1989) covering the temperate and tropical regions and at times it has been a very destructive pest of citrus. *B. tryoni* infestation is confirmed from 49 families of plants, represented by 234 species (Hancock *et al*., 2000). A heavy outbreak of *B. tryoni* in New South Wales during 1940-41 resulted in the rejection of 5–25% of citrus at harvest. In Australia, the *B. tryoni* inhabits parts of Northern Territory, Queensland, New South Wales and the eastern corner of Victoria, with outbreaks in South Australia. In 1989, *B. tryoni* became established in Perth, Western Australia, but an eradication campaign using baits, male lures and sterile insect techniques eradicated it (White and Elson-Harris, 1994; CSIRO, 2004; GISD, 2011).

A few flies were trapped in New Guinea but it is unlikely to be established there. Occasional flies were trapped in the Austral and Society Islands of the Pacific. However it is now widespread in New Caledonia, French Polynesia and Pitcairn Islands. It was twice detected on Easter Island, but eradicated (White and Elson-Harris, 1994; GISD, 2011).

The adults are known to diapause in winter. The total life cycle requires 2 to 3 weeks in summer and up to 2 months in the fall. Adult females live for many months and four or five overlapping generations are observed. Females deposit up to 7 eggs in groups, with the result that many eggs often occur in a single cavity. As many as 40 larvae have been found in one peach, and as many as 67 adults have been reared from one apple. Eggs hatch in 2 to 3 days under favorable weather conditions. The ensuing larval development may be completed in as little as 5 days. Pupation normally occurs in the soil. Pupal development requires from a week in summer to a month or more in cooler weather. Adults live a year or more feeeding primarily upon juices of host plants, nectar, and honeydew secreted by insects.

More than 100 species of fruits and vegetables have been recorded as hosts of *B. tryoni*. Bananas are attacked only when overripe, and other fruits, such as grapes, are attacked only in peak years. Wild hosts include passionflower, *Passiflora* spp., and *Eugenia* spp. (Myrtaceae). Males attracted to cue lure (White and Elson-Harris, 1994) and is used as an attractant to trap the flies.

Sustainable control of the invasive pests can probably be achieved by classical biological control using natural enemies from the homeland. Preparedness in terms of our knowledge, source of these natural enemies will be helpful in avoiding huge losses. Some of the organizations like the Invasive Species Specialist Group (ISSG), International Network for Barcoding Invasive and Pest Species (INBIPS) and Global Invasive Species Programme (GISP) are updating the information on such invasives which are handy for identification and to track their movement. These organizations, in addition to listing of invasives have specified natural enemies for immediate management also. Each country has to come out with their threat perceptions about the invasive pests and in addition to excercising strict internal quarantine regulations stringent international quarantine measures will help in combating these invasive insect pests.

Table 2. Invasive insect pests of quarantine importance to India

Sl. No.	Insect Pests	Order	Family
1	West Indian fruit fly *Anastrepha obliqua* (Macquart)	Diptera	Tephritidae
2	Sweetpotato weevil *Euscepes postfasciatus*	Coleoptera:	Curculionidae
3	Fruit mealybug *Pseudococcus elisae*	Homoptera	Pseudococcidae
4	Cassava mealy bug *Phenacoccus manihoti*	Homoptera	Pseudococcidae
5	Red coconut scale *Furcaspis oceanica*	Homoptera	Coccidae
6	Fruit trees Soft scale *Ceroplastes japonicas*	Homoptera	Coccidae
7	Cucurbit beetle *Diabrotica speciosa* (Germar)	Coleoptera	Chrysomelidae
8	Mediterranean fruit fly *Ceratitis capitata* Wiedemann	Diptera	Tephritidae
9	Bean aphid *Picturaphis vignaphilus* Blanchard	Homoptera	Aphididae
10	Dry wood termite *Incisitermes incisus* (Silvestri)	Isoptera	Kalotermitidae
11	Coconut leaf beetle *Brontispa longissima*	Coleoptera	Chrysomellidae
12	African mole cricket *Gryllotalpa africana* Palisot de Beauvois	Orthoptera	Gryllotalpidae
13	South African citrus thrips *Scirtothrips aurantii* Faure	Thysanoptera	Thripidae
14	Apple curculio *Anthonomus quadrigibbus*	Coleoptera	Curculionidae
15	European pear scale *Epidiaspis leperii*	Homoptera	Coccidae
16	Scarlet mealybug *Pseudococcus calceolariae*	Homoptera	Pseudococcidae
17	Comstack mealybug *Pseudococcus comstocki*	Homoptera	Pseudococcidae
18	Western flower thrips *Frankliniella occidentalis*	Thysonoptera	thripidae
19	Apple maggot *Rhagoletis pomonella*	Diptera	Tephritidae
20	Mexican fruit fly *Anastrepha ludens*	Diptera	Tephritidae
21	Caribbean fruit fly *Anastrepha suspensa*	Diptera	Tephritidae
22	Amerian fruit fly *Anastrepha fraterculus*	Diptera	Tephritidae
23	Medeterranian fruit fly *Ceratitis capitata*	Diptera	Tephritidae
24	Sapota fruit fly *Anastrepha serpentine*	Diptera	Tephritidae
25	Cotton boll weevil *Anthonomus grandis*	Coleoptera	curculionidae
26	Lentil bruchid *Bruchus ervi*	Coleoptera	Bruchidae
27	Lucerne pest *Bruchophagus gibbus*	Coleoptera	Bruchidae
28	Store grain pest *Pachymerus lacerdae*	Coleoptera	Bruchidae
29	Banded cucumber beetle *Diabrotica balteata* LeConte	coleoptera	chrysomelidae
30	Colorado potato beetle, *Leptinotarsa decemlineata* (Say)	coleoptera	chrysomelidae
31	Pepper weevil *Anthonomus eugenii* Cano	coleoptera	curculionidae
32	Rose weevil *Naupactus godmanni* Crotch Fuller	coleoptera	curculionidae
33	Sugarcane weevil or Apopka weevil citrus pest *Diaprepes abbreviatus* (L.)	coleoptera	curculionidae
34	Alfalfa weevil, *Hypera postica* (Gyllenhal)	coleoptera	curculionidae
35	Silky sugarcane weevil, *Metamasius hemipterus* (L.)	coleoptera	curculionidae
36	Small hive beetle pest of honey comb *Aethina tumida Murray*	coleoptera	nitidulidae
37	Caribbean fruit fly *Anastrepha suspensa* (Loew)	Diptera	Tephritidae
38	Papaya fruit fly *Toxotrypana curvicauda* Gerstaecker	Diptera	Tephritidae
39	Brown stink bug of various crops *Euschistus quadrador* Rolston	Hemiptera	Pentatomidae
40	Sugarcane lace bug *Leptodictya tabida* (Herrich-Schaeffer)	Hemiptera	Tingidae
41	Hemlock woolly adelgid *Adelges tsugae*	Hemiptera:	Adelgidae
42	Beech scale *Cryptococcus fagisuga* Lindinger	Hemiptera	Coccidae
43	Spruce spark beetle *Dendroctonus micans* (Kugelann)	Coleoptera	Scolytidae
44	Horse chestnut leafminer *Cameraria ohridella* Delschka & Dimic	Lepidoptera	Lithocolletidae
45	Firethorn leafminer *Phyllonorycter leucographella* Zeller	Lepidoptera	Gracillariidae

Table 3. Quarantine pests reported on different crops at different ports of entry

Crop plants	Quarantine pests reported
Cassava	Shoot fly – (*Carpolonchaea chalybea* (Wiedemann)), Mite (*Mononychellus* spp.), Thrips (*Frankliniella willamsi* Hood), *Phenacoccus madeirensis* Green (Cassava mealybug)
Cocoa	Mirids (*Sahlbergia singularis* Haglund, *Distantiella theobroma* (Dist.)), Cocoa moth – *Acorocercops cramerella* (Snellen), Cocoa capsid moth – *Sahlbergiella theobroma* Haglund, Cocoa beetle – *Steirastoma brevi* (Sulzer)
Coconut	Coconut leaf beetle, *Brontispa longissima* Gestro; American palm weevil, *Rhyncophorus palmarum* (L.); leaf miner, *Promecotheca cumingi* Baly; palm kernel borer, *Caryobruchus* spp.; *Pachymerus lacerdae* Chevrolat; fringed nettle grub, *Darna nararia* (Moore)
Coffee	Berry borer, *Sophronica ventralis* Aurivillius; coffee thrips, *Diarthrothrips coffeae* Williams
Citrus	Citrus bud mite, *Eriophyes sheldoni* (Ewing); Citrus rust mite, *Phyllocoptruta oleivora* Ashmead; Aucuba scale, *Aspidiotus nerii* Bouche; *Bactrocera aquilonis* (May); *Bactrocera jarvisi* (Tryon); *Bactrocera neohumeralis* (Hardy); *Bactrocera tryoni* (Froggatt) (Queensland fruit fly); *Ceratitis capitata* (Wiedemann) (Mediterranean fruit fly); *Epiphyas postvittana* (Walker) (light brown apple moth); *Pseudococcus calceolariae* (Maskell) (scarlet mealybug); *Unaspis citri* (Comstock) (citrus snow scale); *Pantomorus cervinus* (Bohemann) (Fuller's rose beetle); *Peridroma saucia* (Hubner) (pearly underwing moth); *Diaprepes abbreviatus* (Linn.) (citrus weevil)
Cotton	Boll weevil, *Anthonomus grandis* Boheman, *Anthonomus peninsularis* Dietz and *A. vestitus* Boheman); seed bruchids, *Amblycerus* spp., *Megacerus* spp., *Spermophagus* spp.
Oak	Oak bark beetles, *Pseudopityophthorus* spp.; seed bruchids, *Bruchidius* sp.
Pine	Seed chalcid, *Eurytoma sciromatis* Bugbee; seed bruchids, *Bruchidius* sp.
Walnut	Codling moth, *Carpocapsa pomonella* Linn.
Groundnut	Seed bruchid, *Stator pruininus* (Horn)
Sugarcane	American sugarcane borer, *Diatraea saccharalis* (Fabricius)
Kiwi fruits	Aucuba scale, *Aspidiotus nerii* Bouche; Mealy bug, *Paracoccus cavaticus* Cox.; Citrophilus mealy bug, *Pseudococcus calceolariae* (Maskell)
Papaya	Papaya fruit fly, *Bactrocera papaya* Drew & Hancock
Pineapple	Aucuba scale, *Aspidiotus nerii* Bouche; banded greenhouse thrips, *Hercinothrips femoralis* (Reuter); banana moth, *Opogona sacchari* (Bojer); mango flower beetle, *Protaetia fusca* (Herbst); jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* Gimpel & Miller; *Pyroderces rileyi* (Walsinham), fruit borer caterpillar, *Thecla basilides* Geyer; citrus snow scale, *Unaspis citri* (Comstock)
Potato	Colarado potato beetle, *Leptinotarsa decemlineata* Say; Andean potato weevil *Premnotrypes* spp.
Soybean	Soyabean looper, *Chrysodeixis includens* Walker; Eastern flower thrips, *Frankliniella tritici* Fitch; tarnished plant bug, *Lygus lineolaris* Palisot de Beauvols; pearly underwing moth, *Peridroma saucia* Hubner
Strawberry	Strawberry mite, *Phytonemus pallidus* (Banks)
Grapes	Grapevine Phylloxera or vine louse (*Viteus vitifoliae*, syn. *Daktulosphaira vitifoliae* Fitch; *Pseudococcus calceolariae;* grape berry moth, *Lobesia botrana* Denis & Schiffermuller

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